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Fuzzy SWOT-DEA Approach for Selecting Electrical Component Vendors in Offshore Structure Projects

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ABSTRAK

Penelitian ini menganalisis pemilihan vendor komponen electrical pada proyek EPC bangunan lepas pantai pada tahap detailed engineering design *(DED) dan pengadaan, evaluasi vendor menjadi faktor penting untuk memastikan kualitas proyek serta kepatuhan terhadap jadwal. Pendekatan pengambilan keputusan multi-kriteria yang menggabungkan metode Fuzzy SWOT dan* data envelopment analysis *(DEA) digunakan untuk menilai 15 vendor electrical cable yang mengikuti tender untuk Proyek X pada sebuah perusahaan EPC yang berbasis di Jakarta. Metode Fuzzy SWOT digunakan untuk menilai setiap vendor secara kualitatif berdasarkan kriteria seleksi yang telah ditentukan, sementara DEA digunakan untuk mengukur efisiensi relatif mereka secara kuantitatif. Hasil analisis mengidentifikasi dua vendor, yaitu PT. STD dan PT. KBL, sebagai vendor paling efisien dengan skor efisiensi sebesar 1. Pendekatan terintegrasi ini menawarkan kerangka kerja yang kuat dan objektif dalam pemilihan vendor, sehingga mendukung keputusan pengadaan yang lebih efisien, selaras dengan kebutuhan proyek, serta mengurangi risiko keterlambatan dan masalah kualitas pada tahap konstruksi.*

Kata Kunci: *pemilihan vendor, komponen electrical, proyek bangunan lepas pantai, fuzzy SWOT, DEA.*

ABSTRACT

This study analyzes the selection of electrical component vendors in an offshore structure EPC project during the detailed engineering design (DED) and procurement stages, vendor evaluation is critical to ensuring project quality and schedule compliance. A multi-criteria decision-making approach combining the Fuzzy SWOT and data envelopment analysis (DEA) methods was employed to assess 15 electrical cable vendors bidding for Project X in an EPC company based in Jakarta. The Fuzzy SWOT method was used to qualitatively assess each vendor based on predetermined selection criteria, while DEA measured their relative efficiency quantitatively. The analysis identified two vendors, PT. STD and PT. KBL, as the most efficient with an efficiency score of 1. This integrated approach offers a robust, objective framework for vendor selection, supporting efficient procurement decisions that align with project requirements and reduce the risk of delays and quality issues in the construction phase.

Keywords: vendor selection, electrical component, offshore structure project, fuzzy SWOT, DEA.

INTRODUCTION

Offshore structure projects are generally executed by engineering, procurement, and construction (EPC) companies that provide services starting from engineering design, material, and equipment procurement to construction execution. In an EPC project and megaprojects, deep collaboration is required to carry out the entire project cycle, from early planning stages to project completion [1]. These projects are regulated by contracts that require contractors to complete the project within a specified timeframe. These contracts also require contractors to comply with the specifications stated in the contract. Thus, deep collaboration is needed in an EPC project to ensure the project runs smoothly and according to the contract.

Vendor selection plays an important role in determining project success, as companies must recognize the importance of selecting vendors that meet quality and time requirements [2]. The

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selection process involves multiple criteria that must be considered simultaneously, of which in recent studies on vendor selection most chosen are product quality, delivery, track record, and warranty policy [3]. Procurement management in vendor selection plays a significant role in companies because 60–80 percent of total costs are external costs, including vendor purchases [4]. The supplier performance system is essential to assist decision makers in collecting, assessing, and evaluating suppliers [5]. The effective vendor selection can significantly impact project cost, quality, and completion time.

In offshore projects, multiple divisions are involved in the engineering phase. One such division is electrical engineering, which requires special attention during vendor selection. Failure in electrical systems can cause significant losses to both contractors and project owners. Average insurance claims increased from €2 million during 2010–2015 to €3.6 million in 2020, with total claims arising from €145 million to €585 million [1]. Electrical cable failures accounted for approximately 50% to 80% of these claims.

The explosion of the Deepwater Horizon floating drilling rig on April 20, 2010 was caused by four sequential failures, one of which involved an electrical and instrument component, a pressure transmitter. The device failed to function and did not identify that the well was not sealed, leading to an explosion. This incident caused the rig to sink, the death of 11 crew members, and the largest oil spill in drilling history, releasing four million barrels of oil over 87 days. The U.S. later filed a lawsuit, resulting in a record Clean Water Act penalty of $5.5 billion and up to $8.8 billion in natural resource damages. Given such risks, vendor selection must consider various factors to ensure that the chosen electrical components meet offshore demands as well as support overall project success, and conventional vendor selection methods often involve conflicting criteria such as quality and delivery time, requiring a trade-off analysis between vendors to balance these opposing criteria.

