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Development of Integrated AHP-Topsis Model for Construction Equipment Supplier Assessment

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Abstract

The selection of construction equipment suppliers heavily impacts project quality and supply chain sustainability. The research gap addressed here is that previous studies rarely integrate operational procurement metrics with global sustainability standards. This study fills this gap by developing an integrated AHP-TOPSIS multi-criteria decision-making model for PT Gamila Buana Nusantara. Pairwise-comparison data were obtained from 3 experts directly involved in the company's procurement process—specifically a Procurement Manager, a Senior Buyer, and a Supply Chain Specialist — each with 10 years of professional experience, selected through purposive sampling. The AHP method determines priority weights, while TOPSIS ranks alternative suppliers. Results show that quality, price, and delivery are the main criteria. The novelty of this study lies in bridging internal corporate operational evaluation directly with Sustainable Development Goals (SDG 9) frameworks, providing a highly systematic and transparent model. This study contributes to SDG 9 (Industry, Innovation, and Infrastructure) by strengthening resilient infrastructure, value chain management, and process innovation in the construction equipment procurement system.

Keywords: *supplier selection, construction equipment, AHP, TOPSIS, resilient infrastructure*

INTRODUCTION

One of the main industries that contributes significantly to the infrastructure development and economic growth of a country is the construction sector [1]. Supply chain management efficiency, especially in the acquisition of construction equipment, has a significant impact on the success of construction projects [2]. Mistakes in selecting a construction equipment provider can result in reduced work quality, operational disruptions, and higher financial and technical risks during project execution [3].

Choosing a construction equipment provider is not an easy choice [4]. Price, tool quality, delivery reliability, after-sales support, supplier reputation, parts availability, risk, and sustainability are just a few of the interconnected factors considered in this process [5]. Depending on the features of the project, these criteria have different levels of significance and are often quantitative and qualitative at the same time [6], [7]. Methodical, transparent, and multi-criteria decision-making methodologies are becoming increasingly necessary [8]. Complex decision-making processes are often supported by an approach *Multi-Criteria Decision Making* (MCDM) [9], [10].

Analytic Hierarchy Process (AHP) is one of the most popular MCDM techniques [11], [12] One of the important benefits of guaranteeing the authenticity of results is that the AHP offers a consistency testing mechanism in the evaluation of decision-makers [13], [14].

However, the AHP essentially only serves to determine the relative level of importance of each criterion and has not provided an alternative ranking mechanism that takes into account the proximity to the best solution overall [15], [16]. In the framework of this study, AHP is therefore assigned a single, clearly defined role: to derive consistency-tested priority weights for the criteria and subcriteria, which subsequently serve as inputs to the alternative-ranking stage.

Technique for Order Preference by Similarity to Ideal Solution (TOPSIS) is one of the MCDM methods that is widely used to rank alternatives based on their distance to the positive ideal solution and the negative ideal solution [17]. This method allows decision-makers to choose the alternatives that have the greatest proximity to ideal conditions and the furthest distance from the worst conditions. TOPSIS has a relatively simple calculation procedure, is easy to implement, and is able to accommodate various quantitative and qualitative criteria in the evaluation process [18]. Accordingly, in this study TOPSIS is applied exclusively to rank the supplier alternatives using the criteria weights generated by AHP, whis the AHP-based priority synthesis is reported only as a comparative reference to examine the robustness of the final ranking.

The integration of AHP and TOPSIS provides an advantage in producing more comprehensive decisions. AHP is used to systematically determine the weight of criteria and subcriteria based on decision-makers' preferences, while TOPSIS is used to rank supplier alternatives based on the value of their proximity to the ideal solution [18], [19], [20]. The combination of these two methods is able to produce a more objective, transparent, and easy-to-understand supplier evaluation process [21].

There is still a large gap in the actual implementation of integrated decision models in the context of construction equipment procurement, despite the fact that previous research has addressed the difficulties of supplier selection within the framework of sustainability and MCDM. Because it can combine quantitative and qualitative factors, the AHP technique is often used when choosing a construction equipment supplier [22]. However, the use of AHP alone has not been able to produce an alternative ranking that considers proximity to the ideal solution [23], [24], [25], [26]. Therefore, this study proposes the integration of AHP–TOPSIS to produce a more accurate supplier selection process and support strategic decision-making in the procurement of construction equipment. Specifically, the research gap addressed in this study is twofold: (1) most prior AHP- or TOPSIS-based supplier studies have focused on construction materials or other sectors—for example, ship docking materials [20] and building materials [26]—rather than on heavy construction equipment suppliers at the contractor level in Indonesia; and (2) few studies explicitly compare the AHP-based priority synthesis with the TOPSIS ranking when both are derived from the same expert judgments. The novelty of this study therefore lies in a fully integrated AHP–TOPSIS model comprising five criteria and fifteen subcriteria applied to a real construction equipment procurement case, in which the AHP-derived weights serve as direct inputs to TOPSIS and the two resulting rankings are compared to test the robustness of the final recommendation.

