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Framework for Strategic Selection of Maintenance Contractors

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Abstract: Selecting the right maintenance contractor is crucial for efficient operation and project success. Traditionally, this selection has been cost-driven, but the ever-growing complexity of projects has led to a shift towards best-value selection. The best value selection criteria evaluate the contractors based on factors like experience and past performance, along with the proposed cost. However, this approach lacks substantiated knowledge of these factors and often includes factors that cannot be validated at the time of procurement. This paper proposes a framework that applies the Analytical Hierarchy Process (AHP) to the maintenance contractor selection process. A detailed literature review was carried out to identify factors involved in maintenance selection. Data were collected from experts through a questionnaire developed based on the identified factors, facilitating AHP implementation. Substantiation strategies were identified using expert judgments. Our findings reveal that past performance criteria hold the maximum weight in the selection process. The proposed framework offers a more comprehensive approach for selecting maintenance contractors, ensuring both value and efficiency.

Keywords: best value criteria; maintenance contractor; analytical hierarchy process (AHP); substantiated framework

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1. Introduction

The quality of life inside multistory buildings relies heavily on the uninterrupted availability of services such as elevators, HVAC, and water pumps [1]. Recognizing this, building owners prioritize the maintenance of these facilities to ensure continuous operation, enhance the long-term value, and ensure user satisfaction [2]. These facilities cannot provide their intended services without regular maintenance [3]. Observations made since 2002 indicate that more than half of the building operations have been maintenance-related [4]. According to reports, maintenance work has experienced a 66% increase over the past decade. Additionally, between the early 1990s and 2000, maintenance work increased by 43%, while in contrast, building work only saw an increase of 28% during the same period [5–7]. Often, maintenance contractors are chosen based on the lowest bid instead of performance, leading to errors and complaints during the operation phase [8]. Selecting the contractor that offers the lowest annual fee results in overlooking the best-value criteria such as past performance, technical capabilities, and personnel [9]. Therefore, it is important for building owners to select a maintenance contractor after evaluating the contractor's technical qualifications to safeguard their interests [10].

Various procedures for contractor selection have been proposed by researchers and applied in the field over the past few decades [11]. Contractor selection is a multi-criteria problem, not limited to bid price only [12]. Extensive research and practices in the construction industry have focused on multi-criteria decision methods for contractor selection. This includes the application of the ANP technique by Cheng and Li [13], and in addition, detailed analysis on contractor selection has been covered at the pre-qualification and procurement stages by [14–18]. These studies recommend using non-price criteria, such as past performance and experience, in contractor selection instead of low-priced traditional selection. Similarly, many other studies on the maintenance contractor selection process have been carried out by Zavadskas and Vilutienė [11], Zavadskas et al. [19], Hadidi and Khater [20], and Zubair and Zhang [21], which also focus on the use of non-price factors. There is limited research performed in the literature on maintenance contractor selection [11,22] and a gap exists in evidence-based knowledge for substantiating the selection criteria. When companies hire a maintenance contractor, they may struggle to make informed choices if they lack awareness of the variables involved in evaluating the contractor, leading to subpar work and increased costs. According to Zavadskas and Vilutienė [11], maintenance and construction processes differ fundamentally, as clients in maintenance prioritize both the final outcome and the ongoing maintenance process. Consequently, the selection criteria for maintenance work significantly differ from those applicable to construction projects. Additionally, most efforts concentrate on creating models for new construction projects, often lacking relevance for maintenance work. The irrelevance may be due to the fact that the nature of maintenance work is better perceived as a service than a product [22], emphasizing the necessity for specific approaches in determining decision-making attributes. Adhikary et al. [23] highlighted that inaccurate design or improper selection of any parameter in the maintenance process can have a high negative impact on the overall cost and efficiency, and [24] emphasized that selecting maintenance contractors is a critical decision-making process that requires careful evaluation of several criteria. An effective approach for assessing and choosing the right contractors for maintenance projects involves the use of multi-criteria decision-making methods. Hence, traditional methods are insufficient for executing maintenance contractor selection [25], highlighting the need for a dedicated framework made specifically for maintenance selection.