Decision-making is an important aspect in vendor selection within an EPC offshore structure project. A rational approach to decision-making involves problem identification, development of alternative solutions, and selection of the best solution based on the analysis results [6]. The rational decision-making process based on Simon's model [7] explains that the process consists of three main phases: intelligence, design, and choice, each playing an important role in ensuring that the decision made is the best and most efficient.

To mitigate risks in the supply chain flow and vendor selection, and to ensure project success, it is essential to adopt an appropriate vendor selection method that encompasses various criteria aligned with the objectives of vendor selection [8]. This study proposes the use of multi-criteria decision making (MCDM), MCDM is a method for selecting alternatives to obtain the best solution from various decision alternatives by considering more than one criterion or objective that are in conflict [9]. The approach by combining fuzzy SWOT and data envelopment analysis (DEA) methods. Fuzzy SWOT assists in vendor pre-qualification by considering multiple factors to assess internal and external environments, and to develop strategies for maximizing potential or mitigating risks [10], and addressing uncertainty in qualitative assessments, while DEA is used for final selection by measuring the relative efficiency of pre-qualified vendors [11].

Compared with commonly used MCDM methods such as AHP and TOPSIS, the proposed Fuzzy SWOT–DEA approach offers additional advantages. AHP primarily derives priority weights without measuring relative efficiency, while TOPSIS ranks alternatives based on distance to ideal solutions without benchmarking capability. In contrast, DEA identifies efficient frontiers and peer references, enabling performance gap analysis. The integration with fuzzy SWOT further strengthens the model by incorporating strategic and uncertainty considerations, making it particularly suitable for offshore EPC vendor selection. Thus, compared with single-stage MCDM methods such as AHP or TOPSIS, the proposed hybrid framework offers a more comprehensive evaluation by combining qualitative strategic assessment and quantitative efficiency measurement in a unified structure.

Companies need to evaluate vendor outputs, as this assessment has become a crucial component in enhancing organizational efficiency [12]. Every company strives to meet demand, improve quality, and reduce costs to optimize business processes through effective and efficient supply chain management, which largely depends on how well the company selects vendors to provide the

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required materials [13]. Effective vendor selection is crucial, as delays in delivery or technical failures in materials can lead to project delays and significant financial losses [14]. This approach supports more accurate decision-making in selecting the most appropriate vendor for the project and the results are expected to contribute significantly to supply chain management and vendor selection strategies in offshore EPC projects.

METHOD

Decision-making is carried out based on the level of understanding of technical aspects by the experts to be selected. Another criterion that must be considered is the experts' comprehension of the research being conducted, in order to minimize misinterpretation of the selection parameters. The respondents involved in this study consist of experts who oversee the project from the engineering phase. The requirements for the experts are presented in Table 1.

Table 1. Criteria and requirements of expert

Criteria	Description
Role	Serves as an expert for fuzzy SWOT analysis.
Education	Minimum of a bachelor's degree in an engineering.
Experience	Minimum of 15 years of experience.
Position	Lead Engineer, Project Engineering Manager.
Competence	Minimum requirement of certification or training.

Table 2. SWOT categories and criteria

SWOT Categories	Criteria
Strength/Weakness	Quality Delivery Time After-Sales Service Production Capability Project Experience Vendor Communication
Opportunity/Threat	Regulatory Compliance Standards Compliance Collaboration Potential Transfer of Knowledge

The experts consist of one project engineering manager and one lead electrical engineer. Although the panel consists of two experts, their decision-making authority and technical competence ensure high reliability of assessment. Moreover, the application of fuzzy logic and subsequent sensitivity analysis in DEA enhances the robustness of the results despite the limited number of experts. Vendor selection criteria vary depending on their application. Criteria serve as tools used by experts to evaluate an electrical component. The determination of these criteria is based on discussions and feedback provided by experts in relevant fields, taking into account commonly used criteria in previous vendor selection processes for electrical components in offshore structure projects. The criteria used in this study are presented in Table 2.

Current offshore structure EPC projects require a limited number of vendors due to the difficulty in managing a large number of vendors efficiently. Therefore, this stage aims to filter out inefficient vendors and reduce the number of vendors to a manageable level that meets acceptable criteria. SWOT analysis can be used to evaluate vendors, but it can also be applied to prequalify suitable vendors [15]. From the SWOT matrix, experts can select a pool of vendors. In this research, fuzzy opinions are represented using triangular fuzzy numbers (TFN) due to their intuitive nature and ease of use. Fuzzy logic allows the use of membership degree values that reflect the level of certainty of a given factor, thereby providing a more flexible and realistic evaluation under complex conditions. The integration of fuzzy logic into the SWOT framework leads to more accurate decision-making, as it is capable of capturing the dynamics of uncertainty that frequently occur in rapidly changing business environments [16]. A TFN can be defined as (a_1, a_2, a_3), as shown in

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Figure 1. The representation of the linguistic scale referred to in this study is shown in Figure 2. The Triangular Fuzzy Number (TFN) with the corresponding scores is shown in Table 3.