METHODS

This study supports the selection of construction equipment suppliers at PT Gamila Buana Nusantara (PT GBN) by utilizing a quantitative approach using the MCDM method through the integration of AHP and TOPSIS. Criteria and subcriteria are identified and validated through a literature review and expert input. The pairwise-comparison questionnaires were completed by 3 experts of PT GBN—[state positions, e.g., procurement manager, project manager, and logistics supervisor]—each with 10 years of professional experience in construction equipment procurement; the experts were selected using purposive sampling on the basis of their direct involvement and decision-making authority in the procurement process. In this framework, AHP is used solely to determine the weights of the criteria and subcriteria, while TOPSIS is used solely to rank the supplier alternatives, and the two sets of results are subsequently compared to verify the stability of the recommendation. Furthermore, the decision hierarchy structure was compiled and the weight of the criteria was determined using the AHP method through paired comparisons and consistency testing. The weights obtained are then used in the TOPSIS method to evaluate and rank the supplier's alternatives based on their proximity to the positive ideal solution and its distance from the negative ideal solution. Through this approach, the best suppliers can be determined systematically, objectively, and measurably, supporting more effective decision-making in the construction equipment procurement process.

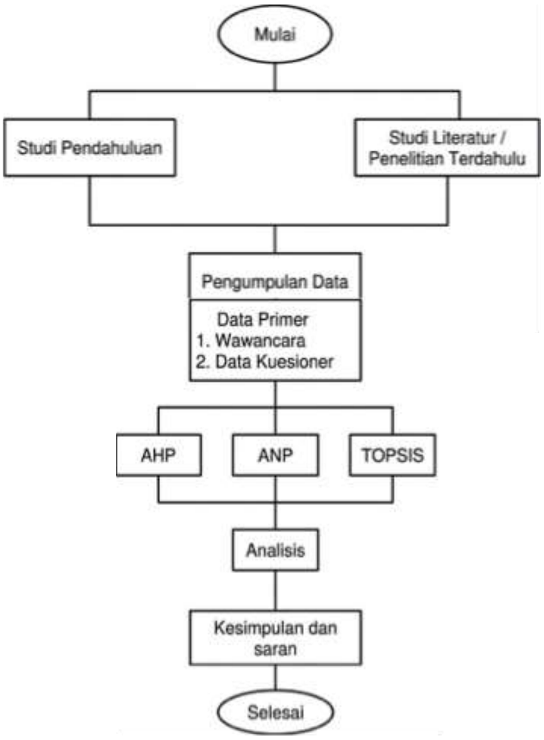

Figure 1. Research Flow Chart

RESULTS AND DISCUSSION

Process Analysis Hierarchy Analytics (AHP)

The initial stage in the AHP method is to identify the criteria and subcriteria used as the basis for evaluating construction equipment suppliers. The criteria and subcriteria are compiled based on literature studies, the company's operational conditions, and the considerations of the experts involved in the procurement process. The hierarchical structure used in this study is presented in Table 1.

Table 1. Criteria and Subcriteria

Yes	Criteria	Subcriteria
1	Quality (K1)	- Conformity with the desired detail specifications - Consistency or similarity of quality/quality - Quality of service provided
2	Delivery (K2)	- Accuracy of delivery amounts - Delivery timeliness - Continuity in delivery
3	Price (K3)	- Price is adjusted according to the raw material - Shipping or Transportation Costs of Raw Materials - Insurance costs or claims if there is damage in delivery
4	Warranty and Complaints Service (K4)	- Ease in the claims process - Make sure the goods arrive on time - Sustainability of raw material warranty - Respond quickly to complaints
5	Previous Performance Achievements (Q5)	- Ability to meet set schedules - Ability to maintain contractual agreements

This sub-criterion is in line with the actual situation of PT GBN. Customers often report issues with the service complaints, including inconsistent specifications, delivery delays, warranty claim filing issues, and inconsistent suppliers. Each subcriterion was selected because it significantly affected the likelihood of risk or success of the acquisition of the tool. To guarantee that each element of the decision is fairly represented, a hierarchical structure starts with objectives, criteria, subcriteria, and alternative suppliers. The resulting weights serve as the basis for the supplier's assessment at the next stage of the analysis and represent the respondent's assessment of the importance of each criterion.

