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Vendor Selection in Mud Removal Project at Coal Mine (Case Study of PT. Darma Henwa, Indonesia)

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Abstract

This study aims to identify the criteria used in determining vendors for the mud removal project in a coal mine using the Analytical Hierarchy Process (AHP) method. Another objective is to determine the best vendor for the project based on the AHP method. PT. Darma Henwa, Tbk, as one of the leading mining contractor services in Indonesia, needs to improve efficiency and effectiveness in carrying out coal mining operations to remain competitive and increase business revenue.

The results of the study show that the criteria used for selecting mud removal project service providers in the coal mine are Service/Experience, Contract and Commercial, and Machine/Manufacturing. Based on the overall calculations, Alternative 3 obtained the highest score of 23.273% and ranked first. Alternative 2 obtained a score of 23.089% and ranked second, followed by Alternative 4 with a score of 17.190% and ranked third. Alternative 1 obtained a score of 16.686% and ranked fourth, while Alternatives 5 and 6 scored 11.147% and 8.616% respectively, ranking fifth and sixth. This indicates that PT. Darma Henwa, Tbk prefers Alternative 3 as the best vendor based on all the criteria used.

In this study, the Analytical Hierarchy Process (AHP) method was successfully applied to determine the best vendor for the mud removal project in the coal mine. The AHP method was used to calculate the weights of criteria and vendor alternatives based on expert assessments. The criteria used were Service/Experience, Contract and Commercial, and Machine/Manufacturing. The evaluated vendor alternatives were Alternative 1 to Alternative 6. This study used the Analytical Hierarchy Process (AHP) method to determine the best vendor for the mud removal project in the coal mine. The criteria used were Service/Experience, Contract and Commercial, and Machine/Manufacturing. Based on the AHP analysis results, Alternative 3 was selected as the best vendor with an AHP value of 23.273%. Alternative 2 ranked second with a value of 23.089%. The Service/Experience criterion had the highest weight with a value of 0.568, followed by the Contract and Commercial criterion with a weight of 0.334, and the Machine/Manufacturing criterion with a weight of 0.098. The recommendation provided is to choose Alternative 3 as the best vendor while considering other relevant aspects for the company.

Keywords: Vendor Selection; Mud Removal Projects; Analytical Hierarchy Process (AHP.)

1. Introduction

With the passage of time, competition among companies is increasing. This is mainly due to rapid advancements in technology. To enhance operational efficiency, various research efforts have been undertaken by companies, not only in production but also in procurement of goods, raw materials, and financial management. The objective of achieving efficiency is to maximize output in terms of products and profits while minimizing costs.

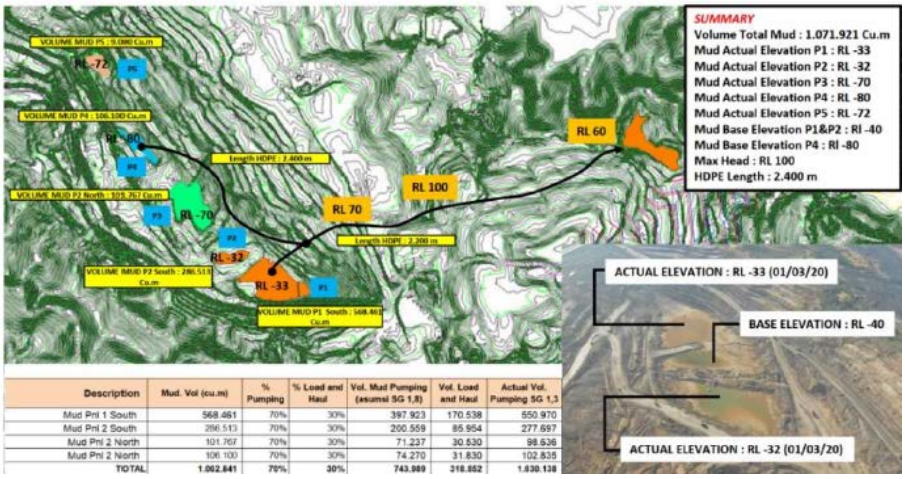
One of the ongoing coal mining projects by PT. Darma Henwa, Tbk is located in Bengalon District, East Kutai Regency, and East Kalimantan Province. The targeted coal production for the year 2020 is 12 million tons. However, one of the challenges faced by the Bengalon Project is the significant volume of sludge in Pit B, reaching 1,071,921 cubic meters. If not handled properly, effectively, and efficiently, this can disrupt the mining sequence.

