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Designing Vendor Performance Criteria Using Analytic Hierarchy Process Method On The Engineering Procurement Construction Project Company

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ABSTRACT

Indonesia's electrical power supply is insufficient to meet the population's demands. Therefore, the rise of Renewable Energy (RE) is anticipated to fulfill the needs. One of Indonesia's renewable energy industries implementing project management in its operations encountered delays in its engineering procurement construction project due to material delay, and the project's quality failed to meet requirements due to an incompetent vendor. Furthermore, the existing key performance indicators were insufficiently comprehensive, lacked criteria related to business permits, and had unclear Critical Success Factors (CSF). The primary goal was to develop narrowly focused criteria to evaluate vendor construction performance through Multi-Criteria Decision-Making (MCDM). The Analytical Hierarchy Process (AHP) method is one of the techniques utilized in MCDM to determine the ranking of alternatives based on selection criteria that have hierarchical interdependence relationships. This study produced six main criteria based on literature studies, including management capability, financial capability, quality, delivery time, customer services, and safety. The most important sub-criteria from the results of this study are speed and accuracy of delivery time with a weight of 23,90%, where the factor of completing the project activity on time is a key factor for project success. For further handling, this criterion is considered as CSF for vendor selection at EPC projects, especially in the RE industry.

***Keywords**: Analytic Hierarchy Process (AHP), Key Performance Indicator (KPI), Project Management, Procurement Management, Vendor*

Introduction

The phenomenon of increasing electricity consumption in Indonesia continues to increase every year, especially in 2021-2022, there was the largest increase over the last 5 decades of 1,173 kWh/capita; it turns out that it still cannot meet the needs of the entire Indonesian people. Based on the lack of electrical energy, it is hoped that the high potential of renewable energy in Indonesia can meet the needs of the community as an alternative to conventional energy [1]. Conventional energy in Indonesia itself is still a primary energy source, including coal, natural gas, and oil [2]. PT XYZ is an Indonesian company in the field of renewable energy, especially solar energy, and has applied project management knowledge to its business line activities, including engineering procurement construction, operation & maintenance, retail, and investment to compete and survive in the renewable energy industry to meet disruptive community demand. Project management means the application of knowledge, skills, tools, and methods to meet project criteria with estimates of the activities to be carried out [3]. A project can be defined as a series of temporary activities, having a beginning and an end, to create something that has new or special characteristics and has never been done before [4]. The importance of project management knowledge in the energy industry may enhance the effectiveness of company management procedures for environmental transformation while empowering environmentally conscious companies to increase the level of health in society [5]. Therefore, the application of project management knowledge is very much needed as the key to the success of EPC construction projects at solar energy companies in Indonesia. The success of a project can be measured based on indicators of project quality, timeliness of completion, budget adequacy, and customer satisfaction levels [3].

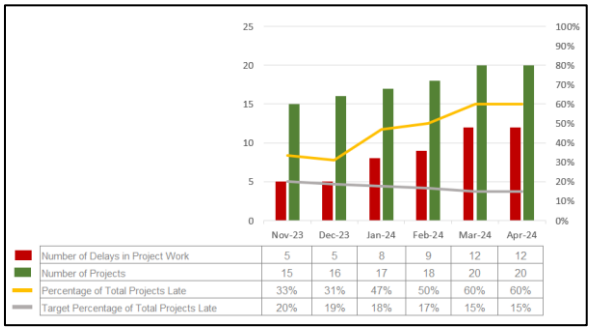

Figure 1. Project Delay PT XYZ (2023-2024)

The data graph in Figure 1 shows the delays that occurred in the PT XYZ project where from the end of 2023 till the first quarter of 2024, along with the increase in projects at the beginning of the year. Material vendor delays caused project delay, rework on project deliverables because the project quality failed to meet requirements, and the key performance indicators were insufficiently comprehensive, lacking criteria related to vendor capabilities to have expertise construction certificates or business permits, making the selected vendor difficult to access the project location according to client's SOP. This results in the selected vendors being less competent. Previous research indicated that EPC project delays in Indonesia were caused by some issues, including project equipment or materials delays, rework due to unfulfilled construction deliverables, and delays in the work of subcontractors [6]. Based on prior research, it is necessary to know the frequency of occurrence of causes of delays in construction projects that arise in developing countries, where contract management and skills are one of the causes with the highest frequency of occurrence frequency of 13,6% [7]. Similar problems were found related to project delays based on previous research and the PT XYZ project, which experienced delays in the solar energy EPC project caused by poor vendor performance, which is described in Figure 2.