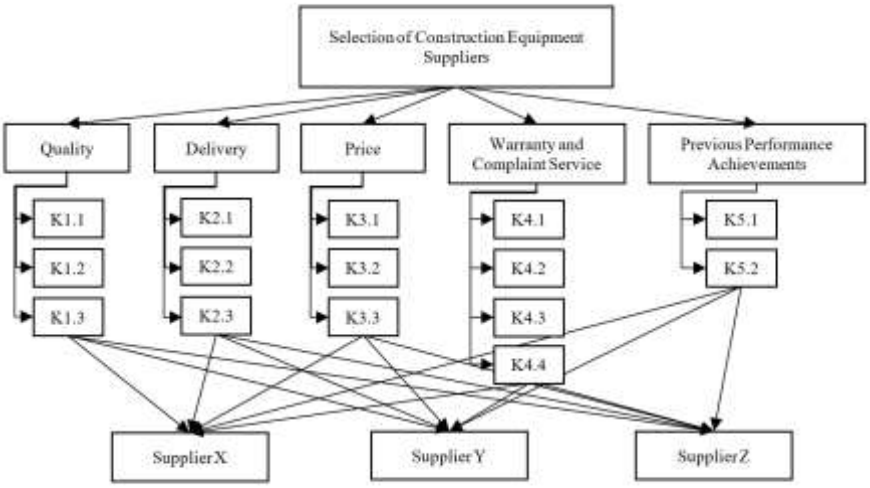

Figure 2. Selection of AHP Hierarchical Structure Construction Equipment Suppliers

Based on the hierarchical structure in Figure 2, the next step is to conduct a pair comparison to determine the level of relative importance between the criteria. This process aims to obtain priority weights that reflect the preferences of decision-makers in the selection of construction equipment suppliers.

Table 2. Paired Comparison Matrix on Key Criteria

	K1	K2	K3	K4	K5	Total Score
K1	1,00	1,55	2,37	6,12	5,35	16,39
K2	0,64	1,00	1,55		3,94	11,65
K3	0,42	0,64	1,00	5,72	4,36	12,15
K4	0,16	0,22	0,17	1,00	0,34	1,90
K5	0,19	0,25	0,23	2,95	1,00	4,62

According to Table 2, Quality (K1) is the main criterion for choosing a supplier, with Price (K3), Delivery (K2), Previous Performance Achievement (K5), and Warranty and Complaint Services (K4) as supporting elements. These findings indicate that companies prioritize product reliability and operational efficiency over cost considerations. The analysis is then focused on the quality subcriteria to find out the most influential factors in that aspect.

Table 3. Paired Comparison Matrix on Quality Subcriteria

	K1.1	K1.2	K1.3	Total Score
K1.1	1,00	0,38	0,47	1,85
K1.2	2,63	1,00	1,72	5,35
K1.3	2,14	0,58	1,00	3,72

Table 3 shows that consistency or uniformity of product quality (K1.2) is the most important factor in assessing suppliers, followed by service quality (K1.3). Following the technical specifications is the least important (K1.1). The results of paired comparisons on the quality subcriteria show that product quality consistency is the most dominant factor in assessing suppliers. These findings show that the company prioritizes quality stability over specification alone.

Table 4. Paired Comparison Matrix on Delivery Subcriteria

	K2.1	K2.2	K2.3	Total Score
K2.1	1,00	0,53	1,25	2,77
K2.2	1,90	1,00	1,90	4,81
K2.3	0,80	0,53	1,00	2,33

According to Table 4, the most important aspects in supplier evaluation are delivery timeliness (K2.2), followed by delivery quantity accuracy (K2.1), and delivery continuity (K2.3). After analyzing the delivery aspect, it was obtained that the timeliness of delivery became a major consideration in the evaluation of suppliers. Furthermore, an analysis of the price aspect was carried out to determine the influence of cost on the decision to select suppliers.

Table 5. Paired Comparison Matrix on Price Subcriteria

	K3.1	K3.2	K3.3	Total Score
K3.1	1,00	0,27	0,47	1,74
K3.2	3,68	1,00	2,67	7,35
K3.3	2,14	0,37	1,00	3,52

Table 5 shows that the most important factor in evaluating the price aspect is the cost of shipping or transporting raw materials (K3.2), followed by insurance costs or damage claims for goods (K3.3) and prices adjusted for raw materials (K3.1). The results of the price aspect analysis show that the cost of transportation of raw materials has the greatest influence compared to other cost components. Therefore, the next evaluation is focused on warranty services and handling supplier complaints.

Table 6. Paired Comparison Matrix on Warranty and Complaint Services Subcriteria

	K4.1	K4.2	K4.3	K4.4	Total Score
K4.1	1,00	3,94	2,81	3,27	11,02
K4.2	0,25	1,00	0,72	0,47	2,45
K4.3	0,36	1,38	1,00	0,39	3,13
K4.4	0,31	2,14	2,54	1,00	5,98

According to Table 6, the most important aspect is the ease of claims processing (K4.1), followed by the speed of complaint handling (K4.4). Ensuring punctuality in the event of delays (K4.2) has the least impact, while the continuation of raw material warranty (K4.3) is a medium priority. In addition to the after-sales service factor, the supplier's track record of performance is also an important indicator in ensuring the sustainability of long-term cooperation. Therefore, the next evaluation is carried out on the performance of the previous supplier.

Table 7. Paired Comparison Matrix on Previous Performance Subcriteria

	K5.1	K5.2	Total Score
K5.1	1,00	0,64	1,64
K5.2	1,55	1,00	2,55

The most important factor in Table 7 is the capacity of suppliers to enforce contractual commitments (K5.2), followed by capacity to meet (K5.1). After all paired comparisons at the subcriteria level are performed, the next stage is to test the consistency of respondents' assessments. This test aims to ensure that the resulting weight can be used as a basis for valid decision-making.

