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Performance Analysis of Property Construction Vendors Using the Analytical Hierarchy Process and Decision Tree Methods

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Abstract

Vendor performance evaluation in property construction projects is often dominated by subjective assessments, which may lead to inconsistent decision-making. This study aims to analyse the performance of property construction vendors at PT PELNI (Persero) using the Analytical Hierarchy Process (AHP) and the C4.5 Decision Tree method. Evaluation criteria and sub-criteria were identified through expert interviews, after which priority weights were calculated using AHP. The C4.5 Decision Tree algorithm was then employed to classify vendor performance based on historical data. To address class imbalance in the training dataset, the Synthetic Minority Oversampling Technique (SMOTE) was applied. The results identified four evaluation criteria and ten sub-criteria, with Quality emerging as the most influential criterion, receiving the highest priority weight of 0.432. The C4.5 Decision Tree model achieved an accuracy of 88.89% and a recall of 83.33%, generating seven interpretable classification rules. A comparison of the two methods indicates that AHP is effective for determining the priority weights of evaluation indicators and ranking vendors, while the Decision Tree method effectively identifies classification patterns from historical performance data. The integration of these methods provides a more objective and consistent vendor evaluation framework, supporting informed decision-making in vendor selection and performance assessment at PT PELNI (Persero).

Introduction

PT Pelayaran Nasional Indonesia (Persero) (PT PELNI) plays a dual strategic role in maintaining national logistics connectivity while optimising its property assets to generate revenue beyond its core shipping business. The company's property portfolio consists of approximately 7% heritage buildings inherited from the former *Koninklijke Paketvaart-Maatschappij* (KPM) and 29% idle assets, including office buildings and vacant land. Optimising these assets, particularly through the revitalisation of heritage buildings, has become a strategic priority to transform them from cost centres into revenue-generating assets (Tavakoli et al., 2026; Mohsin et al., 2016).

However, heritage building revitalisation projects present significant challenges, particularly regarding the performance of construction service providers. Unlike conventional construction projects, heritage conservation requires specialised technical expertise and preservation methods to maintain the historical integrity of the buildings (Miran & Husein, 2023; Mazzetto, 2024; Liang et al., 2023). Zeadat (2024) identified the shortage of skilled professionals with expertise in heritage conservation as one of the most critical barriers to adaptive reuse projects. Nevertheless, the vendor evaluation system currently implemented

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by many organisations remains largely transactional and heavily emphasises the lowest bid (Shakil et al., 205; Jyoti & Akter, 2022; Lakhal et al., 2025; Oztas et al., 2024). According to Arfa et al. (2022), such an approach frequently overlooks sustainability considerations as well as architectural and cultural values that cannot be adequately measured through financial indicators alone.

The limitations of this evaluation system are reflected in the inconsistent performance of construction vendors. Gunawan (2025) reported that the absence of standardised evaluation criteria and the reliance on subjective judgement often lead to the selection of vendors with unsatisfactory operational performance. Similarly, Okereke et al. (2021) argued that inappropriate contractor selection is one of the primary causes of project rework and schedule overruns. At PT PELNI, these issues are manifested in recurring quality deficiencies and finishing works requiring corrective revisions due to non-compliance with technical specifications. Such conditions indicate the existence of evaluation blind spots that fail to accurately identify vendors' actual technical capabilities (Munekata et al., 2023; Rajaseakaran Nair, 2026; Bell et al., 2022).

To address these challenges, vendor performance evaluation should shift from an intuitive judgement-based approach toward a structured and objective framework based on the QCDFR dimensions (Quality, Cost, Delivery, Flexibility, and Responsiveness). Previous studies have debated the most appropriate evaluation approach, particularly between knowledge-driven methods, such as the Analytical Hierarchy Process (AHP), and data-driven approaches, such as Decision Tree algorithms. Ulutaş et al. (2022) highlighted that AHP is effective in capturing managerial preferences when determining the relative importance of evaluation criteria, although it inherently involves subjective judgement. Conversely, the C4.5 Decision Tree algorithm has been recognised for its competitive predictive performance while providing transparent and interpretable decision rules, making it more practical than many black-box machine learning models (Chaudhary, 2024; Hassija et al., 2024; Topuz et al., 2025; Tursunalieva et al., 2024).