To mitigate potential risks in the future, it is appropriate to procure materials from multiple vendors, even for the same type of material [1]. However, having too many vendors can result in higher costs and potential losses. One solution is for the contractor to select suppliers by considering important aspects possessed by those suppliers. Suppliers will always highlight the advantages and positive aspects of their companies, and the selection process will be more rigorous and competitive. Through accurate evaluation, the contractor can assess the potential for project completion with maximum efficiency and minimal costs. [2].

The contractor's decisions during the selection process are crucial, especially in determining the criteria. Some important criteria include price, time, and professionalism. Evaluating the performance of vendors or suppliers is essential to consider continuously in the company's operations. This can serve as a basis for improving vendor performance or considering the

use of alternative suppliers. When a company has multiple suppliers, performance evaluations can be used as a basis for future order allocation. Suppliers with better performance will receive more orders, thereby motivating suppliers to improve their performance through this system. [3].

In supplier selection, the criteria used to evaluate performance also need to be considered. Supplier performance assessments focus on aspects such as quality, timeliness, flexibility, and pricing offered over a specific period of time. [3]–[6]. The primary objective of supplier selection is to achieve the best outcomes in project completion according to the agreed-upon timeframe, budget, and quality. [7]–[9]. The challenges in the construction sector include low productivity, high costs, declining construction quality, and decreased project owner satisfaction. [10]–[12]. Lack of trust and poor cooperation are major issues in any project. Therefore, the key to project success lies in selecting reliable suppliers. [13].



Description	Mud. Vol (cu.m)	% Pumping	% Load and Haul	Vol. Mud Pumping (asumsi SG 1,8)	Vol. Load and Haul	Actual Vol. Pumping SG 1,3
Mud Pit 1 South	568.461	70%	30%	397.923	170.538	550.970
Mud Pit 2 South	286.513	70%	30%	200.559	85.954	277.697
Mud Pit 2 North	101.767	70%	30%	71.237	30.530	98.636
Mud Pit 2 North	106.100	70%	30%	74.270	31.830	102.835
TOTAL	1.062.841	70%	30%	743.989	318.852	1.030.138

Figure 1. Sludge Volume (Pit B) of Bengalon Coal Project

Based on the actual conditions in April 2020, a total sludge volume of 1,071,921 cubic meters was recorded in Pit B of the Bengalon Coal Project. It is estimated that this sludge will be generated over the first 6 months and will reach 2,143,841 cubic meters by the end of 2020. If not effectively addressed, significant issues in mining operations can be caused by this. [14].

To address these challenges, the selection of appropriate material suppliers will be crucial. This research aims to develop an effective supplier evaluation model for the Bengalon Coal Project at PT. Darma Henwa, Tbk. With the use of this model, the contractor can choose suppliers that can efficiently meet the project's requirements while considering important aspects such as price, time, and professionalism. The expected outcome is to improve project efficiency and performance, as well as mitigate potential risks in the future. [15], [16].

The selection of suppliers or supplier performance evaluation can be done by considering several criteria and sub-criteria. Here is an explanation of each variable criterion and sub-criterion based on Garvin's theory for product quality characteristics and Kotler's theory for dimensions of service quality:

1. Product Quality Characteristics (Garvin's Theory): a. Performance: The ability of the product to perform its intended function effectively and efficiently. b. Features: Additional attributes or functionalities that enhance the product's value and customer satisfaction. c. Reliability: The consistency and dependability of the product's performance over time. d. Conformance: The extent to which the product meets established standards and specifications. e. Durability: The product's ability to withstand wear and tear and maintain its quality over an extended period. f. Serviceability: The ease of repair, maintenance, and customer support provided for the product. g. Aesthetics: The visual appeal, design, and sensory aspects of the product. h. Perceived Quality: The overall perception of the product's excellence and value by customers.
2. Dimensions of Service Quality (Kotler's Theory): a. Tangibles: The physical facilities, equipment, and appearance of personnel associated with the service. b. Reliability: The ability to perform the promised service dependably and accurately. c. Responsiveness: Willingness and promptness in providing service, as well as addressing customer needs and inquiries. d. Assurance: Knowledge, competence, and courtesy displayed by service providers,

instilling trust and confidence. e. Empathy: Caring, individualized attention, and understanding shown to customers to meet their specific needs.