Current contractor selection frameworks are lacking in substantiated knowledge and effective strategies to help owners evaluate maintenance contractors' attributes, especially their past performance, rendering them less helpful in actual practice. This study aims to fill this gap by providing a substantiated framework by collecting data from industry experts and framing their opinions alongside best-value attributes. The best value attributes in contractor selection encompass various factors contributing to the overall quality, efficiency, and success of a project [26]. This approach will assist building owners in evaluating contractors' attributes using the provided evaluation technique. The research will integrate current best practices and industry insights to refine the selection process, thereby mitigating risks and increasing project success. The proposed framework will offer specific quality assessment methods to ensure industry adoption. This research aims to facilitate building owners by focusing on a well-informed selection of maintenance contractors through a best-value approach. Utilizing multi-criteria decision-making methods like the AHP, this research provides a balance between cost-effectiveness and service quality. The contributions of this study are as follows: (1) Identifying the factors influencing the selection criteria of maintenance contractors. (2) Developing a framework for employing maintenance contractors. (3) Devise strategies to aid owners in substantiating factors in the best-value process.

2. Literature Review

Contractor selection is one of the most important tasks in a project and crucial for ensuring successful execution. This challenging and exhaustive process requires considering numerous interrelated factors and uncertainties to make an informed decision [27]. An ineffective selection process can adversely affect future decisions [14]. Most of the time, the selection of a contractor takes place purely on the basis of the lowest bid instead of the best value criteria [28]. Mostly, a bidder is selected based on the lowest cost, a practice that might not guarantee the lowest cost upon completion due to potential claims, litigation during construction, project delays, and poor work quality [27].

The best value (BV) criteria have been adopted in many developed countries; however, it often faces barriers such as liability claims of bias as the BV contractor price is high compared to some other bidders [29]. A study was carried out on Design-Bid-Build (DBB) contractors in the USA, focusing on the BV selection process, and gathered data from 167 DBB contracts. The results indicated that BV contractors were selected 52% of the time over the lowest bid contractors, and 67% of these contractors also ranked within the top two for lowest bids, highlighting the preference for a balance between cost and quality, where people often prioritize the efficiency of a qualified contractor over the desire for greater quality at an expensive cost [30]. BV criteria are not only applicable in contractor selection but have also been utilized in many other sectors of the construction industry [31]. One of the most common techniques used in BV criteria is AHP, which has found application in many construction management problems. It has been used in risk management, sustainable construction, bidding processes, contractor prequalification, and more [32].

Different techniques have been applied for contractor selection. Cheng and Li [13] used the analytical network process (ANP) and the multiple-layer fuzzy pattern recognition (MFPR) approach to solve the contractor selection problem [14]. Another study incorporated quantitative and qualitative factors in selection criteria, developing a framework through generalized comparative linguistic ELECTRE III [18]. A 2013 study analyzed text from design-build contractor RFPs. RFPs samples included residential, commercial, heavy civil work, institutional, industrial, and renovation work. The study identified 23 factors across 10 different categories, with price and experience being the most frequent considerations. Price was considered 91% of the time, followed by experience at 83%. Technical approach, management approach, qualification, and schedule had 72%, 68%, 62%, and 60%, respectively, while past performance, financial capability, responsiveness to RFP, and legal status had 54%, 37%, 37%, and 14%, respectively [16]. Another study was carried out in 2017 on the procurement methods of contractors, with a focus on factors considered in the literature. Results reveal that quality is most important at 9.2%, followed by cost, staff features, financials, company management, experience, and time at 8.2%, 7.9%, 7.9%, 7.6%, 6.5%, and 6%, respectively [17].

Studies on maintenance contractor selection have used various methodologies. Zavadskas et al. [33] used a simulation approach using data from 15 maintenance contractors to identify best practices for enhancing the maintenance contractor selection process. In a subsequent study in 2006, a multi criteria evaluation of a maintenance contractor was conducted through a case study. Sixteen maintenance firms and 11 client data sets were analyzed to create a statistical model linking client satisfaction and maintenance performance. Clients ranked cost as the highest priority, followed by maintenance level, quality standard of service, reliability of the firm, employee qualification, and implementation of needs [11]. Another study was conducted to determine the criteria prioritized by all parties involved in the selection of maintenance contractors. This study evaluated maintenance contractors by ranking attributes that would be acceptable to all parties during both the selection process and the execution of maintenance tasks [19]. Hadidi and Khater [20] concluded that maintenance contractors should be procured based on their past performance, expertise, technical plans, and health and safety plans. Zubair and Zhang [21] developed a framework for elevator maintenance contractors through text analysis of RFPs. This study focused on improving the current practices for maintenance contractor selection through content analysis of existing RFPs.