Table 8. Summing and Normalization of the Main Criteria Matrix

Summing of the Main Criteria of the Matrix Column					
	K1	K2	K3	K4	K5
K1	1,00	1,55	2,37	6,12	5,35
K2	0,64	1,00	1,55	4,51	3,94
K3	0,42	0,64	1,00	5,72	4,36
K4	0,16	0,22	0,17	1,00	0,34
K5	0,19	0,25	0,23	2,95	1,00
Quantity	2,42	3,67	5,33	20,31	14,98

Normalization of the Main Criteria Matrix						
	K1	K2	K3	K4	K5	Average
K1	0,41	0,42	0,45	0,30	0,36	0,39
K2	0,27	0,27	0,29	0,22	0,26	0,26
K3	0,17	0,18	0,19	0,28	0,29	0,22
K4	0,07	0,06	0,03	0,05	0,02	0,05
K5	0,08	0,07	0,04	0,15	0,07	0,08
Self-Vector						1,00

$$\lambda_{max} = (2{,}42 \times 0{,}39) + (3{,}67 \times 0{,}26) + (5{,}33 \times 0{,}22) + (20{,}31 \times 0{,}05) + (14{,}98 \times 0{,}08) = 5{,}24$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n - 1} = \frac{5{,}24 - 5}{5 - 1} = 0{,}06$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}06}{1{,}12} = 0{,}05$$

According to Table 8, Quality (K1) is the most important criterion for choosing a supplier, followed by Delivery (K2) and Price (K3). Previous Performance (K5) and Warranty and Complaint Services (K4) have lower weights as supporting variables. The weight of the resulting criteria is considered valid and reliable when the Consistency Ratio (CR) score is 0.05, indicating that the respondent's assessment is at an acceptable level of consistency. Next, a consistency test was carried out on the subcriteria of each criterion. The following are presented the results of the consistency test of the quality subcriteria in Table 9.

Table 9. Summing and Normalization of Quality Subcriteria Matrix

Matrix Column Summation K1			
	K1.1	K1.2	K1.3
K1.1	1,00	0,38	0,47
K1.2	2,63	1,00	1,72
K1.3	2,14	0,58	1,00
Quantity	5,77	1,96	3,19

K1 Matrix Normalization				
	K1.1	K1.2	K1.3	Average
K1.1	0,17	0,19	0,15	0,17
K1.2	0,46	0,51	0,54	0,50
K1.3	0,37	0,30	0,31	0,33
Self-Vector				1,00

$$\lambda_{max} = (5{,}77 \times 0{,}17) + (1{,}96 \times 0{,}50) + (3{,}19 \times 0{,}33) = 3{,}01$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n - 1} = \frac{3{,}01 - 3}{3 - 1} = 0{,}01$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}01}{0{,}58} = 0{,}01$$

According to Table 9, specification conformity (K1.1) has the lowest weight, while quality/quality consistency (K1.2) is the top priority with the highest weight, followed by service quality (K1.3). The respondents' assessment was very consistent, as can be seen from the Consistency Ratio (CR) value of 0.01, which was below the threshold of 0.10. Based on the results of the normalization of quality subcriteria, product quality consistency has the highest weight. The next stage is to evaluate consistency on the delivery subcriteria.

Table 10. Summing and Normalizing Delivery Subcriteria Matrix

Summing of K2 Matrix Columns			
	K2.1	K2.2	K2.3
K2.1	1,00	0,53	1,25
K2.2	1,90	1,00	1,90
K2.3	0,80	0,53	1,00
Quantity	3,71	2,05	4,15

K2 Matrix Normalization				
	K2.1	K2.2	K2.3	Average
K2.1	0,27	0,26	0,30	0,28
K2.2	0,51	0,49	0,46	0,49
K2.3	0,22	0,26	0,24	0,24
Self-Vector				1,00

$$\lambda_{max} = (3{,}71 \times 0{,}28) + (2{,}05 \times 0{,}49) + (4{,}15 \times 0{,}24) = 3{,}01$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n - 1} = \frac{3{,}01 - 3}{3 - 1} = 0{,}01$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}01}{0{,}58} = 0{,}01$$

According to Table 10, the highest priority is delivery timeliness (K2.2) with a weight of 0.49, followed by delivery quantity accuracy (K2.1) with a weight of 0.28, and continuity of delivery (K2.3) with a weight of 0.24. The respondents' evaluation was very consistent when the CR = 0.01 value was very low. After obtaining the weight of the shipping subcriteria, the analysis is continued on the price aspect to find out the cost priorities that affect the selection of suppliers.