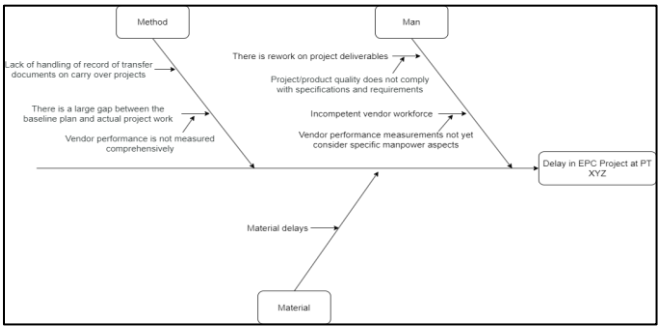

Figure 2. Cause and Effect Diagram of EPC Project Delays

The issue of EPC project delays is a significant concern, as illustrated in the cause-and-effect diagram. The man factor is a significant factor, as the project results do not match the agreed specifications and requirements, leading to increased project duration. The vendor's KPI is not comprehensive and does not account for the personnel component, such as competence certification and company permit, which affects their ability to carry out installations at various locations. The method factor involves projects still being carried over due to a lack of handling in fulfilling project completion documents and a large gap between the baseline plan and actual project work. This is due to inadequate measurement of the selected vendor's performance. Also, delays in the arrival of materials due to the vendor's error. Vendor performance is crucial for the success of an electrical construction project, with research studies showing its impact on time, cost, and quality [8]. A solution to address EPC project delays at PT XYZ is the design of vendor performance criteria to assist in decision-making in evaluating vendors for EPC projects. KPIs are indicators for creating a successful organization by determining the right and clear CSF in achieving organizational goals [9]. Contracting & procurement is a common component of many projects that includes solutions, labor, services, materials, capital equipment, and supplies. Project managers usually do not have contractual authority in the organization. Instead, they collaborate with contract officers or other specialists in the fields of law, regulation, and contracts [3].

Research Methods

Research Systematics

The MCDM framework is expected to facilitate alternative decision-making based on significant criteria at a hierarchical level and solve problems with multiple objectives and multi-criteria. This study utilized the AHP approach to identify performance criteria for construction vendors and establish their weight in the vendor selection process. The AHP method can solve problems that have multiple objectives and multi-criteria with a flexible and easy-to-understand model [10]. The vendor evaluation process involves a list of alternative vendors and selection criteria considering factors like cost, quality, and time [11]. The AHP method is used in several steps to design vendor performance criteria and ranking evaluation, aiming to solve problems discovered in the study. It involves determining vendor selection criteria from previous research, designing hierarchical criteria relationships, and assessing criteria and sub-criteria. Geometric mean calculations and a pairwise comparison matrix is used to establish the relative importance of vendor selection criteria. Priority vector calculation as a determinant of importance weight. The Consistency Ratio (CR) is calculated to determine the consistency of the evaluation. Figure 3 below is the systematic flow of this research.

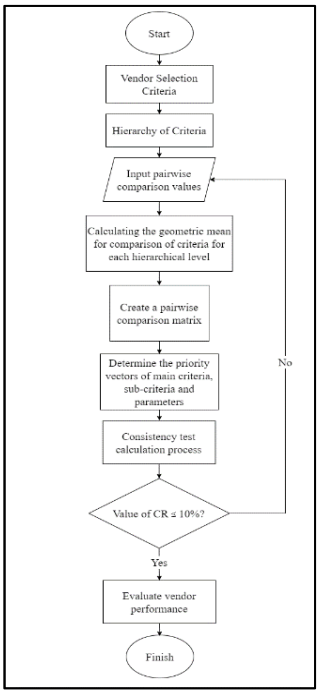

Figure 3. Conceptual Framework

Developing Vendor Performance Criteria

The process of developing vendor performance criteria involves seven steps, which are as follows:

1. Identify the problem by performing direct observations and interviews about current issues while assessing them to relevant literature research.
2. Conduct decomposition of vendor performance criteria in a hierarchical model based on relevant literature research.
3. Conduct comparative judgment with a pairwise comparison matrix. Experts at PT XYZ conducted the assessment. It consists of procurement managers and staff with at least 6 years of experience, as well as project managers with at least 2 years of experience, who are considered to have sufficient knowledge based on their experience. The assessment is conducted using a basic scale of paired comparison with an importance level of 1-9 with the following description and calculation formulation of the AHP method, which is detailed in Table 1 [12].

Table 1. Basic Scale of Pairwise Comparison

Level of interest	Information
1	Both criteria are equally important

Level of interest	Information
3	One criteria is slightly more important than the second element
5	One criteria is more important than the second element
7	One criteria is very much more important than the second element
9	One criteria is absolutely more important than the second element
2, 4, 6, 8	A value between two adjacent assessments
Reciprocal	If element i has one of the above values when compared to j, then j has the opposite value when compared to element i

If multiple experts with different assessments carry out the pairwise comparison, the geometric mean calculation with the following formula must be used [13].

$$G = \sqrt[n]{x_1 \times x_2 \times \ldots \times x_n} \quad (1)$$

4. Score the criteria pairs in each level of the hierarchy by comparing the geometric value of one criterion with another criterion, as in Table 2.

Table 2. Pairwise Comparison Matrix

	A_1	A_2	…	A_j
A_1	$\frac{w_1}{w_1}$	$\frac{w_1}{w_2}$	…	$\frac{w_1}{w_j}$
A_2	$\frac{w_2}{w_1}$	$\frac{w_2}{w_2}$	...	$\frac{w_2}{w_j}$
⋮	⋮	⋮	⋮	⋮
A_i	$\frac{w_i}{w_1}$	$\frac{w_i}{w_2}$	…	$\frac{w_i}{w_j}$

After creating the pairwise comparison matrix, the next step is to create a normalization matrix with the following calculations [14].

$$w_{ij} = \frac{\frac{w_i}{w_j}}{\sum_j^n \frac{w_i}{w_j}} \quad (2)$$

5. Perform synthesis of priority or priority vector calculations and also eigenvalue calculations with the equation Aw=nw, which describes n and w as eigenvalues and eigenvectors [12].

$$w_i = \frac{1}{n}\sum_i w_{ij} \quad (3)$$

$$Aw = \begin{pmatrix} \frac{w_1}{w_1} & \frac{w_1}{w_2} & \cdots & \frac{w_1}{w_n} \\ \frac{w_2}{w_1} & \frac{w_2}{w_2} & \cdots & \frac{w_2}{w_n} \\ \vdots & \vdots & \ddots & \vdots \\ \frac{w_n}{w_1} & \frac{w_n}{w_2} & \cdots & \frac{w_n}{w_n} \end{pmatrix} \begin{pmatrix} w_1 \\ w_2 \\ \vdots \\ w_n \end{pmatrix} = \begin{pmatrix} nw_1 \\ nw_2 \\ \vdots \\ nw_n \end{pmatrix} \quad (4)$$

6. Determine logical consistency by dividing the Consistency Index (CI) value by the Random Index (RI) to produce the CR value. The following are some equations in the process of calculating the CR value [12].

$$\lambda max = \frac{1}{n}\sum_j \lambda_i \quad (5)$$

$$CI = \frac{\lambda max - n}{n-1} \quad (6)$$

Table 3 shows the R.I. values used and also the CR calculation formula [12].

Table 3. Random Index (RI)

n	1	2	3	4	5	6	7	8	9	10
Random Consistency Index (R.I.)	0	0	0,52	0,89	1,11	1,25	1,35	1,40	1,45	1,49

$$CR = \frac{CI}{RI} \quad (7)$$

Formula description:
G = geometric mean
n = number of respondents
x = individual assessment

$\frac{w_i}{w_j}$ = pairwise comparison values i and j

7. Evaluate the Consistency Ratio (CR) value of each paired comparison criteria to calculate the consistency value of the paired assessment. The CR value must be 10% or ≤ 0,1 for the decision to be considered consistent.