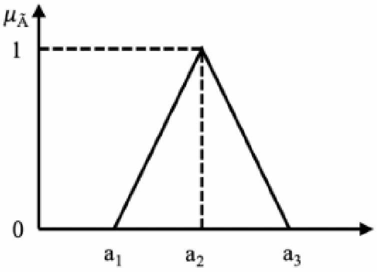

Figure 1. Triangular Fuzzy Number (TFN)

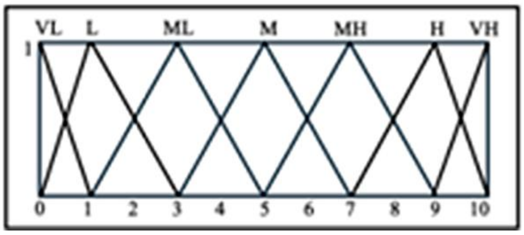

Figure 2. Linguistic Scare Representation

Table 3. Triangular fuzzy number (TFN) score

Score	Description	Numeric Scale	TFN (a1, a2, a3)
VL	Very Low	1	(0, 0, 1)
L	Low	2	(0, 1, 3)
ML	Medium Low	3	(1, 3, 5)
M	Medium	4	(3, 5, 7)
MH	Medium High	5	(5, 7, 9)
H	High	6	(7, 9, 10)
VH	Very High	7	(9, 10, 10)

TFN is defined as a triplet (a_1, a_2, a_3), where a_1 is the minimum value, a_2 is the most likely value, and a_3 is the maximum value. Each value within the domain of the fuzzy number has a degree of membership represented by a membership function $\mu_A(x)$. The fuzzy SWOT analysis consists of the following steps:
Step 1: Determine the vendors to be compared.
Step 2: Finalize the SWOT criteria.
Step 3: Collect data from expert assessments.
Step 4: Defuzzify using TFN to calculate the weight of each criterion and normalized the score.
Step 5: Defuzzify using TFN to calculate the weight of each vendor and normalized the score.
Step 6: Calculate the Total Weighted Value (TWV) of SWOT and benchmarking value using mean.
Step 7: Calculate the SWOT coordinates and plot them on the SWOT matrix quadrant.
Step 8: Determine the vendors to be advanced to the DEA analysis stage.

The defuzzified weight are calculated by using following eq. 1.

$$Defuzzied\ Weight = \frac{\mathrm{a1 + a2 + a3}}{3} \quad (1)$$

The normalized scores are calculated by using eq. 2.

$$Normalized\ Score = \frac{\mathrm{DFWi}}{\mathrm{Max\ DFWi}} \quad (2)$$

This is the final stage of vendor evaluation and selection. The output of the pre-qualification stage is a list of selected vendor candidates after eliminating inefficient vendors. Using this selected vendor list, the final efficiency scores are evaluated using the DEA method. In DEA, vendors are referred to as decision making units (DMUs). By definition, DMUs are units that will be evaluated and analyzed in the DEA method to calculate their efficiency. The parameters for DMUs in the DEA method require that the units share similar characteristics. DEA is also a mathematical programming technique based on linear programming, which is used to evaluate the efficiency of a decision-making unit (DMU) that is responsible for utilizing a set of input resources to achieve the targeted output [17]. The DMUs used in this study are vendors involved in Project X at an offshore structure EPC company based in Jakarta.

The DMU efficiency is defined as the ratio of the weighted sum of outputs (performance) to the weighted sum of inputs (resources used). For each DMU, DEA will determine a combination of weights that maximizes the efficiency score of that particular DMU without allowing the efficiency score of any other DMU to exceed 1. The weights in DEA are derived from the data rather than being predetermined [18]. Each DMU is assigned an optimal set of weights, the values of which may vary from one DMU to another. This assumes a Constant Return to Scale model [19], meaning each DMU can scale its input and output linearly without increasing or decreasing its efficiency.
The DEA analysis in this study consists of the following implementation steps:
Step 1: Calculate output values (SWj and OTj) for each vendor using the TWV from the fuzzy SWOT analysis. Using the following eqs. 3 and 4.

$$SWj = \sum SWCriteria\ Weight\ x\ Normalized\ Score\ For\ Vendor \tag{3}$$

$$OTj = \sum OTCriteria\ Weight\ x\ Normalized\ Score\ For\ Vendor \tag{4}$$

Step 2: Calculate the efficiency score using Linear Programming with the help of LINGO software. The equation 5 calculates the efficiency of each DMU.

$$Zx = Max(SWj\ x\ U1 + OTj\ x\ U2) \tag{5}$$

Step 3: Rank the vendors based on the efficiency scores that have been calculated.