By considering these criteria and sub-criteria, the evaluation of supplier performance can be more comprehensive and aligned with both product quality and service quality aspects. [17]:
he criteria and sub-criteria for vendor selection or supplier performance evaluation based on Garvin's theory (product quality characteristics) and Kotler's theory (service quality dimensions) include[17]:

1. Delivery: Timeliness; Lead time; Quantity/Capacity of goods; Flexibility
2. Service: Reliability; Empathy; Responsiveness; Assurance
3. Product: Product variety; Availability of new products; Product performance; Product durability; Reliability; Conformance; Aesthetics
4. Supplier Quality: Reputation; Rejection rate
5. Cost: Purchase price; Logistics (including transportation costs)

This research aims to identify the criteria used in selecting vendors for the mud removal project in coal mining using the Analytical Hierarchy Process (AHP) method. This method will help measure and compare the relative importance of each criterion in vendor selection.

Furthermore, the objective of this research is to determine the best vendor for the mud removal project based on the AHP method. By employing this approach, PT. Darma Henwa, Tbk, as one of the leading mining service contractors in Indonesia, is expected to enhance efficiency and effectiveness in coal mining operations. By selecting the best vendor, the company can ensure that the mud removal project runs smoothly, on schedule, and in accordance with established quality standards.

By improving the efficiency and effectiveness of coal mining operations, PT. Darma Henwa, Tbk will also be able to remain competitive in the increasingly competitive mining industry. Additionally, by maximizing production output and reducing costs, the company can enhance its overall business revenue.

This research aims to have the most relevant and significant criteria in determining the best vendor for the mud removal project identified. By using the AHP method, recommendations regarding the most suitable vendor for the project will also be provided, based on the established criteria priorities.

Overall, the objective of this research is to contribute to the development of an effective vendor selection method, enabling PT. Darma Henwa, Tbk to improve its operational performance in the implementation of the mud removal project in coal mining.

2. Research Methodology

The initial stage of this research involves problem formulation and research objective determination. The identified problem is the difficulty in the vendor selection process for the mud removal project in coal mining. The research objective is set to provide a solution to this problem by determining the vendor for the mud removal project and proposing priority strategies to the mining company's management.

In this stage, the following steps are taken: identifying the existing problem, determining specific research objectives related to the identified problem, conducting literature review and relevant research, collecting necessary data, designing the research methodology to be used, analyzing the collected data, interpreting the results of data analysis, drawing research conclusions, and providing recommendations based on the research findings.

This research aims to improve the vendor selection process and supplier management in coal mining companies through the integration of the Simple Additive Weighting (SAW) and Analytical Hierarchy Process (AHP) methods. Therefore, this research is expected to provide a valuable contribution to the development of an effective vendor selection method in the context of the mud removal project in coal mining.

In the context of the proposed research, Cheng and Li (2004) and Yadav and Sharma (2015) propose the integration of the Simple Additive Weighting (SAW) method and the Analytical Hierarchy Process (AHP) as a more comprehensive approach for multi-criteria decision-making, specifically in vendor performance assessment and supplier management [6], [18]. The SAW method is used to calculate the weighted scores of each vendor alternative based on the predetermined criteria. On the other hand, the AHP method is used to develop the hierarchy of criteria and determine the relative weights

of the criteria. The integration of these two methods will provide more objective and informative results in decision-making related to supplier selection or supplier performance improvement.

In this research, several steps need to be taken. Firstly, we need to identify the relevant criteria for vendor performance assessment. These criteria may include quality, timeliness, flexibility, price, and other factors deemed important in relation to suppliers. Then, the AHP method is used to develop the hierarchy of criteria and determine the relative weights of each criterion. The AHP process involves decomposition, comparative assessment, priority determination, logical consistency, consistency testing, and ranking determination. In the context of this research, the AHP method will be used to obtain the relative priorities of the identified criteria. Next, we need to create pairwise comparison matrices to determine the relative importance levels between criteria at each level of the hierarchy. These matrices reflect the relative preferences between criteria and are used to obtain the relative weights of each criterion.