Analytic Hierarchy Process (AHP) is an easy-to-use Multi-Criteria Decision-Making (MCDM) method that uses hierarchy and pairwise comparisons. It ensures consistency by calculating the consistency index before establishing rankings. Other MCDM methods, like Simple Additive Weighting (SAW) and Weighted Product (WP) methods, rely on a weighted average approach but lack built-in consistency checks. AHP is user-friendly, but for more complex scenarios with numerous criteria and alternatives, it becomes less practical due to the increased effort and time required [34]. SAW and WP, while less intricate, provide alternative decision-making approaches without the same consistency as AHP [35]. AHP was chosen for this study due to its ease of implementation and the limited number of attributes in this paper. Its simplicity makes it a practical choice for decision-making with fewer criteria.

In conclusion, current maintenance contractor selection frameworks emphasize a multi-criteria approach; however, there is a lack of robust strategies for evaluating these criteria. The proposed study identifies the different attributes and their weights in the selection of a maintenance contractor through AHP. Additionally, substantiation strategies for these attributes are identified by industry expert consultants.

3. Research Methodology

This chapter presents the research method used to analyze and achieve our objectives. The proposed methodology starts with a detailed literature review aimed at identifying the attributes/factors for the selection of a maintenance contractor. Following this, a preliminary questionnaire survey is conducted to validate these attributes from industry professionals and consultants. After that, a final questionnaire survey is conducted, which facilitates the pairwise comparison of attributes. The analytical hierarchy process is employed in this step as a multi criteria decision making (MCDM) technique. This final questionnaire also helps in the substantiation of attributes. Survey participants were identified via LinkedIn, specifically targeting individuals with extensive expertise in the relevant field. The methodology adopted in this research is shown in Figure 1. The following sections below explain the methodology in detail.

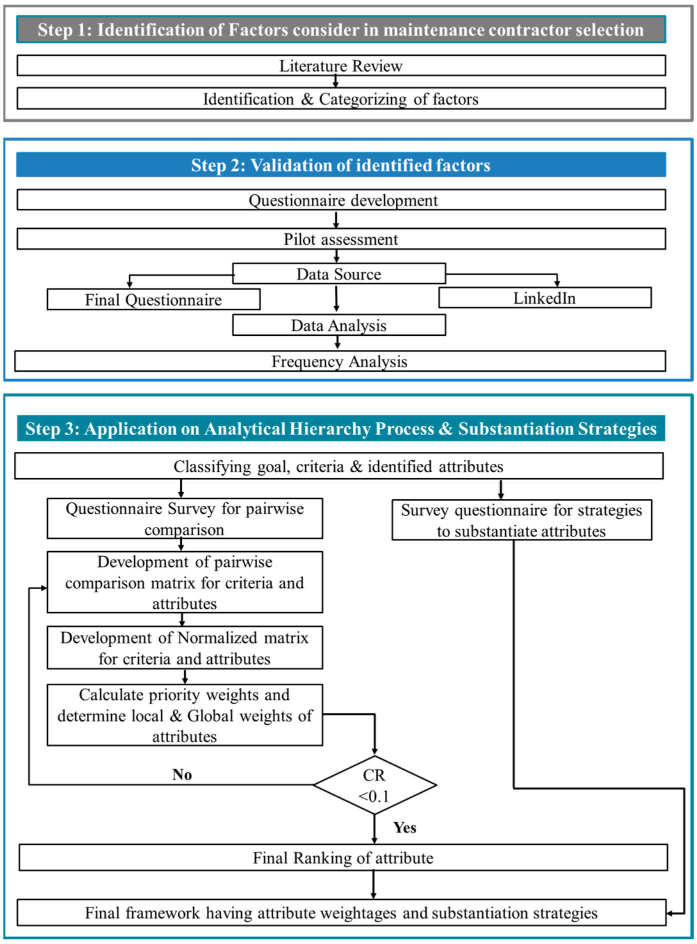

Figure 1. Research Methodology.

3.1. Factors Identification

A detailed literature review regarding the selection of maintenance contractors was conducted to identify the factors. Various databases, such as Science Direct, Google Scholar, Scopus, and Web of Science, were utilized to gather a comprehensive set of studies on the given topic. Multiple combinations of keywords, including maintenance contractor, best value selection, and contractor selection factors, as well as synonymous terms, were utilized to ensure the retrieval of a maximum number of results. After a literature review, a total of 21 factors were identified. These factors and their respective sources are shown in Table 1.

Table 1. Factor identification through a literature review.