Table 11. Summing and Normalizing the Price Subcriteria Matrix

Summing Matrix Columns K3			
	K3.1	K3.2	K3.3
K3.1	1,00	0,27	0,47
K3.2	3,68	1,00	2,67
K3.3	2,14	0,37	1,00
Quantity	6,82	1,65	4,13

K3 Matrix Normalization				
	K3.1	K3.2	K3.3	Average
K3.1	0,15	0,17	0,11	0,14
K3.2	0,54	0,61	0,65	0,60
K3.3	0,31	0,23	0,24	0,26

Self-Vector	1,00

$$\lambda_{max} = (6{,}82 \times 0{,}14) + (1{,}65 \times 0{,}60) + (4{,}13 \times 0{,}26) = 3{,}03$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n-1} = \frac{3{,}03 - 3}{3 - 1} = 0{,}01$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}01}{0{,}58} = 0{,}02$$

With a weight of 0.60, the cost of shipping or transporting raw materials (K3.2) is ranked as a top priority in Table 11, significantly higher than the other two subcriteria. Adjusted prices for raw materials (K3.1) had the lowest weight of 0.14, while insurance costs or damage claims (K3.3) came in second with a weight of 0.26. The respondents' evaluation was very consistent, as shown by the CR score = 0.02. Findings on the price aspect show the dominance of raw material transportation costs. Furthermore, an analysis was carried out on warranty services and complaint handling as part of the evaluation of supplier services.

Table 12. Summing and Normalizing the Subcriteria Matrix of Warranty and Complaint Services

Summation of Matrix Columns K4				
	K4.1	K4.2	K4.3	K4.4
K4.1	1,00	3,94	2,81	3,27
K4.2	0,25	1,00	0,72	0,47
K4.3	0,36	1,38	1,00	0,39
K4.4	0,31	2,14	2,54	1,00
Quantity	1,92	8,46	7,07	5,13

K4 Matrix Normalization					
	K4.1	K4.2	K4.3	K4.4	Average
K4.1	0,52	0,47	0,40	0,64	0,51
K4.2	0,13	0,12	0,10	0,09	0,11
K4.3	0,19	0,16	0,14	0,08	0,14
K4.4	0,16	0,25	0,36	0,19	0,24
Self-Vector					1,00

$$\lambda_{max} = (1{,}92 \times 0{,}51) + (8{,}46 \times 0{,}11) + (7{,}07 \times 0{,}14) + (5{,}13 \times 0{,}24) = 4{,}15$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n-1} = \frac{4{,}15 - 4}{4 - 1} = 0{,}05$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}05}{0{,}9} = 0{,}06$$

Ease of processing claims (K4.1), with a weight of 0.51, and speed in handling complaints (K4.4), with a weight of 0.24, rank as the top priority in Table 12. The last two sub-criteria, punctuality guarantee (K4.2) and raw material warranty sustainability (K4.3), have lower weights of 0.11 and 0.14, respectively. The respondents' evaluation can be considered consistent because the CR value of 0.06 is still below the tolerance limit of 0.10. In addition to after-sales service, the supplier's historical performance is an important factor that reflects the reliability of cooperation. Therefore, an evaluation was carried out on previous performance achievements.

Table 13. Summing and Normalizing the Subcriteria Matrix of Previous Performance Achievement

Summing Matrix Columns K5		
	K5.1	K5.2
K5.1	1,00	0,64
K5.2	1,55	1,00
Quantity	2,55	1,64

K5 Matrix Normalization			
	K5.1	K5.2	Average
K5.1	0,39	0,39	0,39
K5.2	0,61	0,61	0,61
Self-Vector			1,00

$$\lambda_{max} = (2{,}55 \times 0{,}39) + (1{,}64 \times 0{,}61) = 2{,}00$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n-1} = \frac{2{,}00 - 2}{2 - 1} = 0{,}00$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}00}{0{,}00} = 0{,}00$$

With a weight of 0.61, the ability to enforce contractual commitments (K5.2) is ranked as the highest priority in Table 13, while meeting deadlines (K5.1) has a lower weight of 0.39. The respondents' evaluation was very constant and without variation, as indicated by the value CR = 0.00.

Table 14. Addition and Normalization of Alternative Matrices – Quality Criteria

Matrix Column Summation Alt. K1

	X	Y	Z
X	1,00	0,72	2,95
Y	1,38	1,00	4,66
Z	0,34	0,21	1,00
Quantity	2,72	1,94	8,62

Normalization of Matrix Alt. K1				
	X	Y	Z	Average
X	0,37	0,37	0,34	0,36
Y	0,51	0,52	0,54	0,52
Z	0,12	0,11	0,12	0,12
Self-Vector				1,00

$$\lambda_{max} = (2{,}72 \times 0{,}36) + (1{,}94 \times 0{,}52) + (8{,}62 \times 0{,}12) = 3{,}00$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n - 1} = \frac{3{,}00 - 3}{3 - 1} = 0{,}001$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}001}{0{,}58} = 0{,}002$$

Compared to the other two suppliers, Supplier Y was evaluated as having the highest weight (0.52) in Table 14. Supplier Z received the lowest weight of 0.12, while Supplier X came in second with a weight of 0.36. Respondents' assessments were very consistent, as shown by the very low CR = 0.002 score. When it comes to product quality, Supplier Y is the best choice.