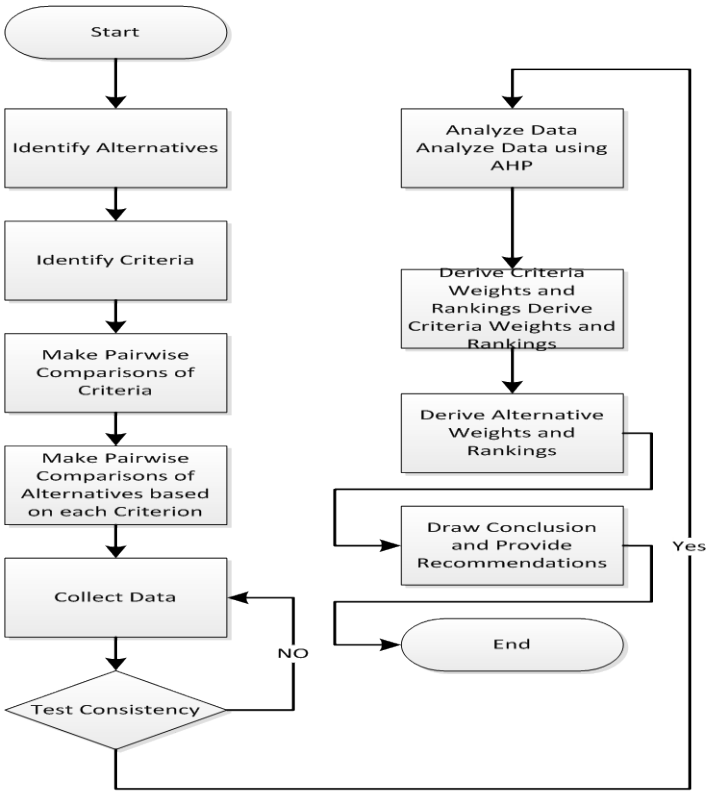


Figure 2. Research Flowchart

After obtaining the relative weights of the criteria through the AHP method, we can use the SAW method to calculate the weighted scores of each vendor alternative based on the predetermined criteria. The SAW method involves data normalization, allocation of weights to criteria, and calculation of weighted scores for each alternative. These weighted scores reflect the relative performance levels of each vendor based on the established criteria.

After obtaining the weighted scores for each vendor alternative, we can determine their rankings based on these scores. These rankings can be used as a basis for decision-making regarding supplier selection or supplier performance improvement.

In this research, pairwise comparison matrices are used in the AHP method to obtain the relative weights of the criteria, as well as pairwise comparison matrices for vendor performance assessment. These matrices assist in the calculation of weights and weighted scores needed in the integration of the SAW and AHP methods.

3. Results And Discussion

In this study, data collection was carried out through interviews and questionnaires. The purpose was to obtain the necessary data as a reference for the formation of desired supplier criteria. Data collection involved respondents who are stakeholders authorized to make decisions regarding the selection of vendors for the mud removal project in the coal mine.

The initial stage of this research involves problem formulation and research objective determination. The identified problem is the difficulty in the vendor selection process for the mud removal project in coal mining. The research objective is set to provide a solution to this problem by determining the vendor for the mud removal project and proposing priority strategies to the mining company's management.

In this stage, the following steps are taken: identifying the existing problem, determining specific research objectives related to the identified problem, conducting literature review and relevant research, collecting necessary data, designing the research methodology to be used, analyzing the collected data, interpreting the results of data analysis, drawing research conclusions, and providing recommendations based on the research findings.

This research aims to improve the vendor selection process and supplier management in coal mining companies through the integration of the Simple Additive Weighting (SAW) and Analytical Hierarchy Process (AHP) methods. Therefore, this research is expected to provide a valuable contribution to the development of an effective vendor selection method in the context of the mud removal project in coal mining.