Results and Discussion

Selected Vendor Performance Criteria

The performance criteria of the selected vendors for this research were sourced from two previous researchers [15] [16], with 6 criteria that have been set and adjusted to the current needs of the company, including management capability, financial capability, quality, delivery time, customer services, and safety. Following the selection of the main criteria based on previous studies, the following stage is to establish the sub-criteria of each existing main criteria as a vendor evaluation KPI, along with the parameters utilized as an assessment decision tool which is explained in Table 4.

Table 4. Vendor Performance Criteria

Main criteria	Sub-criteria	Parameter	Source
Management Capability (MC)	Administrative Requirements (MC1)	Complete Incomplete (in process) Incomplete	[17], [18] + Expert
	Vendor Capabilities (MC2)	Has a construction services business permit/IUJK Does not have a construction services business permit/IUJK	[15], [17], [18], [19], [20], [21]
	Past Job Performance (MC3)	Meets the criteria in the list of selected partners Does not meet the criteria in the list of selected partners	[15], [17], [18], [19], [20], [21]
Financial Capability (FC)	Payment System Policy (FC1)	Follows the company's payment system policy Has its payment system policy/with the agreement of both parties Has its payment system policy that cannot be contested and does not comply with company policy	[19], [20], [22] + Expert
	Price of Services Offered (FC2)	Service prices offered are below owner's estimate Service prices offered are above owner's estimate	[15], [16], [19], [22], [23] + Expert
Quality (Q)	Results of Services Performed (Q1)	All work is in accordance with the requirements and specifications Some work does not comply with the requirements and specifications All work does not comply with the requirements specifications but is accepted by the client All work does not comply with the requirements and specifications	[15], [16], [18], [19], [22], [23], [24] + Expert
Delivery Time (DT)	Speed & Accuracy of Delivery Time (DT1)	Faster/on time or late not due to its fault (force majeure) Late due to its fault	[16], [19], [20], [22], [23], [24] + Expert
Customer Services (CS)	Responsiveness in Coordination or Complaints (CS1)	Responsive/quick response in coordination or complaints Slow in responding to both coordination and complaints No response at all	[16], [19], [24], [25] + Expert
	Frequency of Complaints (CS2)	No complaints during the contract period There are complaints, but they no have a big impact on the project There are often complaints during the work contract period	[18], [23]
Safety (S)	Implementation of Occupational Safety and Health (S1)	Use of occupational safety and health support tools Not using occupational safety and health support tools	[15], [17], [18], [19], [20], [21] + Expert
		No lost work hours	

Main criteria	Sub-criteria	Parameter	Source
	Safety Performance (S2)	Lost work hours due to incidents	[15], [17], [20], [21], [25]
		Lost work hours due to fatal accidents	

Indonesian government regulations mandate national construction services business entities (IUJK) to employ workers with work competency certificates [26]. Risky business permits include Business Identification Number (NIB) and standard certificates [27]. The parameters related to business permit ownership by vendors are expected to make vendor performance measurements more comprehensive in terms of manpower.

Hierarchy Criteria

After the performance criteria are determined, a hierarchy of criteria is designed based on their levels, namely the objective level, the criteria level, and the alternative level. The following Figure 4 are the hierarchy criteria of selecting vendor.