Factors	References	Factors	References
		Work Approach	
Flexibility to change	Tayeh et al. [8]; Zavadskas and Vilutienė [11]; de Araújo et al. [17]; Assaf et al. [36]; Araújo et al. [37]	Proposed maintenance approach and plans	Zavadskas and Vilutienė [11]; Singh and Tiong [14]; Araújo et al. [37]
Respond rate of complaints.	Zubair and Zhang [21]; Araújo et al. [37]; Ahmed and Kangari [38]; Enshassi et al. [39]; Tan et al. [40]	Understanding insight of clients and project needs.	Tayeh et al. [8]; Zubair and Zhang [21]; Hasnain et al. [26]; Assaf et al. [36]; Enshassi et al. [39]; Al-Hammad and Assaf [41]; Arslan et al. [42]
		Experience	
General work Experience	Tayeh et al. [8]; Zavadskas and Vilutienė [11]; Cheng and Li [13]; de Araújo et al. [17]; Araújo et al. [37]; Arslan et al. [42]; Egemen and Mohamed [43]; Naji et al. [44]	Employee qualification	Zubair and Zhang [21]; Araújo et al. [37]; Tan et al. [40]; Naji et al. [44]; Bintoro and Malani [45]
Experience of similar works	Zavadskas and Vilutienė [11]; Zubair and Zhang [21]; Tan et al. [40]; Arslan et al. [42]; Egemen and Mohamed [43]; Naji et al. [44]	Availability of technical skilled/Trained staff	Zavadskas and Vilutienė [11]; Hosny et al. [15]; de Araújo et al. [17]; Hasnain et al. [26]; Araújo et al. [37]; Enshassi et al. [39]; Tan et al. [40]; Al-Hammad and Assaf [41]; Arslan et al. [42]; Egemen and Mohamed [43]; Watt et al. [46]
		Past Performance	
Past performance	Cheng and Li [13]; Singh and Tiong [14]; Hosny et al. [15]; Enshassi et al. [39]; Watt et al. [46]	Performance In similar project	Hosny et al. [15]; Zubair and Zhang [21]; Hasnain et al. [26]; Enshassi et al. [39]
Safety of work	Cheng and Li [13]; Singh and Tiong [14]; de Araújo et al. [17]; Hasnain et al. [26]; Araújo et al. [37]; Al-Hammad and Assaf [41]; Arslan et al. [42]; Egemen and Mohamed [43]; Naji et al. [44]; Watt et al. [46]; Puri and Tiwari [47]	Previous work quality	Tayeh et al. [8]; Hosny et al. [15]; de Araújo et al. [17]; Hasnain et al. [26]; Araújo et al. [37]; Ahmed and Kangari [38]; Enshassi et al. [39]; Tan et al. [40]; Arslan et al. [42]; Egemen and Mohamed [43]; Naji et al. [44]; Puri and Tiwari [47]; Topcu [48]; Wireman [49]; Banaitiene and Banaitis [50]
Previous Client satisfaction/Reputation earned.	Tayeh et al. [8]; Zavadskas and Vilutienė [11]; Singh and Tiong [14]; Hosny et al. [15]; [17]; Zubair and Zhang [21]; Hasnain et al. [26]; Enshassi et al. [39]; Tan et al. [40]; Egemen and Mohamed [43]; Watt et al. [46]; Wireman [49]	Operations management plan/capability	Singh and Tiong [14]; Hosny et al. [15]; de Araújo et al. [17]; Araújo et al. [37]; Enshassi et al. [39]; Al-Hammad and Assaf [41]; Naji et al. [44]; Watt et al. [46]; Puri and Tiwari [47]

Table 1. *Cont.*

Factors	References	Factors	References
	Personal Record and Resources		
Ongoing projects	Zavadskas and Vilutienė [11]; Cheng and Li [13]; Singh and Tiong [14]; de Araújo et al. [17]; Egemen and Mohamed [43]; Naji et al. [44]; Watt et al. [46]	Inventory in stock/Resources	Au-Yong et al. [3]; Tayeh et al. [8]; Zavadskas and Vilutienė [11]; Cheng and Li [13]; Singh and Tiong [14]; Zubair and Zhang [21]; Assaf et al. [36]; Enshassi et al. [39]; Al-Hammad and Assaf [41]
Failed contractors	Cheng and Li [13]; Singh and Tiong [14]; Hosny et al. [15]; Naji et al. [44]; Puri and Tiwari [47]; Banaitiene and Banaitis [50]		
	Financial		
Financial Capability/stability	Cheng and Li [13]; Singh and Tiong [14]; de Araújo et al. [17]; Enshassi et al. [39]; Arslan et al. [42]; Egemen and Mohamed [43]; Watt et al. [46]; Puri and Tiwari [47]; Banaitiene and Banaitis [50] Hasnain et al. [26]; Araújo et al. [37], Zubair and Zhang [21]; Naji et al. [44]	Proposed Price	Zavadskas and Vilutienė [11]; Cheng and Li [13]; Singh and Tiong [14]; Hasnain et al. [26]; Enshassi et al. [39]; Egemen and Mohamed [43]; Naji et al. [44]; Banaitiene and Banaitis [50]
	Legal Status		
Availability of required licenses to perform maintenance.	Tayeh et al. [8]; Tan et al. [40]	Litigation and claim history	Tayeh et al. [8]; Hosny et al. [15]; Egemen and Mohamed [43]; Banaitiene and Banaitis [50]