3.1 Criteria Identification

In this research, several steps need to be taken. Firstly, we need to identify the relevant criteria for vendor performance assessment. These criteria may include quality, timeliness, flexibility, price, and other factors deemed important in relation to suppliers. The important factors in mud removal management data that have been collected will then be discussed and processed using Gap Analysis on the existing conditions. Gap analysis will be supported by the processing of historical data in mud removal management, as well as interviews and brainstorming sessions with stakeholders in the coal mining company. The results of the gap analysis will provide alternative strategies that can be implemented in the mud removal project in the coal mine. The process of identifying criteria was conducted using a review of previous research and through interviews with the company's stakeholders. The outcome of this process is a list of relevant criteria for vendor performance assessment. Table 1 presents the identified criteria, along with their respective codes and descriptions.

Table 1. Selected Criteria

No	Criteria	Code	Description
1	Machine/Manufacturing	K1	This criterion focuses on the quality and capability of the supplier's machines or equipment. It assesses the supplier's manufacturing capabilities and the quality of the equipment they possess.
2	Service/ Experience	K2	This criterion evaluates the level of service provided by the supplier and their overall experience in the industry. It considers factors such as responsiveness, customer support, and the supplier's track record in delivering satisfactory services.
3	Contract and Commercial	K3	This criterion examines the contractual and commercial aspects of the supplier's offering. It includes factors such as pricing, terms and conditions, delivery schedules, and overall value for money.

3.2 Alternative Identification

Alternative solutions that can be chosen are identified. This list of alternatives can come from existing suppliers or potential suppliers that can be considered. Table 2 presents the identified list of alternatives, along with their corresponding codes.

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Table 2. Alternatives list

No	Alternative	Code	No	Alternative	Code
	Alternative1	A1		Alternative4	A4
	Alternative2	A2		Alternative5	A5
	Alternative3	A3		Alternative6	A6

3.3 Questionnaire Data

The questionnaire data is used to collect data from respondents regarding the pairwise comparisons between criteria and alternatives. Each respondent is asked to provide relative assessments of the compared elements on a rating scale [19]. The questionnaire data is essential for collecting information from respondents regarding the pairwise comparisons between criteria and alternatives. Respondents are requested to provide relative assessments of the compared elements using a rating scale.

3.4 Ranking and Prioritization

By utilizing the data from the questionnaire and the values of relative comparisons, the ranking and prioritization of each alternative can be determined. Qualitative and quantitative criteria can be compared according to the established assessments to generate rankings and priorities. sing the data collected from the questionnaire and the relative comparison values, it is possible to establish the ranking and prioritization of each alternative. Qualitative and quantitative criteria can be compared based on the predetermined assessments to derive rankings and priorities.

After the data collection process, data processing is carried out using the AHP method. The purpose of data processing is to gain insights from the gathered information. Following the pairwise comparisons conducted through the questionnaire completed by experts, a consistency test is performed to examine the consistency of the data. The consistency ratio (CR) is calculated to measure the intensity of relationships between objects or ideas based on specific criteria. In this study, a consistency test is conducted for each criterion and alternative. Based on the pairwise comparisons from the questionnaire, the consistency value is calculated using the provided formula. If the Consistency Ratio (CR) is less than or equal to 0.1, the data is considered consistent and can be used for decision-making calculations. However, if the CR value is greater than 0.1, the data is considered inconsistent, and revision or rechecking is necessary.

After conducting the consistency test, the next step is to normalize the pairwise comparison matrix. The purpose of normalization is to convert the comparison data into relative values. In the AHP method, normalization is performed by dividing each element in the pairwise comparison matrix by the sum of its respective column. Once the pairwise comparison matrix is normalized, the next step is to calculate the relative weights for each criterion and alternative. The relative weight is the sum of each row in the normalized pairwise comparison matrix. These relative weights reflect the relative importance of each criterion and alternative.

After calculating the relative weights for each criterion and alternative, the final step is to compute the relative rankings of all the alternatives. The relative rankings can be obtained by multiplying the relative weights of the criteria by the relative comparison values of the alternatives. Thus, the AHP method can generate relative rankings for each alternative based on the predetermined criteria. These rankings can serve as a basis for decision-making in selecting the most optimal or suitable alternative.

The process of identifying criteria and alternatives, as well as collecting data, is an important step in the AHP method to generate strategic priorities and determine the vendor for the mud removal project in coal mining. By identifying the relevant criteria and alternatives, the AHP method ensures that all important factors are considered in the decision-making process. The criteria provide a framework for evaluating the performance and suitability of the vendors, while the alternatives represent the different options available for selection.