Table 15. Addition and Normalization of Alternative Matrices – Delivery Criteria

Matrix Column Summation Alt. K2			
	X	Y	Z
X	1,00	0,72	2,67
Y	1,38	1,00	4,36
Z	0,37	0,23	1,00
Quantity	2,75	1,95	8,03

Normalization of the Alt. K2 Matrix				
	X	Y	Z	Average
X	0,36	0,37	0,33	0,36
Y	0,50	0,51	0,54	0,52
Z	0,14	0,12	0,12	0,13
Self-Vector				1,00

$$\lambda_{max} = (2{,}75 \times 0{,}36) + (1{,}95 \times 0{,}52) + (8{,}03 \times 0{,}13) = 3{,}00$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n - 1} = \frac{3{,}00 - 3}{3 - 1} = 0{,}002$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}002}{0{,}58} = 0{,}003$$

With a weight of 0.52 in Table 15, Supplier Y is once again the best, demonstrating the greatest capacity to meet delivery continuity, quantity, and punctuality. Supplier Z received the lowest weight of 0.13, while Supplier X came in second with a weight of 0.36. The consistency of respondents' assessment was shown by a relatively small CR = 0.003 value. When it comes to shipping, Supplier Y is the best choice.

Table 16. Addition and Normalization of Alternative Matrix – Price Criteria

Matrix Column Summation Alt. K3			
	X	Y	Z
X	1,00	2,37	0,21
Y	0,42	1,00	0,18
Z	4,66	5,71	1,00
Quantity	6,08	9,08	1,39

Normalization of Matrix Alt. K3				
	X	Y	Z	Average
X	0,16	0,26	0,15	0,19
Y	0,07	0,11	0,13	0,10
Z	0,77	0,63	0,72	0,70
Self-Vector				1,00

$$\lambda_{max} = (6{,}08 \times 0{,}19) + (9{,}08 \times 0{,}10) + (1{,}39 \times 0{,}70) = 3{,}08$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n - 1} = \frac{3{,}08 - 3}{3 - 1} = 0{,}04$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0{,}04}{0{,}58} = 0{,}07$$

With a weight of 0.70, Supplier Z is ranked as the best option in Table 16. This shows that these suppliers have the most effective cost structure, taking into account the base price, shipping costs, and insurance costs. With a weight of 0.10, Supplier Y is the least competitive in terms of price, while Supplier X ranks second with a weight of 0.19. The consistency of respondents' assessment was shown by the value of CR = 0.07, which was still below the tolerance limit of 0.10. When it comes to pricing valuations, Supplier Z is the most cost-effective option.

Table 17. Addition and Normalization of Alternative Matrix – Warranty Criteria and Complaint Service

Matrix Column Summation Alt. K4			
	X	Y	Z
X	1,00	0,47	2,14
Y	2,14	1,00	2,85
Z	0,47	0,35	1,00
Quantity	3,61	1,82	5,99

Normalization of Alt. K4 Matrix				
	X	Y	Z	Average
X	0,28	0,26	0,36	0,30
Y	0,59	0,55	0,48	0,54
Z	0,13	0,19	0,17	0,16
Self-Vector				1,00

$$\lambda_{max} = (3,61 \times 0,30) + (1,82 \times 0,54) + (5,99 \times 0,16) = 3,03$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n-1} = \frac{3,03-3}{3-1} = 0,02$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0,02}{0,58} = 0,03$$

With a weight of 0.54, Table 17 shows that Supplier Y is the best choice when it comes to managing complaints, responding quickly, and making simple claims. Supplier Z has the lowest weight of 0.16, making it the least ideal when it comes to after-sales support, while Supplier X ranks second with a weight of 0.30. The consistent assessment of respondents is indicated by a CR value of 0.03. Supplier Y is the most reliable alternative when it comes to warranty and complaint services.

Table 18. Addition and Normalization of Alternative Matrices – Previous Performance Achievement Criteria

Matrix Column Summation Alt. K5			
	X	Y	Z
X	1,00	0,54	2,95
Y	1,84	1,00	4,83
Z	0,42	0,21	1,00
Quantity	3,26	1,75	8,78

Normalization of the Alt. K5 Matrix				
	X	Y	Z	Average
X	0,31	0,31	0,34	0,32
Y	0,56	0,57	0,55	0,56
Z	0,13	0,12	0,11	0,12
Self-Vector				1,00

$$\lambda_{max} = (3,26 \times 0,32) + (1,75 \times 0,56) + (8,78 \times 0,12) = 3,08$$

$$Consistency\ Index\ (CI) = \frac{\lambda_{max} - n}{n-1} = \frac{3,08-3}{3-1} = 0,04$$

$$Consistency\ Ratio\ (CR) = \frac{CI}{RI} = \frac{0,04}{0,58} = 0,07$$

Table 18 shows Supplier Y According to the findings of the calculation of previous performance criteria, Supplier Y has the most weight and is therefore considered the most reliable in meeting work deadlines and contractual obligations. Supplier X is second, while Supplier Z has the lowest performance. Respondents' consistent ratings are indicated by a Consistency Ratio (CR) score of 0.07, which means that Supplier Y was selected as the best option based on past performance.