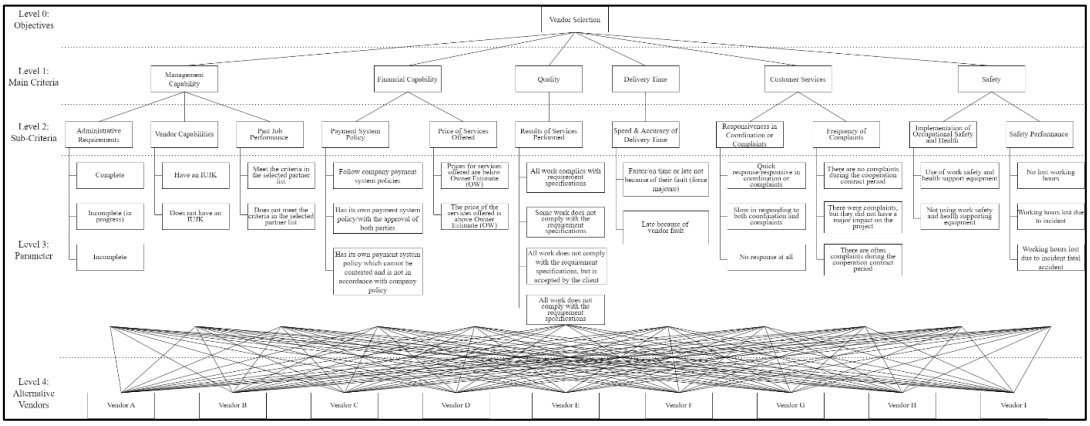

Figure 4. Hierarchy Criteria

The results of the criteria weighting acquired from the priority vector calculations using formula (4), where the results of the criteria weighting in Table 5 represent the importance of the criteria with the largest value as CSF in the KPI.

Table 5. Priority Vector of Main Criteria

	Management capability	Financial capability	Quality	Delivery time	Customer services	Safety	Priority vector
Management capability	0,07	0,06	0,07	0,09	0,13	0,07	0,0816
Financial capability	0,23	0,18	0,15	0,16	0,20	0,26	0,1973
Quality	0,23	0,27	0,22	0,23	0,19	0,17	0,2175
Delivery time	0,21	0,29	0,24	0,25	0,20	0,25	0,2390
Customer services	0,04	0,06	0,08	0,08	0,07	0,06	0,0643
Safety	0,22	0,14	0,25	0,19	0,21	0,19	0,2003

The main criteria of delivery time and quality have the highest priority vector value, indicating that they are key factors or CSFs in the vendor's KPI. A consistency test was carried out to test whether the results of the paired comparison assessment carried out by PT XYZ experts could be said to be consistent with the folowing results with the allowance value for CR is ≤ 10% as seen in Table 6.

Table 6. Consistency Test

Criteria description	λmax	n	CI	RI	CR	Result
Level 1 Hierarchy						
Main Criteria	6,123	6	0,025	1,25	0,020	Consistent
Level 2 Hierarchy						
Sub-Criteria of Management Capability	3,000	3	0,000	0,52	0,000	Consistent
Sub-Criteria of Financial Capability	2,000	2	0,000	0	0,000	Consistent
Sub-Criteria of Quality	1,000	1	0,000	0	0,000	Consistent
Sub-Criteria of Delivery Time	1,000	1	0,000	0	0,000	Consistent

Criteria description	λmax	n	CI	RI	CR	Result
Sub-Criteria of Customer Services	2,000	2	0,000	0	0,000	Consistent
Sub-Criteria of Safety	2,000	2	0,000	0	0,000	Consistent
Level 3 Hierarchy						
Parameters of Administrative Requirements	3,101	3	0,050	0,52	0,097	Consistent
Parameters of Vendor Capabilities	2,000	2	0,000	0	0,000	Consistent
Parameters of Past Job Performance	2,000	2	0,000	0	0,000	Consistent
Parameters of Payment System Policy	3,100	3	0,050	0,52	0,097	Consistent
Parameters of Price of Services Offered	2,000	2	0,000	0	0,000	Consistent
Parameters of Results of Services Performed	4,255	4	0,085	0,89	0,096	Consistent
Parameters of Speed & Accuracy of Delivery Time	2,000	2	0,000	0	0,000	Consistent
Parameters of Responsiveness in Coordination or Complaints	3,095	3	0,047	0,52	0,091	Consistent
Parameters of Frequency of Complaints	3,096	3	0,048	0,52	0,092	Consistent
Parameters of Implementation of Occupational Safety and Health	2,000	2	0,000	0	0,000	Consistent
Parameters of Safety Performance	3,085	3	0,043	0,52	0,082	Consistent

Table 7 shows the global weights of the sub-criteria and their ranks.