This fuzzy SWOT–DEA integration consists of two main output variables, SWj: TWV derived from the Strength and Weakness dimensions and OTj: TWV derived from the Opportunity and Threat dimensions. To complete the model, a dummy input with a constant value of 1 is assigned to each DMU, enabling the use of an output-oriented DEA model. The integration framework of the fuzzy SWOT–DEA method used is presented in Table 4.

Table 4. Fuzzy SWOT-DEA integration

DMUs	Output 1 (SWj)	Output 2 (OTj)	Input (Dummy)
DMU1	$W1_1$	$W1_2$	1
DMU2	$W2_1$	$W2_2$	1
DMU3	$W3_1$	$W3_2$	1
…..	…..	…..	…..
DMUn	Wn_1	Wn_2	1

These values are used in a linear programming model for efficiency evaluation. The next step is to determine the final ranking of the vendors based on the efficiency scores obtained from the DEA analysis. To ensure the reliability of this ranking, sensitivity analysis is conducted to help decision-makers identify the optimal combination of vendors and verify whether small changes in parameters can affect the final decision. In vendor selection using the fuzzy SWOT-DEA method, it is expected that the robustness of the results is tested through several forms of sensitivity analysis to validate the stability of the results [20].

In DEA, a vendor may appear efficient by excelling in one output despite underperformance in others. To verify this, peer analysis identifies which inefficient units use an efficient unit as a benchmark. Peer analysis provides sensitivity information in DEA analysis [21]. The sensitivity analysis consists of the following steps:

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Step 1: Identify the results of DEA analysis, distinguishing efficient and inefficient vendors.
Step 2: Select peer vendors as a reference for benchmarking and improvement.
Step 3: Calculate peer weights.
Step 4: Evaluate the changes in the values of assessment criteria.
Step 5: Interpret the sensitivity results to determine which vendors remain efficient or inefficient.

This procedure ensures that the identified efficient vendors truly represent balanced performance across outputs and that the final ranking remains stable under benchmarking evaluation.

RESULTS AND DISCUSSION

The pre-qualification stage using Fuzzy SWOT analysis was carried out through a questionnaire method filled in by the experts involved. This pre-qualification stage was followed by 15 electrical cable vendors who submitted their bids for electrical cable components in Project X at an offshore structure EPC company based in Jakarta. The assessment consists of two types of evaluation: evaluation of selection criteria and vendor assessment based on SWOT criteria listed in Table 2 using assessment references listed in Table 3 previously. The evaluations were conducted by experts with relevant experience in offshore engineering projects to ensure the reliability and validity of the assessment results, as listed in Table 1. Their judgments served as the foundation for determining the relative importance of each evaluation criterion, ensuring that the weighting process accurately reflected expert knowledge, experience, and practical considerations relevant to the decision-making context of vendor selection.

Table 5. Evaluation of research criteria

Criteria	Importance Grade	Numeric Scale	Defuzzied Weight	Normalized Weight
Quality	VH	7	9.67	0.21
Delivery Time	H	6	8.67	0.19
After-Sales Service	MH	5	7	0.15
Production Capability	M	4	5	0.11
Project Experience	MH	5	7	0.15
Vendor Communication	MH	5	7	0.15
Regulatory Compliance	H	6	8.67	0.31
Standards Compliance	H	6	8.67	0.31
Collaboration Potential	M	4	5	0.18
Transfer of Knowledge	M	4	5	0.18

Table 6. Vendor performance evaluation on strength/weakness

Vendor	Quality	Delivery Time	After-Sales Service	Production Capability	Project Experience	Vendor Communication
PT. JMB	MH	H	H	H	VH	H
PT. SI	H	H	MH	H	H	H
PT. KMI	MH	H	H	VH	H	MH
PT. KBL	H	H	MH	H	H	MH
PT. PRY	MH	MH	M	MH	H	MH
PT. MKR	H	H	MH	MH	VH	H
PT. GM	H	M	M	M	H	M
PT. PDJ	M	M	M	M	MH	MH
PT. JPR	H	MH	MH	H	H	VH
PT. SNP	H	MH	M	H	H	H
PT. PMT	NH	M	M	M	MH	MH
PT. STD	H	H	H	MH	VH	H
PT. LN	H	M	M	MH	MH	MH
PT. NB	H	H	M	M	MH	M
PT. TRS	MH	M	M	MH	MH	MH

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Table 7. Vendor performance evaluation on opportunity/threat

Vendor	Regulatory Compliance	Standards Compliance	Collaboration Potential	Transfer of Knowledge
PT. JMB	H	MH	H	H
PT. SI	H	VH	H	MH
PT. KMI	MH	H	H	MH
PT. KBL	H	H	H	H
PT. PRY	H	H	MH	H
PT. MKR	M	H	MH	M
PT. GM	M	MH	MH	M
PT. PDJ	M	MH	MH	M
PT. JPR	M	H	H	M
PT. SNP	MH	H	H	MH
PT. PMT	MH	MH	MH	M
PT. STD	H	H	H	H
PT. LN	M	MH	MH	M
PT. NB	M	MH	MH	M
PT. TRS	M	MH	H	M