Table 19. Priority Weight Calculation

Alternatives	Criteria	Eigen Utuh	Own criteria	Multiplied	Percentage	Ratings
Supplier X	Quality	0,388	0,361	0,140	31,60%	II
	Shipping	0,263	0,355	0,093		
	Pricing	0,222	0,193	0,043		
	Warranty	0,047	0,297	0,014		
	Performance Achievements	0,080	0,318	0,026		
	Quantity			0,316		
Supplier Y	Quality	0,388	0,521	0,202	43,16%	I
	Shipping	0,263	0,519	0,136		
	Pricing	0,222	0,102	0,023		
	Warranty	0,047	0,540	0,025		
	Performance Achievements	0,080	0,562	0,045		

	Quantity			0,432		
Supplier Z	Quality	0,388	0,117	0,045	25,24%	III
	Shipping	0,263	0,126	0,033		
	Pricing	0,222	0,705	0,157		
	Warranty	0,047	0,163	0,008		
	Performance Achievements	0,080	0,120	0,010		
	Quantity			0,252		

According to Table 19, Supplier Y was placed first with the largest weight of 0.432 (43.16%), which was supported by the company's strong performance in warranty complaints and previous performance, as well as its dominant contribution to the quality (0.202) and delivery criteria (0.136). With a weight of 0.316 (31.60%), Supplier X ranks second, showing a somewhat balanced performance but still lacking that of Supplier Y. Supplier Z ranks third with a weight of 0.252 (25.24%), although they perform well in terms of price (0.157) but poorly in terms of quality and delivery.

TOPSIS Analysis of Supplier Alternative Assessment

TOPSIS is used to rank supplier alternatives based on their proximity to a positive ideal solution and their distance from a negative ideal solution. The analysis was carried out using the assessment data of three alternative suppliers (Supplier X, Supplier Y, and Supplier Z) against 15 sub-criteria which included aspects of quality, delivery, price, warranty services and complaint handling, as well as previous performance achievements. The weight of the subcriteria was obtained from the results of AHP weighting and used in the weighted normalization process in the TOPSIS method. Next, each normalized value is multiplied by the global weight of the subcriteria (AHP result) to obtain a weighted normalized matrix $v_{ij} = w_j \cdot r_{ij}$.

Table 20. TOPSIS Decision Matrix

Yes	Criteria	Code	Subcriteria	X	Y	Z	Global Weight
1	K1 – Quality	K1.1	Conformity with detailed specifications	9	7	6	0,2472
		K1.2	Consistency or similarity of quality/quality	9	7	6	0,1001
		K1.3	Quality of service provided	8	6	7	0,0407
2	K2 – Delivery	K2.1	Accuracy of delivery amounts	8	7	6	0,0429
		K2.2	Delivery timeliness	9	7	5	0,142
		K2.3	Continuity in delivery	8	6	7	0,0781
3	K3 – Price	K3.1	Price is adjusted according to the raw material	7	9	8	0,1414
		K3.2	Shipping or transportation costs of raw materials	7	9	8	0,0573
		K3.3	Insurance costs or damage claims	7	9	8	0,0233
4	K4 – Warranty & Complaints	K4.1	Ease in the claims process	8	6	7	0,0131
		K4.2	Guaranteed delivery accuracy	8	6	6	0,0078
		K4.3	Sustainability of raw material warranty	7	6	6	0,0034
		K4.4	Speed in responding to complaints	9	6	7	0,0217
5	K5 – Performance Achievement	K5.1	Ability to meet schedules	9	7	6	0,0266
		K5.2	Ability to maintain contractual agreements	9	7	6	0,0534

Table 20 shows the initial decision matrix used in the TOPSIS method. The value of each alternative was obtained based on the results of the assessment of five main criteria, namely quality, delivery, price, warranty services and complaint handling, as well as previous performance achievements. Supplier X obtained high marks on the previous quality, delivery, and performance aspects, while Supplier Y had an advantage in the price aspect. Supplier Z showed relatively moderate performance across all criteria.

Based on the weighted normalized matrix, the positive ideal solution (A^+) and negative ideal solution (A^-) for each criterion are determined. Because all the criteria in this study are of the benefit type, the ideal positive solution is determined based on the maximum value, while the ideal solution is negative based on the minimum value of each criterion. After that, the distance of each alternative to the positive and negative ideal solution is calculated using the Euclidean distance method to determine the degree of proximity of each alternative to the ideal condition.