3.2. Analytical Hierarchy Process (AHP)

Analytical Hierarchy Process (AHP) is a decision support model that was introduced by Saaty [51]. It is a mathematical technique renowned for its effectiveness in solving complex decision-making problems. AHP is the method for making the best decision when the decision-maker has many criteria [52]. This technique helps in disintegrating problems into a hierarchy of criteria and sub-criteria, allowing for a comparative analysis. This process includes both qualitative and quantitative elements and helps structure complex decision problems into a stepwise decision model. It assumes that relationships between clusters are unidirectional across different decision levels in the hierarchy and that there are no correlations between clusters and elements within each cluster or sub-cluster.

The AHP process works as follows: AHP involves identifying criteria and their corresponding sub-criteria. This helps in breaking down the decision into specific factors for consideration. Following this, pairwise comparisons are made between the components, providing a relative scale of their importance. Experts in their respective fields are asked to compare the importance of each pair of elements at every level of the hierarchy. This involves assessing the relative significance of each criterion compared to others at the second level. Similarly, experts compare the importance of each pair of sub-criteria under the same criterion at the second level and continue this process throughout the hierarchy. Since AHP uses subjective judgments from decision-makers, there is no automatic assurance of consistency in these judgments. Hence, it becomes essential to conduct consistency checks to ensure an optimized outcome. Results from these comparisons are normalized, a process where values are adjusted for accurate weight calculations. Subsequently, weights are determined for the decision components (criteria/sub-criteria), and in the end, the weights assigned to the decision components are combined, effectively aggregating all the factors into a final decision.

3.3. Questionnaire Design

After shortlisting factors from the literature review, a preliminary questionnaire was developed to gather expert opinions on the importance of these factors in selecting a maintenance contractor. The questionnaire was distributed to 5 industrial professionals associated with consultancies with 10–25 years of experience. This questionnaire aimed to validate the identified factors and determine their sustainability. Participants were asked to identify the factors they deemed unimportant in selecting a maintenance contractor. Factors marked as unimportant by three or more consultants were subsequently discarded. Four factors received low ratings from industry experts and were discarded. The remaining 17 were shortlisted, and these factors are given in Table 2. These 17 factors were distributed into 5 different categories based on their nature. Using these factors, a final questionnaire was developed aimed at determining the weights of these attributes and exploring the substantiation techniques in the decision-making process of selecting a maintenance contractor. For assigning weights to attributes, a multi-criteria decision making technique is employed due to its significance in solving complex problems. AHP participants compare pairs of evaluation criteria to establish their prioritization. Then they compare each sub-criteria for each criterion.

Table 2. Shortlisted factors.

No.	Main Criteria	Factors/Sub-Criteria
1.	Work Approach	Proposed maintenance approach and plans
		Understanding insight of clients and project needs.
2.	Experience	General work Experience
		Experience of similar works
		Employee qualification
		Availability of technical skilled/Trained staff
3.	Past Performance	Past performance
		Performance In similar project
		Previous Client satisfaction/Reputation earned.
		Safety of work/Accidents Record
		Previous work Quality
4.	Personal Record and Resources	Failed contracts
		Inventory in stock/Resources
5.	Financial and Legal Status	Financial Capability/stability
		Proposed Price
		Availability of required licenses to perform maintenance.
		Litigation and Claim History

3.4. Pairwise Comparisons

Pairwise comparisons were determined through a survey with experts, which included the final questionnaire for experts to make pairwise comparisons. Alongside AHP's pairwise comparison section for criteria and sub-criteria, this questionnaire contains another section aimed at identifying strategies to substantiate the attributes. As per the literature, a sample size of one qualified expert can be used [53,54]. Other researchers have used sample sizes ranging from four to nine [55–57]. These findings indicate that AHP can be implemented with a few experts to achieve useful decision models. For the survey, our sample size consisted of seven experts. Their details are shown in Figure 2. To aggregate the individual judgments of experts, the literature suggests taking a geometric mean [58] or an arithmetic mean [59]. By taking the geometric mean, pairwise comparisons were identified, along with various strategies that can be used to evaluate specific attributes.