This study aims to comparatively analyse the performance evaluation of property construction vendors at PT PELNI by integrating the Analytical Hierarchy Process (AHP) and the C4.5 Decision Tree algorithm. The AHP method is employed to determine the priority weights of evaluation criteria based on managerial preferences, whereas the Decision Tree model is used to identify vendor performance classification patterns from historical project data. Through this hybrid approach, the study seeks to develop a more accurate, objective, and consistent vendor evaluation framework that can support decision-making and mitigate the risks associated with heritage property revitalisation projects.

Methods

Research Design

This study employed a quantitative research approach integrating a multi-criteria decision-making (MCDM) method with data mining techniques. The research framework was systematically designed, beginning with field observation, problem identification, data collection, and concluding with a comparative analysis between managerial judgments and historical data patterns.

Data Collection

The study utilised both primary and secondary data sources. Primary data were collected through direct observation conducted over a three-month period (July–October 2025) within the Property Business Department of PT PELNI (Persero). In addition, semi-structured interviews and pairwise comparison questionnaires were administered to three experts representing key decision-makers: the Property Business Department Manager, the

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Procurement Manager, and the General Affairs Division Manager. Secondary data were obtained from company records, including historical project summaries, weekly project monitoring reports (*Berita Acara Monitoring Pekerjaan*—BAMP) covering the 2024–2026 period, and vendor performance evaluation forms.

Analytical Hierarchy Process (AHP)

The Analytical Hierarchy Process (AHP) was employed to determine the priority weights of vendor evaluation criteria based on expert knowledge. The hierarchical structure consisted of four main criteria: Quality, Cost, Responsiveness, and Vendor Capability. Pairwise comparisons were performed using Saaty's nine-point fundamental scale (1–9) to assess the relative importance of each criterion. Unlike the conventional AHP approach that compares alternatives directly, this study adopted the Absolute Measurement (Rating Model), whereby vendors were evaluated against predefined performance standards established by the company rather than against one another. The consistency of expert judgments was verified using the Consistency Ratio (CR), with a threshold of $CR \leq 0.10$ indicating acceptable consistency. All AHP computations were conducted using Expert Choice software.

C4.5 Decision Tree Algorithm

The C4.5 Decision Tree algorithm was applied to objectively identify vendor performance classification patterns from historical project data. Data processing followed the CRISP-DM (Cross-Industry Standard Process for Data Mining) framework, consisting of the following stages: 1) Data Pre-processing: This stage included data cleaning, feature selection, and data transformation. A Log10 transformation was applied to the bid price attribute to reduce the effect of extreme values and improve data distribution; 2) Class Imbalance Handling: Since the historical dataset exhibited an unequal distribution of vendor performance classes, the Synthetic Minority Oversampling Technique (SMOTE) was applied exclusively to the training dataset to balance class representation and minimise model bias toward the majority class; 3) Model Development: The decision tree model was constructed using the Gain Ratio splitting criterion. The dataset was divided into 70% training data and 30% testing data, and the entire modelling process was implemented using the KNIME Analytics Platform through a visual workflow environment.

Model Evaluation and Comparative Analysis

The predictive performance of the C4.5 Decision Tree model was evaluated using a Confusion Matrix, from which accuracy, precision, recall, and Cohen's Kappa coefficient were calculated. Finally, a comparative analysis was conducted to examine the consistency between the priority weights generated by AHP, representing managerial preferences, and the classification rules derived from the Decision Tree, representing patterns extracted from historical project data. The integration of these complementary approaches provides managerial insights for developing a more objective, consistent, and effective vendor performance evaluation system at PT PELNI (Persero).

Results and Discussion

Priority Analysis of Evaluation Criteria and Sub-Criteria Using AHP

The Analytical Hierarchy Process (AHP) analysis began by determining the relative importance of the evaluation criteria based on expert judgments from PT PELNI (Persero). The problem decomposition produced a hierarchical structure consisting of four main criteria: Quality, Cost, Responsiveness, and Vendor Capability. Pairwise comparisons yielded a Consistency Ratio (CR) of 0.07, which is below the acceptable threshold of 0.10, indicating that the expert judgments were sufficiently consistent. Among the four criteria, Quality was identified as the highest-priority criterion.