Table 7. Priority Weights of Criteria & Sub-Criteria

Main criteria	Weight	Sub-criteria	Weight	Global weight of sub-criteria	Global weight ranking
Management Capability	8,16%	Administrative Requirements	24,82%	2,02%	10
		Vendor Capabilities	49,02%	4,00%	8
		Past Job Performance	26,16%	2,13%	9
Financial Capability	19,73%	Payment System Policy	52,53%	10,37%	4
		Price of Services Offered	47,47%	9,37%	5
Quality	21,75%	Result of Services Performed	100,00%	21,75%	2
Delivery Time	23,90%	Speed & Accuracy of Delivery Time	100,00%	23,90%	1
Customer Services	6,43%	Responsiveness in Coordination or Complaints	85,71%	5,51%	7
		Frequency of Complaints	14,29%	0,92%	11
Safety	20,03%	Implementation of Occupational Safety and Health	71,01%	14,22%	3
		Safety Performance	28,99%	5,81%	6

The recapitulation of the priority weight results of each main criterion and sub-criteria to the parameters that will be used in the vendor assessment process is shown in Table 7 and Table 8. It can be seen that the highest weight of the main criteria is occupied by delivery time (DT), with a weight of 23,90%. The highest global weight of sub-criteria is speed & accuracy of delivery time (DT1), with a weight of 23,90%. The present research's vendor assessment process provides parameters with varying weighting levels depending on priority vector results.

Table 8. Priority Weight of Parameter

Main criteria	Sub-criteria	Parameter	Weight
Management Capability	Administrative Requirements	Complete	67,3%
		Incomplete (in process)	24,8%
		Incomplete	7,9%
	Vendor Capabilities	Has a construction services business permit/IUJK	86,8%
		Does not have a construction services business permit/IUJK	13,2%
	Past Job Performance	Meets the criteria in the list of selected partners	87,5%
		Does not meet the criteria in the list of selected partners	12,5%
	Payment System Policy	Follows the company's payment system policy	69,5%

Main criteria	Sub-criteria	Parameter	Weight
Financial Capability		Has its payment system policy/with the agreement of both parties	22,5%
		Has its payment system policy that cannot be contested and does not comply with company policy	8,1%
	Price of Services Offered	Service Prices offered are below the owner's estimate	74,4%
		Service Prices offered are reasonable/above the owner estimate	25,6%
Quality	Results of Services Performed	All work is in accordance with the requirements and specifications	64,6%
		Some work does not comply with the requirements and specifications	19,5%
		All work does not comply with the requirements specifications but is accepted by the client	10,8%
		All work does not comply with the requirements and specifications	5,1%
Delivery Time	Speed & Accuracy of Delivery Time	Faster/on time or late not due to its fault (force majeure)	87,9%
		Late due to his/her fault	12,1%
Customer Services	Responsiveness in Coordination or Complaints	Responsive/quick response in coordination or complaints	69%
		Slow in responding to both coordination and complaints	22,4%
		No response at all	8,6%
	Frequency of Complaints	No complaints during the contract period	74,8%
		There are complaints, but no have a big impact on the project	17,2%
		There are often complaints during the work contract period	7,9%
Safety	Implementation of Occupational Safety and Health	Use of occupational safety and health support tools	86,8%
		Not using occupational safety and health support tools	13,2%
	Safety Performance	No lost work hours	77,1%
		Lost work hours due to incidents	14,8%
		Lost work hours due to fatal accidents	8,1%

The existing vendor evaluation scores using a 0-100 scale differ from the assessment ratings in this study, which employ AHP with precise decimal values. Some of the existing KPIs are given equal weight, making it difficult to pinpoint CSFs in vendor performance, as seen in Table 9. The evaluation utilizing AHP weights gives more accurate and effective results, as well as scores that CSFs clearly impact.