Table 21. Relative Proximity Values and Alternative Ratings

Alternatives	(D_i^+)	(D_i^-)	(C_i)	Ratings
Supplier X	0,0222	0,0801	0,783	1
Supplier Y	0,0507	0,0384	0,431	2
Supplier Z	0,0798	0,0134	0,144	3

The results of the TOPSIS analysis showed that Supplier X had the highest relative proximity value (C_X=0.783), making it the closest alternative to ideal conditions and ranked first. Supplier Y is ranked second (C_Y=0.431), while Supplier Z ranks third (C_Z=0.144). These results show a difference with the results of AHP weighting which places Supplier Y as the best alternative with a priority weight of 0.432 (43.16%), followed by Supplier X of 0.316 (31.60%) and Supplier Z of 0.252 (25.24%). The difference occurs because AHP focuses on weighting and synthesis of preferences based on paired comparisons, while TOPSIS considers the proximity of each alternative to a positive ideal solution and its distance to a negative ideal solution. Although Supplier Y obtained the highest priority weight on the AHP, the TOPSIS results showed that Supplier X had a more balanced performance on all criteria so that it was the closest alternative to ideal conditions. Based on the results of the TOPSIS ranking, Supplier X is recommended as the best supplier to support the procurement needs of construction equipment at PT Gamila Buana Nusantara.

Discussion

The findings show that the selection of construction equipment suppliers is a multidimensional decision-making process involving five main criteria: quality, delivery, price, warranty and complaint handling services, and previous performance. Among them, quality and delivery emerged as the most influential factors, followed by price, while service quality and historical performance served as indicators of supplier reliability. Contractors tend to prioritize product quality and delivery accuracy over low prices because these factors directly affect project continuity, cost efficiency, and risk mitigation. These results are consistent with previous research, which emphasizes that quality, delivery performance, and supplier reliability are key determinants of supplier selection in the construction sector [4], [5], [6], [7], [14]. From a Supply Chain Management (SCM) perspective, these criteria reflect the core dimensions of customer value (quality, cost, and time) and highlight the strategic role of suppliers in overall supply chain performance.

The results of supplier ranking using the AHP–TOPSIS approach show that suppliers who have a more balanced performance on all criteria tend to get a better position than suppliers who only excel in certain aspects. These findings show that the supplier selection process cannot be based on one criterion alone, but must consider all aspects that contribute to the success of a construction project. The integration of AHP and TOPSIS allows the evaluation process to be carried out more comprehensively because it considers the level of importance of each criterion as well as the ability of each alternative to approach the ideal conditions expected by the company. Consistent with previous MCDM studies [5], [6], [20], [26], the results show that structured weighting and ranking methods result in more objective supplier evaluations and support strategic supply chain decisions. Quantitatively, the dominance of quality in this study (weight = 0.388), followed by delivery (0.263) and price (0.222), corroborates the integrated AHP–TOPSIS evaluation of Vavanoli et al. [20], who likewise identified quality as the top-priority criterion, although in their case cost ranked second and delivery timeliness last; the higher position of delivery in the present study reflects the schedulecritical nature of heavy equipment procurement, in which late mobilization directly delays project execution. The judgment consistency achieved here (CR = 0.05 for the main criteria and CR ≤ 0.07 for all subcriteria and alternative matrices) is well below the 0.10 acceptance threshold, a level of reliability comparable to prior AHP–TOPSIS applications [5], [21]. Moreover, the wide margin of relative closeness between the first- and second-ranked suppliers (C = 0.783 versus 0.431, a difference of 0.352) demonstrates the strong discriminating power of the integrated model, in line with Chen [26], who showed through sensitivity analysis that hybrid TOPSIS-based models produce robust supplier rankings.

Based on these findings, PT Gamila Buana Nusantara is recommended to implement a structured supplier evaluation system by integrating AHP and TOPSIS in the procurement process. AHP can be used to prioritize criteria relevant to the company's needs, while TOPSIS can be used to objectively evaluate and rank supplier alternatives. Companies need to conduct periodic monitoring and evaluation of product quality, delivery accuracy, complaint handling, and contract compliance to maintain consistency of supplier performance. The implementation of this approach is expected to improve procurement effectiveness, reduce supply chain risks, and support the success of construction projects in a sustainable manner.

CONCLUSION

The results of the study show that quality, delivery accuracy, and supplier commitment are the main factors in the selection of construction equipment suppliers. The AHP analysis places Supplier Y as the highest priority based on the weighting criteria, while the TOPSIS analysis shows Supplier X as the best alternative because it has the highest proximity to the ideal solution. The difference in results shows that AHP emphasizes the importance of the criteria, while TOPSIS assesses the balance of alternative performance against ideal conditions. The integration of AHP and TOPSIS can be an effective, objective, and systematic approach in supporting supplier selection decisions.

PT Gamila Buana Nusantara is advised to prioritize product quality, delivery accuracy, claim service, and contract commitment in the supplier evaluation process, while still considering price as a supporting factor. Companies also need to implement a structured and periodic supplier evaluation system by integrating the AHP method to determine the weight of criteria and TOPSIS to rank supplier alternatives. The implementation of this system is expected to increase objectivity, consistency, and transparency in the procurement process and help companies choose the supplier that best suits the needs of the project.

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