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Table 1. Priority Ranking of Evaluation Criteria

Criteria	Priority Weight	Rank
Quality	0.432	1
Vendor Capability	0.301	2
Responsiveness	0.212	3
Cost	0.055	4

As shown in Table 1, management places the greatest emphasis on Quality, assigning it a priority weight of 0.432. This finding reflects the company's strategic focus on minimising project risks, particularly those associated with construction defects and rework. Following the determination of the main criteria, the AHP analysis was extended to the sub-criteria level to calculate global weights, which were subsequently used as the basis for evaluating individual vendor performance.

Table 2. Global Weights of Evaluation Sub-Criteria

Criteria	Criteria Weight	Sub-Criteria	Local Weight	Global Weight	Rank
Quality	0.432	Defect	0.064	0.0276	4
		Workmanship Neatness	0.432	0.1867	5
		Inspection Evidence	0.504	0.2178	2
Cost	0.055	Bid Price	0.875	0.0484	6
		Payment Term Flexibility	0.125	0.0069	10
Responsiveness	0.212	On-Time Delivery	0.755	0.1597	3
		Problem Response	0.092	0.0195	9
		Administrative Response	0.154	0.0325	7
Vendor Capability	0.301	Heritage Project Experience	0.125	0.0376	8
		Approved Vendor List (DPM)	0.875	0.2633	1

As presented in Table 2, the Approved Vendor List (DPM) obtained the highest global weight (0.2633), making it the most influential evaluation indicator. This result suggests that the verification of vendor qualifications, legal compliance, and organisational capability constitutes the primary requirement for ensuring service quality within Indonesian state-owned enterprises. The second-highest-ranked sub-criterion is Inspection Evidence (0.2178), followed by On-Time Delivery (0.1597), indicating that compliance with quality assurance procedures and project schedule performance are also critical considerations in vendor evaluation.

Vendor Performance Evaluation and Ranking

After determining the criterion weights, the performance of 16 property construction vendors was evaluated using the weighted scoring model. Each vendor's final score was calculated by multiplying its actual performance rating on each indicator by the corresponding AHP global weight.

Table 3. Vendor Performance Scores and Rankings

Rank	Vendor	Total Score
1	SPU	2.903
1	SPD	2.903

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3	SRI	2.896
3	CAB	2.896
5	WKM	2.889
5	IKA	2.889
5	PER	2.889
8	DPR	2.884
8	SGS	2.884
8	PSU	2.884
11	DCE	2.877
11	TLE	2.877
13	USO	2.851
14	DAB	2.844
14	HKA	2.844
16	APM	2.792

As shown in Table 3, SPU and SPD achieved the highest performance scores, each obtaining 2.903. The relatively narrow score range among all vendors (0.111 points) indicates that vendor performance at PT PELNI is generally homogeneous. Most vendors satisfy the company's minimum performance standards, although differences remain in several quality-related indicators that ultimately influence the final ranking.

Vendor Performance Classification Using the C4.5 Decision Tree

To complement the AHP evaluation, vendor performance was further analysed using the C4.5 Decision Tree algorithm. The model was trained on a dataset balanced using the Synthetic Minority Oversampling Technique (SMOTE), resulting in an accuracy of 88.89% and a Cohen's Kappa coefficient of 0.824, indicating almost perfect agreement between predicted and actual classifications.

Table 4. Decision Rules Generated by the C4.5 Decision Tree

Rule	IF–THEN Rule	Interpretation
Rule 1	IF Workmanship Neatness ≤ 0.9618 THEN Vendor Performance = Poor	Low workmanship neatness results in poor vendor performance.
Rule 2	IF Workmanship Neatness > 0.9618 AND Administrative Response = 1 day THEN Vendor Performance = Poor	Good workmanship alone is insufficient if administrative response requires one day.
Rule 3	IF Workmanship Neatness > 0.9618 AND Administrative Response = 2 days THEN Vendor Performance = Poor	Slow administrative response leads to poor performance despite acceptable workmanship.
Rule 4	IF Workmanship Neatness > 0.9618 AND Administrative Response < 1 day AND Log(Bid Price) ≤ 7.7626 THEN Vendor Performance = Good	Good workmanship, rapid administrative response, and relatively competitive bid prices result in good performance.
Rule 5	IF Workmanship Neatness > 0.9618 AND Administrative Response < 1 day AND Log(Bid Price) > 7.7626 AND Defect ≤ 0.1896 THEN Vendor Performance = Good	Vendors with higher bid prices can still achieve good performance when defect rates remain low.
Rule 6	IF Workmanship Neatness > 0.9618 AND Administrative Response < 1 day AND Log(Bid Price) > 7.7626 AND Defect >	Good performance is maintained when payment

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	0.1896 AND Number of Payment Terms ≤ 3.1537 THEN Vendor Performance = Good	terms remain relatively simple despite higher defect levels.
Rule 7	IF Workmanship Neatness > 0.9618 AND Administrative Response < 1 day AND Log(Bid Price) > 7.7626 AND Defect > 0.1896 AND Number of Payment Terms > 3.1537 THEN Vendor Performance = Fair	More complex payment terms reduce the overall performance classification to fair.