Table 8. Normalize score for strength/weakness

Vendor	Quality		Delivery Time		After-Sales Service	
	0.21		0.19		0.15	
	Deffuzied	Normalized	Deffuzied	Normalized	Deffuzied	Normalized
PT. JMB	7	0.80	8.67	1	8.67	1
PT. SI	8.67	1	8.67	1	7	0.80
PT. KMI	7	0.80	8.67	1	8.67	1
PT. KBL	8.67	1	8.67	1	7	0.80
PT. PRY	7	0.80	7	0.80	5	0.57
PT. MKR	8.67	1	8.67	1	7	0.80
PT. GM	8.67	1	5	0.57	5	0.57
PT. PDJ	5	0.57	5	0.57	5	0.57
PT. JPR	8.67	1	7	0.80	7	0.80
PT. SNP	8.67	1	7	0.80	5	0.57
PT. PMT	7	0.80	5	0.57	5	0.57
PT. STD	8.67	1	8.67	1	8.67	1
PT. LN	8.67	1	5	0.57	5	0.57
PT. NB	8.67	1	8.67	1	5	0.57
PT. TRS	7	0.80	5	0.57	5	0.57
PT. JMB	8.67	0.89	9.67	1	8.67	0.89
PT. SI	8.67	0.89	8.67	0.89	8.67	0.89
PT. KMI	9.67	1	8.67	0.89	7	0.72
PT. KBL	8.67	0.89	8.67	0.89	7	0.72
PT. PRY	7	0.72	8.67	0.89	7	0.72
PT. MKR	7	0.72	9.67	1	8.67	0.89
PT. GM	5	0.51	8.67	0.89	5	0.51
PT. PDJ	5	0.51	7	0.72	7	0.72
PT. JPR	8.67	0.89	8.67	0.89	9.67	1
PT. SNP	8.67	0.89	8.67	0.89	8.67	0.89
PT. PMT	5	0.51	7	0.72	7	0.72
PT. STD	7	0.72	9.67	1	8.67	0.89
PT. LN	7	0.72	7	0.72	7	0.72
PT. NB	5	0.51	7	0.72	5	0.51
PT. TRS	7	0.72	7	0.72	7	0.72

The experts' cumulative assessments of the research criteria were then systematically processed to obtain the defuzzified and normalized weight to determine of each criterion. These calculated weights reflect the comparative importance of the criteria within the evaluation framework and

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are presented in detail in Table 5. The cumulative assessments provided by the experts in this study regarding each vendor's performance based on the criteria are presented in the following Table 6 for vendor performance evaluation on strength/weakness. For the cumulative assessments provided by the experts for vendor performance evaluation on opportunity/threat are presented in Table 7.

Next, the performance evaluations for strengths/weaknesses and opportunities/threats are normalized. The results of these calculations are shown in Table 8 and Table 9. Next, the total weighted values for each vendor are calculated for both the strength/weakness and opportunity/threat criteria to determine the coordinate points of each vendor, as shown in Table 10.

Table 9. Normalize score for opportunity/threat

Vendor	Regulatory Compliance		Standards Compliance		Collaboration Potential		Transfer of Knowledge	
	0.31		0.31		0.18		0.18	
	Deffuzied	Normalized	Deffuzied	Normalized	Deffuzied	Normalized	Deffuzied	Normalized
PT. JMB	8.67	1	7	0.72	8.67	1	8.67	1
PT. SI	8.67	1	9.67	1	8.67	1	7	0.80
PT. KMI	7	0.80	8.67	0.89	8.67	1	7	0.80
PT. KBL	8.67	1	8.67	0.89	8.67	1	8.67	1
PT. PRY	8.67	1	8.67	0.89	7	0.80	8.67	1
PT. MKR	5	0.57	8.67	0.89	7	0.80	5	0.57
PT. GM	5	0.57	7	0.72	7	0.80	5	0.57
PT. PDJ	5	0.57	7	0.72	7	0.80	5	0.57
PT. JPR	5	0.57	8.67	0.89	8.67	1	5	0.57
PT. SNP	7	0.80	8.67	0.89	8.67	1	7	0.80
PT. PMT	7	0.80	7	0.72	7	0.80	5	0.57
PT. STD	8.67	1	8.67	0.89	8.67	1	8.67	1
PT. LN	5	0.57	7	0.72	7	0.80	5	0.57
PT. NB	5	0.57	7	0.72	7	0.80	5	0.57
PT. TRS	5	0.57	7	0.72	8.67	1	5	0.57