Table 3. List of Respondents

Experts Code	Jabatan
Expert 1	Director
Expert 2	Head of Project
Expert 3	Head PLM
Expert 4	Head Finance
Expert 5	Head SCM

Through data collection, information is gathered from relevant stakeholders and experts (Table 3), enabling a comprehensive assessment of the criteria and alternatives. This data serves as the basis for conducting pairwise comparisons and determining the relative importance of the criteria and the performance of the alternatives. Overall, the process of identifying criteria and alternatives, as well as collecting data, plays a crucial role in the AHP method as it lays the foundation for the subsequent steps of weighting, normalization, and ranking. It ensures a systematic and comprehensive approach to decision-making, leading to informed choices and effective vendor selection for the mud removal project in coal mining.

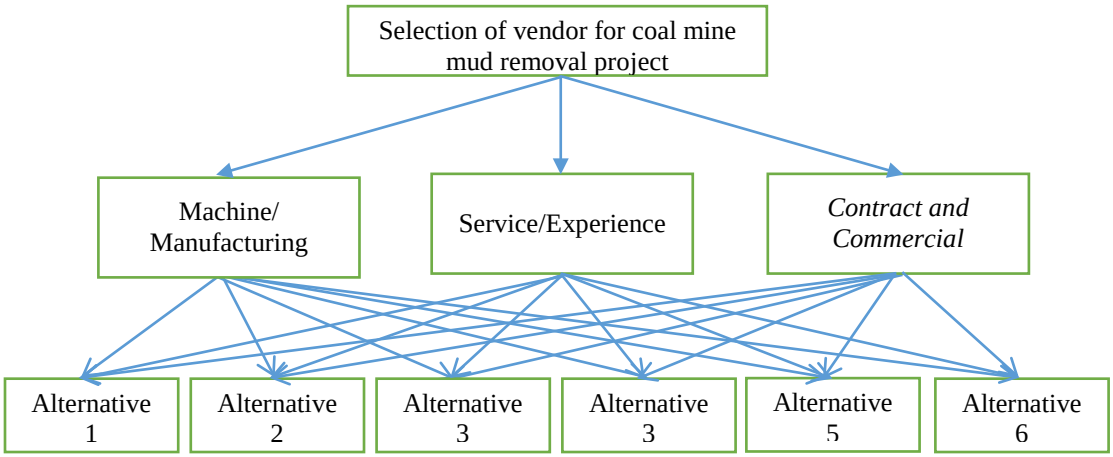

Figure 3. Hierarchy Structure: Selection of Vendor for Coal Mine Mud Removal Project

Table 4. Pairwise Comparison between Criteria

Kriteria A	9	8	7	6	5	4	3	2	1	2	3	4	5	6	7	8	9	Kriteria B
Machine/Manu-facturing (K1)													X					Service/ Experience (K2)
Machine/Manu-facturing (K1)												X						Contract and Commercial (K3)
Service/ Experience (K2)								X										Contract and Commercial (K3)

Table 5. Calculation of Criteria Normalization

Criteria	Machine/ Manufacturing (K1)	Service/ Experience (K2)	Contract and Commercial (K3)
K1	1.00 /10.0 = 0.10	5/10 = 0.50	4/10 = 0.40
K2	0.20 /1.70 = 0.12	1/1.70 = 0.59	0.50/1.70 = 0.29
K3	0.20 /3.25 = 0.12	2/3.25 = 0.59	1/3.25 = 0.29

Table 6. Determination of Criteria Weight Vector

Criteria	Machine/ Manufacturing (K1)	Service/ Experience (K2)	Contract and Commercial (K3)	Total	Weight
Machine/ Manufacturing (K1)	0.1	0.12	0.08	0.29	0.098
Service/ Experience (K2)	0.5	0.59	0.62	1.7	0.568
Contract and Commercial (K3)	0.4	0.29	0.31	1	0.334
Total	1	1	1		1

The Consistency Index (CI) value is calculated

$$Consistency\ Index\ (CI) = \frac{\lambda - n}{RI} = \frac{3{,}02-3}{3-1} = 0{,}012 \text{ and } Consistency\ Ratio(CR) = \frac{0{,}012}{0{,}58} = 0{,}021$$

Since the CR value is ≤ 0.1, it can be concluded that the data used in the AHP method is consistent
A summary of the Consistency Index (CI) values for the alternatives with respect to the criteria can be seen in Tabel 5

After pairwise comparisons and consistency ratio testing for each criterion and alternative in the AHP process, if the consistency ratio requirements are met, the next step is to calculate the weighted scores. The weighted scores are obtained by multiplying the final values of each alternative by the weights of the criteria. These weighted scores help in determining the best alternative based on the criteria used in the evaluation.