Table 9. Existing Key Performance Indicator

Existing criteria	Weight
Administrative Requirements	20
Quality Results of Services Performed	20
Price of Services Offered	10
Payment System Policy	10
Speed & Accuracy of Delivery Time	20
Customer Service	10
Implementation of Occupational Safety and Health	10

Based on the categories that the company has adjusted, there are two categories of vendor eligibility in the assessment. First, there is a feasible category with a minimum score of more than or equal to 59,67% (≥ 59,67%), and an unfeasible category with a score below the feasible category with the maximum score on this evaluation was 77,24%. The feasible category as a minimum requirement to enter the list of selected partners has provisions that at least have an assessment weight, including:

a) Incomplete (in process) administrative requirements (0,5%).
b) Vendor capability that has construction services business permit/IUJK (3,47%).
c) Past job performance that meets criteria (1,86%).
d) Payment system policy that has a payment system policy that is not in accordance with company policy (0,84%).
e) The price of services offered is below the owner estimate (6,97%).

f) The results of the services carried out include at least part of the work that does not meet the specifications, up to a maximum of 10% (4,24%).
g) Delivery time that is faster/on time or late, but not due to their fault (21,01%).
h) Vendors are responsive in coordination or complaints (3,8%).
i) There are complaints, but they do not have a major impact on the project (0,16%).
j) Requirement to use K3 support tools (12,34%).
k) No lost working hours due to incidents/accidents (4,48%).

The selection results shows that four out of nine alternative vendor in Figure 4, namely vendor B, vendor C, vendor G, and vendor H, are considered suitable for the company's standards. The differences were found in previous assessment, all nine vendors were deemed worthy of collaboration. The findings of the vendor performance criteria with designed weight have been established and are presented in the form of an evaluation instrument attached to Table 10.

Table 10. Vendor Assessment Form

Main criteria	Sub-criteria	Parameter	Weight	Score
Management Capability	Administrative Requirements	Complete	1,36%	
		Incomplete (in process)	0,50%	
		Incomplete	0,16%	
	Vendor Capabilities	Has a construction services business permit/IUJK	3,47%	
		Does not have a construction services business permit/IUJK	0,53%	
	Past Job Performance	Meets the criteria in the list of selected partners	1,86%	
		Does not meet the criteria in the list of selected partners	0,27%	
Financial Capability	Payment System Policy	Follows the company's payment system policy	7,21%	
		Has its own payment system policy/with the agreement of both parties	2,33%	
		Has its own payment system policy that cannot be contested and does not comply with company policy	0,84%	
	Price of Services Offered	Service prices offered are below owner estimate	6,97%	
		Service prices offered are reasonable/above owner estimate	2,40%	
Quality	Results of Services Performed	All work is in accordance with the requirements specifications	14,05%	
		Some work does not comply with the requirements specifications	4,24%	
		All work does not comply with the requirements specifications, but is accepted by the client	2,35%	
		All work does not comply with the requirements specifications	1,11%	
Delivery Time	Speed & Accuracy of Delivery Time	Faster/on time or late not due to his/her fault (force majeure)	21,01%	
		Late due to his/her fault	2,89%	
Customer Services	Responsiveness in Coordination or Complaints	Responsive/quick response in coordination or complaints	3,80%	
		Slow in responding to both coordination and complaints	1,23%	
		No response at all	0,47%	
	Frequency of Complaints	No complaints during the contract period	0,69%	
		There are complaints, but no have a big impact on the project	0,16%	
		There are often complaints during the work contract period	0,07%	
Safety	Implementation of Occupational Safety and Health	Use of occupational safety and health support tools	12,34%	
		Not using occupational safety and health support tools	1,88%	
	Safety Performance	No lost work hours	4,48%	
		Lost work hours due to incidents	0,86%	

	Lost work hours due to fatal accidents	0,47%
Total score		

Conclusion

The study identifies 11 key performance indicators for PT XYZ's vendor evaluation process, based on 6 key criteria. These include management capability, financial capability, quality, delivery time, customer service, and safety. The top 3 sub-criteria are speed & accuracy of delivery time (DT1) with a weight of 23,90%, the results of the services carried out (Q1) with a weight of 21,75%, and the implementation of K3 (S1) with a weight of 14,22%. The evaluation process categorizes vendors into feasible and unfeasible categories. As many as 4 out of 9 vendors can be eligible for PT XYZ's selected partners. However, the research is limited to one RE company and may not be suitable for generalization. The use of comprehensive weighted scores on a decimal scale is not common and requires adaptations. Future research should focus on developing more RE enterprises utilizing EPC projects.

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