Table 10. Total weighted values for strengths/weaknesses and opportunities/threats

Vendor	TWV S/W	Benchmarking S/W	TWV O/T	Benchmarking O/T	S/W Coordinate	O/T Coordinate
PT. JMB	0.93		0.91		0.11	0.10
PT. SI	0.92		0.96		0.11	0.16
PT. KMI	0.89		0.87		0.08	0.06
PT. KBL	0.89		0.96		0.08	0.16
PT. PRY	0.76		0.93		-0.05	0.12
PT. MKR	0.92		0.72		0.10	-0.08
PT. GM	0.70		0.66		-0.11	-0.13
PT. PDJ	0.61	0.81	0.66	0.80	-0.19	-0.13
PT. JPR	0.90		0.75		0.08	-0.04
PT. SNP	0.85		0.87		0.03	0.06
PT. PMT	0.66		0.73		-0.14	-0.06
PT. STD	0.95		0.96		0.13	0.16
PT. LN	0.73		0.66		-0.08	-0.13
PT. NB	0.75		0.66		-0.05	-0.13
PT. TRS	0.69		0.70		-0.12	-0.10

The output from the pre-qualification stage using the fuzzy SWOT method is obtained in the form of the following SWOT matrix in Figure 4. The output obtained in the pre-qualification stage will be used in the final selection stage through DEA analysis. The position of each vendor in the SWOT matrix illustrates their competitive position and assists decision-makers or experts in selecting which quadrant's vendors will proceed to the DEA analysis. Based on expert discussions and brainstorming sessions, the vendors eligible for the final selection stage are those in Quadrant I, leveraging internal strengths and external opportunities: PT. JMB, PT. SI, PT. KMI, PT. KBL, PT.

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SNP, and PT. STD, as well as the vendor in Quadrant III, leveraging external opportunities to overcome internal weaknesses: PT. PRY.

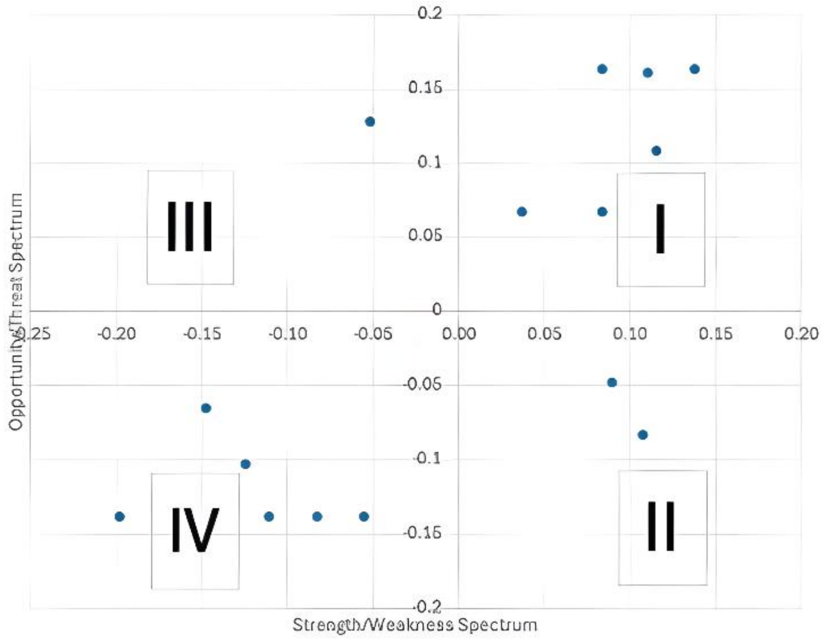

Figure 4. Pre-qualification SWOT matrix

Final Selection: DEA Analysis

The output obtained from the pre-qualification stage using the fuzzy SWOT method will be utilized in this final selection stage through DEA analysis. The DEA analysis incorporates two outputs and a dummy input, as presented in Table 11.

Table 11. Output and Input for DEA Analysis

DMUs	Output 1 (SWj)	Output 2 (OTj)	Input (Dummy)
PT. JMB	0.93	0.91	1
PT. SI	0.92	0.96	1
PT. KMI	0.89	0.87	1
PT. KBL	0.89	0.96	1
PT. SNP	0.85	0.87	1
PT. STD	0.95	0.96	1
PT. PRY	0.76	0.93	1

The mathematical equation used to calculate the efficiency of each DMU (vendor) in DEA analysis is formulated through linear programming. By substituting and adjusting the objective function for each DMU, the efficiency of each vendor can be determined. The mathematical equation used in this study to calculate DMU efficiency is defined in eq. 6.

$$Z_{PT.JMB} = \text{Max}\ (0.93 \times U_1 + 0.91 \times U_2) \quad (6)$$

which subjects to:

$0.93 \times U_1 + 0.91 \times U_2 \leq 1$
$0.92 \times U_1 + 0.96 \times U_2 \leq 1$
$0.89 \times U_1 + 0.87 \times U_2 \leq 1$
$0.89 \times U_1 + 0.96 \times U_2 \leq 1$
$0.85 \times U_1 + 0.87 \times U_2 \leq 1$
$0.95 \times U_1 + 0.96 \times U_2 \leq 1$
$0.76 \times U_1 + 0.93 \times U_2 \leq 1$
$U_1 \geq 0$
$U_2 \geq 0$

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By substituting the objective function in the mathematical equation for each vendor, efficiency can be calculated. In this study, professional software LINGO was used to solve the linear programming problem, resulting in the final efficiency scores as shown in Table 12.

Table 12. Vendor efficiency

Vendor	Efficiency Score
PT. JMB	0.97
PT. SI	0.99
PT. KMI	0.94
PT. KBL	1
PT. SNP	0.90
PT. STD	1
PT. PRY	0.96

Results of the Fuzzy SWOT-DEA Integration

The integration results of the Fuzzy SWOT-DEA analysis, which were applied during the pre-qualification and final selection stages, produced a ranking of each DMU (Vendor). The rankings of each DMU (Vendor) are presented in the following Table 13.

Table 13. Vendor ranking

Vendor	Efficiency Score	Ranking
PT. JMB	0.97	4
PT. SI	0.99	3
PT. KMI	0.94	6
PT. KBL	1	2
PT. SNP	0.90	7
PT. STD	1	1
PT. PRY	0.96	5

The results indicate that PT. STD and PT. KBL operate on the efficient frontier, meaning no other vendor demonstrates superior performance across both internal and external dimensions simultaneously. The peer analysis further confirms PT. STD as a benchmark for most inefficient vendors, highlighting its best-practice performance structure. From a managerial perspective, this finding provides practical guidance for procurement decision-makers, as inefficient vendors can improve performance by aligning their operational strategies with benchmark vendors. The model therefore not only ranks vendors but also provides actionable improvement insights. In addition, the dominance of quality and compliance-related criteria reflects the high-risk characteristics of offshore electrical systems. This confirms that strategic alignment and regulatory adherence are critical determinants of vendor efficiency in EPC projects. Therefore, the proposed framework supports risk-informed and strategically aligned procurement decisions.

Sensitivity Analysis

Sensitivity analysis was conducted to test the robustness and reliability of the results obtained in the previous stages of the study. In this study, sensitivity analysis was performed using peer analysis, which identifies the reference set or benchmarks (peers) for each inefficient DMU. The peer analysis results, derived from solving the linear programming models using LINGO, help determine which efficient vendors are used as performance benchmarks by the inefficient ones that can serve as practical references for enhancing the efficiency of underperforming vendors. The detailed results of this peer analysis are presented in Table 14.

Table 14. Peer analysis

DMUs	Efficiency Score	Peer Vendors	Peer Weights
PT. JMB	0.97	PT. STD	0.97
PT. SI	0.99	PT. STD	0.99
PT. KMI	0.94	PT. STD	0.94
PT. KBL	1	PT. KBL	1
PT. SNP	0.90	PT. STD	0.90
PT. STD	1	PT. STD	1
PT. PRY	0.96	PT. STD	0.96

Based on Table 14, PT. STD serves as a peer for five inefficient vendors: PT. JMB, PT. SI, PT. KMI, PT. SNP, and PT. PRY. This indicates that PT. STD is used as a performance benchmark for these vendors. The peer analysis can therefore be used as a reference for improving their operational and managerial practices. The inefficient vendors may enhance their performance by adopting relevant strategies from the efficient vendor, guided by the corresponding peer weights. Furthermore, this analysis provides a what-if scenario to evaluate whether such improvements could help them achieve an efficiency score of 1.

CONCLUSION

This study successfully applied the Fuzzy SWOT-DEA method to evaluate and rank the efficiency of vendors based on internal and external factors. The proposed model integrates expert assessments with fuzzy logic and DEA to support vendor selection for electrical components in an offshore EPC project. Among the evaluated criteria, quality, regulatory compliance, and standard compliance were identified as the most critical. The analysis identified PT. STD and PT. KBL as the most efficient vendors, both achieving an efficiency score of 1. Sensitivity analysis confirmed the robustness of the model, showing that variations in key criteria did not significantly alter the efficiency scores or vendor rankings.