Table 7. CI and CR Values and Criteria Weights

No	Criteria	CI	CR	Vector of Weights
	Machine/ Manufacturing	0.012	0.021	0.098
	Service/ Experience	0.095	0.077	0.568
	Contract and Commercial	0.057	0.046	0.334

After the pairwise comparison and consistency ratio testing process for each criterion and alternative is completed and satisfied, the calculation of alternative values is carried out. This evaluation is performed by multiplying the final values with the values of each criterion for each alternative. The AHP values are then presented as percentages, as follows:

Table 8. Assessment of Alternatives for Each Criterion

No	Alternative	Kode	Machine/ Manufacturing (K1)	Service/ Experience (K2)	Contract and Commercial (k3)	Nilai AHP	Persentase
1	Alternative 3	A3	0.00687	0.2145	0.01136	0.23273	23.273%
2	Alternative 2	A2	0.01505	0.07976	0.13607	0.23089	23.089%
3	Alternative 4	A4	0.00334	0.13407	0.03449	0.1719	17.190%
4	Alternative 1	A1	0.03208	0.05568	0.07909	0.16686	16.686%
5	Alternative 5	A5	0.03208	0.06085	0.01854	0.11147	11.147%
6	Alternative 6	A6	0.00876	0.02301	0.05439	0.08616	8.616%

The Table 8 above presents the assessment of alternatives for each criterion based on the AHP method. The values represent the calculated AHP values and the corresponding percentages for each alternative. According to the calculations, Alternative 3 has the highest AHP value of 0.23273, corresponding to a percentage of 23.273%. Alternative 2 follows closely with an AHP value of 0.23089, accounting for 23.089%. Alternative 4 obtains an AHP value of 0.1719 (17.19%), ranking third. Alternative 1 achieves an AHP value of 0.16686 (16.686%) and holds the fourth position. Alternative 5 and Alternative 6 obtain AHP values of 0.11147 (11.147%) and 0.08616 (8.616%), respectively, ranking fifth and sixth.

These results indicate that, based on the given criteria, PT. Darma Henwa, Tbk prefers Alternative 3 as the best vendor for the mud removal project in coal mining, as it obtains the highest AHP value. Alternative 2 is the second-best choice, followed by Alternative 4. Alternative 1, Alternative 5, and Alternative 6 rank lower in terms of their suitability for the project.

The AHP method allows for a systematic evaluation of alternatives based on the predetermined criteria, providing a quantitative basis for decision-making in selecting the most optimal vendor.

4. Conclusion

This research has successfully applied the Analytical Hierarchy Process (AHP) method to determine the best vendor for the mud removal project in the coal mine. The AHP method is used to calculate the weights of criteria and vendor alternatives based on expert assessments. The criteria used in this study are Service/Experience, Contract and Commercial, and Machine/Manufacturing. The considered vendor alternatives are Alternative 1 to Alternative 6.

Based on the AHP analysis results, it is found that the Service/Experience criterion is the most important criterion in vendor selection with a weight of 0.568. Furthermore, the Contract and Commercial criterion has a weight of 0.334, and the Machine/Manufacturing criterion has a weight of 0.098. Among the six evaluated vendor alternatives, Alternative 3 is selected as the best vendor with an AHP value of 0.23273 or 23.273%. Alternative 3 excels in the Service/Experience criterion with a value of 0.21450 but performs less favourably in the Contract and Commercial criterion with a value of 0.01136. Alternative 2 ranks second with an AHP value of 0.23089 or 23.089%. Alternative 2 has an advantage in the Contract and Commercial criterion with a value of 0.13607 but falls short in the Machine/Manufacturing criterion with a value of 0.01505. Although the difference between Alternative 3 and Alternative 2 is very small, Alternative 3 is recommended as the best vendor considering other relevant aspects for the company.

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