The decision tree selected Workmanship Neatness as the root node, indicating that it is the most influential attribute for classifying vendor performance. This finding is consistent with the AHP results, which identified quality-related indicators as the highest priority in the evaluation process. However, the Decision Tree provides additional insights beyond the weighting mechanism offered by AHP. Once satisfactory workmanship quality has been achieved, Administrative Response emerges as the next critical factor influencing vendor classification, followed by Bid Price, Defect Rate, and Payment Terms. These results demonstrate that vendor performance is determined not only by construction quality but also by operational responsiveness and contractual efficiency. Overall, the comparison between the two methods reveals their complementary strengths. AHP effectively captures managerial preferences by assigning priority weights to evaluation criteria, making it suitable for structured vendor assessment and ranking. In contrast, the C4.5 Decision Tree objectively discovers classification patterns from historical project data and produces transparent decision rules that explain the relationships among performance indicators. The integration of these approaches therefore provides a more comprehensive, objective, and evidence-based framework for vendor performance evaluation at PT PELNI (Persero), supporting better decision-making in the selection and management of property construction vendors.

The findings demonstrate a strong organisational emphasis on quality as the primary consideration in vendor performance evaluation at PT PELNI (Persero). The AHP results indicate that Quality received the highest priority weight (0.432), substantially exceeding Cost, which obtained a weight of only 0.055. This result reflects a shift in managerial priorities from a lowest-price procurement strategy toward a value-oriented approach that prioritises long-term project quality and sustainability. Such an orientation is particularly important in heritage building revitalisation projects, where poor workmanship may result in costly rework and irreversible damage to historically significant assets (Muftiadi et al., 2025; Savoie et al., 2025; Terlikowski, 2022).

At the sub-criterion level, the Approved Vendor List (DPM) achieved the highest global weight (0.2633), followed by Inspection Evidence (0.2178). These findings suggest that PT PELNI considers vendor qualification, legal compliance, and prequalification verification as the most fundamental mechanisms for ensuring construction quality. The high priority assigned to Inspection Evidence further indicates the company's preference for preventive quality assurance through continuous monitoring during project execution rather than relying solely on post-construction inspection (Gacheru, 2025).

The C4.5 Decision Tree analysis provided an objective perspective derived from historical project data. The model achieved an accuracy of 88.89% with a Cohen's Kappa coefficient of 0.824, indicating almost perfect agreement between predicted and actual vendor performance classifications. The resulting decision tree identified Workmanship Neatness as the root node, confirming it as the most influential factor in distinguishing vendor performance. Vendors whose workmanship neatness score was ≤ 0.9618 were consistently classified as Poor, highlighting the dominant role of workmanship quality in determining overall performance.

The extracted decision rules also revealed operational variables that are not highly prioritised in managerial perception but significantly influence actual vendor performance (Rainy &

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Chowdhury, 2022; Ikbal, 2025). Notably, Administrative Response appeared as the second-level decision node. Although this attribute received a relatively small AHP global weight (0.0325), the historical data demonstrate that the speed with which vendors respond to administrative requirements and revise project documentation is a critical determinant distinguishing Good from Poor performers. This finding suggests that efficient administrative coordination contributes substantially to project execution and organisational collaboration, despite receiving limited strategic attention during expert evaluations (Ongesa et al., 2025; Reza et al., 2025; Olatoye & Aminaho, 2026).