REFERENCES

[1] E.W. Merrow, *Industrial Megaprojects: Concepts, Strategies, and Practices for Success.* Hoboken, NJ: Wiley, 2011. https://doi.org/10.1002/9781119201045

[2] P.A. Wicaksono, I.N. Pujawan, E. Widodo, Sutrisno, and L. Izzatunnisa, “Mixed integer linear programming model for dynamic supplier selection problem considering discounts,” *MATEC Web of Conferences,* vol. 154, p. 01071, 2018. https://doi.org/10.1051/matecconf/201815401071

[3] R.P. Setyono and R. Sarno, “Vendor track record selection using best worst method,” in *Proc. Int. Seminar on Application for Technology of Information and Communication (ISemantic),* 2018, pp. 361–366. https://doi.org/10.1109/ISEMANTIC.2018.8549711

[4] R.B. Handfield, R.M. Monczka, L.C. Giunipero, and J.L. Patterson, *Sourcing and Supply Chain Management.* Boston, MA: Cengage Learning, 2010.

[5] B. Musyahidah and I. Vanany, “Integration assessment and evaluation of supplier performance system in electricity generation company,” *IOP Conf. Ser.: Mater. Sci. Eng.,* vol. 598, p. 012017, 2019. https://doi.org/10.1088/1757-899X/598/1/012017

[6] E. Turban, J. Aronson, and T. Liang, *Decision Support Systems and Intelligent Systems.* Upper Saddle River, NJ: Prentice Hall, 2003.

[7] H. Simon, “Decision making and organizational design,” in *Organization Theory,* D. S. Pugh, Ed. Great Britain: Penguin Education, 1960.

[8] M. Rahmadani and Suparno, “Risk analysis for sustainable supplier selection,” *J. Phys.: Conf. Ser.,* vol. 1726, p. 012005, 2021. https://doi.org/10.1088/1742-6596/1726/1/012005

[9] U. Ciptomulyono, “Paradigma pengambilan keputusan multikriteria dalam perspektif pengembangan projek dan industri yang berwawasan lingkungan,” *Pidato Pengukuhan Guru Besar dalam Bidang Ilmu Pengambilan Keputusan Multikriteria,* ITS, 2010.

[10] E. Gürel and M. Tat, “SWOT analysis: A theoretical review,” *J. Int. Social Res.,* vol. 10, no. 51, pp. 994–1006, 2017.

[11] P. Parthiban, H.A. Zubar, and P. Katakar, “Vendor selection problem: A multi-criteria approach based on strategic decisions,” *Int. J. Prod. Res.,* vol. 51, no. 5, pp. 1535–1548, 2013. https://doi.
org/10.1080/00207543.2012.709644

[12] R.P. Setyono and R. Sarno, “Comparative method of supplier selection in ABC mining company,” *Indones. J. Electr. Eng. Comput. Sci.,* vol. 19, no. 2, pp. 890–899, 2020. https://doi.org/10.11591/
ijeecs.v19.i2.pp890-899

[13] C. Revitasari and I.N. Pujawan, “Shifting orders among suppliers considering risk, price and transportation cost,” *IOP Conf. Ser.: Mater. Sci. Eng.,* vol. 337, p. 012032, 2018. https://doi.org/
10.1088/1757-899X/337/1/012032

[14] H. Kerzner, *Project Management Case Studies,* 5th ed. Hoboken, NJ: Wiley, 2017. https://doi.org/
10.1002/9781119389040
[15] S.H. Amin, J. Razmi, and G. Zhang, "Supplier selection and order allocation based on fuzzy SWOT analysis and fuzzy linear programming," *Expert Syst. Appl.,* vol. 38, no. 1, pp. 334–342, 2011. https://doi.org/10.1016/j.eswa.2010.06.071
[16] C. Kahraman, D. Ruan, and İ. Doğan, "Fuzzy group decision-making for facility location selection," *Information Sciences,* vol. 157, pp. 135–153, 2003. https://doi.org/10.1016/S0020-0255(03)00183-X
[17] A.F. Lumban Gaol and N.P. Negoro, "Penerapan data envelopment analysis dalam pengukuran efisiensi retailer produk kendaraan merek Toyota," *Jurnal Sains dan Seni ITS,* vol. 6, no. 1, 2017. https://doi.org/10.12962/j23373520.v6i1.22309
[18] W.W. Cooper, L.M. Seiford, and K. Tone, *Data Envelopment Analysis: A Comprehensive Text with Models, Applications, References and DEA-Solver Software.* 2nd ed. New York, NY: Springer, 2007.
[19] A. Charnes, W.W. Cooper, and E. Rhodes, "Measuring the efficiency of decision making units," *European Journal of Operational Research,* vol. 2, no. 6, pp. 429–444, 1978.
[20] M.F. Anggamawarti, L.P. Alviari, Y. Sanjiwani, V.Y. Risonarta, "Quality analysis of 5.56 mm ammunition defect using Taguchi method: A review", *International Journal of Mechanical Engineering Technologies and Applications*, vol. 1, no. 1, pp. 29-35, 2020.
[21] R. Ramanathan, An Introduction to Data Envelopment Analysis: A Tool for Performance Measurement. New Delhi: Sage Publications, 2003.