A comparison of the two analytical approaches reveals both convergence and divergence. Both AHP and the Decision Tree consistently identified Workmanship Neatness as a critical determinant of vendor performance (Purohit & Parkhi, 2025; Shoffiyati et al., 2025). However, the attributes Approved Vendor List (DPM) and Inspection Evidence, which received the highest priority weights in the AHP analysis, were absent from the decision tree. This phenomenon can be explained by the limited variability of these attributes within the historical dataset. As reported by Fatonah (2026), nearly all vendors included in the analysis had already satisfied the DPM requirements and inspection documentation standards before participating in PT PELNI projects. Consequently, these attributes possessed insufficient information gain to discriminate between different levels of vendor performance and therefore were not selected as decision nodes by the C4.5 algorithm.

Conversely, operational variables such as Bid Price, Defect Rate, and Number of Payment Terms emerged as important decision nodes within the classification model despite receiving relatively low strategic priority in the AHP analysis. This result demonstrates that operational project characteristics exert a measurable influence on vendor performance outcomes and may reveal relationships that are not immediately apparent through expert judgment alone. Therefore, while AHP reflects managerial preferences and organisational policy, the Decision Tree uncovers empirical patterns embedded within historical project data (Abd Rahman et al., 2023; Belay et al., 2022l; Zhang et al., 2025).

The integration of AHP and the C4.5 Decision Tree provides a comprehensive framework for vendor performance evaluation. The AHP method establishes the strategic priorities that reflect organisational objectives, whereas the Decision Tree validates and enriches these priorities through evidence derived from actual project performance. This complementary approach supports the development of a more robust Decision Support System (DSS) for vendor evaluation at PT PELNI. Practically, the company could implement an integrated evaluation dashboard that combines AHP-derived priority weights with predictive classification rules generated from historical data. By recognising Workmanship Neatness and Administrative Response as empirically validated performance drivers, management can design more targeted vendor development programmes, improve project quality, and enhance administrative efficiency throughout the construction process.

Conclusion

This study successfully evaluated the performance of property construction vendors at PT PELNI (Persero) from two complementary perspectives: managerial strategic preferences, represented by the Analytical Hierarchy Process (AHP), and historical performance patterns, identified through the C4.5 Decision Tree algorithm. The AHP analysis revealed that Quality is the highest-priority evaluation criterion, with a weight of 0.432, reflecting the company's strong commitment to minimising rework and maintaining high construction standards, particularly in the revitalisation of heritage buildings. At the sub-criterion level, the Approved Vendor List (DPM) and Inspection Evidence emerged as the most influential indicators, highlighting the importance of vendor qualification and preventive quality assurance in the evaluation process. From an empirical perspective, the C4.5 Decision Tree demonstrated

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strong predictive performance, achieving an accuracy of 88.89% and identifying Workmanship Neatness as the primary decision node for classifying vendor performance into Good, Fair, and Poor categories. An important finding concerns Administrative Response, which received relatively low priority in the AHP analysis but emerged as the second most influential factor in the decision tree. This result indicates that the speed of processing and revising administrative documents plays a significant role in actual vendor performance despite being underestimated in managerial perception. The vendor ranking further showed that SPU and SPD achieved the highest overall performance scores, whereas APM ranked lowest. Overall, the relatively small variation in performance scores suggests that most vendors have already met the company's minimum performance standards.

For PT PELNI (Persero), the findings of this study provide practical guidance for improving the vendor evaluation system. The company is encouraged to adopt the AHP-derived priority weights and vendor rankings as standard references for periodic performance assessment, vendor development programmes, and contractor selection. Particular attention should be directed toward workmanship quality, on-time project delivery, and administrative responsiveness, as these factors were found to have the greatest influence on vendor performance. Furthermore, the company should develop an integrated Decision Support System (DSS) in the form of a performance evaluation dashboard that combines the strategic weighting generated by AHP with the predictive classification rules produced by the Decision Tree model. Such a system would enable more objective, transparent, and data-driven decision-making in vendor management. From an academic perspective, this study contributes to the growing body of knowledge on vendor performance evaluation by demonstrating the complementary strengths of combining multi-criteria decision-making and machine learning approaches. Future research is recommended to expand the historical dataset and incorporate additional variables that may influence vendor performance, such as project complexity, vendor resource availability, project risk, and contract characteristics. Comparative studies involving other machine learning algorithms, including Random Forest, Naïve Bayes, and Support Vector Machine (SVM), are also recommended to determine whether higher predictive performance can be achieved while maintaining model interpretability. Such developments would further strengthen the application of intelligent decision-support systems for construction vendor evaluation, particularly within state-owned enterprises managing complex infrastructure and heritage asset projects.

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