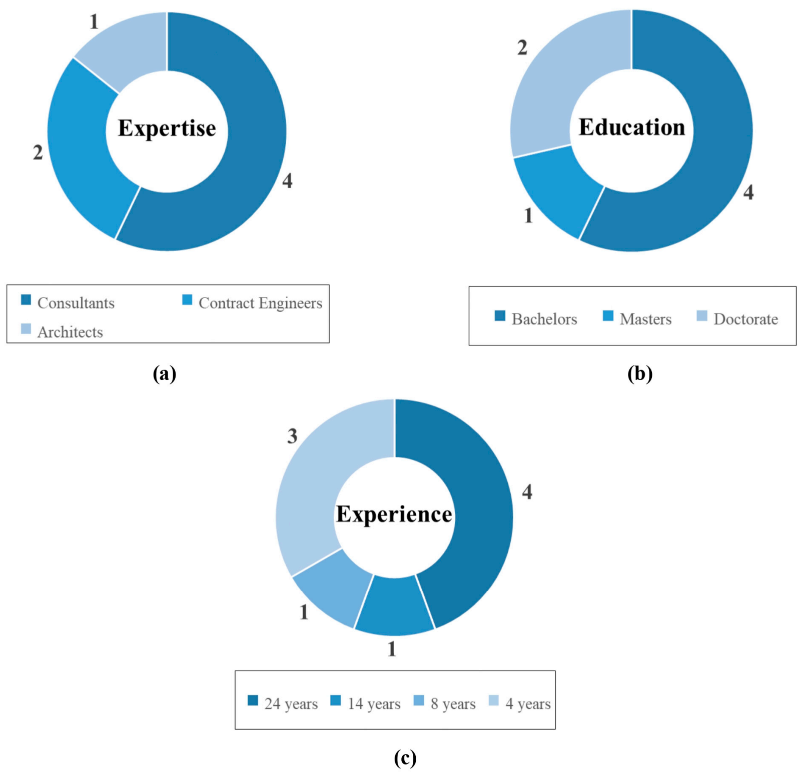

Figure 2. Details of the experts (**a**) Expertise (**b**) Education (**c**) Experience.

Satty et al. [60] presented a nine-point relative scale. The given scale assigns numeric values to denote the importance of options in a decision-making context. A score of 1 implies equal importance, while 3, 5, 7, and 9 indicate increasing levels of importance for one option over the other. Intermediate judgments are expressed using even numbers (2, 4, 6, 8). Pairwise comparisons are made according to this scale. Table 3 shows the questionnaire section for pairwise comparison of criteria. A similar format is utilized for pairwise comparison of sub-criteria. Another section of the final questionnaire asks the experts to suggest strategies that can be used to substantiate the identified factors.

Table 3. Questionnaire section for the relative importance of Criteria.

If "*Option A*" Is Relatively Important											**If "*Option B*" Is Relatively Important**							
Option A	**9**	**8**	**7**	**6**	**5**	**4**	**3**	**2**	**1**	**2**	**3**	**4**	**5**	**6**	**7**	**8**	**9**	**Option B**
Work Approach																		Experience
Work Approach																		Past Performance
Work Approach																		Personal RR
Work Approach																		Financial and Legal Status
Experience																		Past Performance
Experience																		Personal R and R
Experience																		Financial and Legal Status
Past Performance																		Personal R and R
Past Performance																		Financial and Legal Status
Personal R and R																		Financial and Legal Status

4. Results and Discussion

This section presents an AHP analysis of the data collected from questionnaire surveys, along with an in-depth analysis of the findings. The proposed framework uses the Analytical Hierarchy Process (AHP) model for the selection of a maintenance contractor and strategies for evaluating the identified attributes. Utilizing AHP, weights can be assigned to the identified factors derived from the literature review.

4.1. Pairwise Matrices

Through a pairwise comparison, a matrix is created where the diagonal values are equal to 1 and the off-diagonal values are reciprocal of each other, implying that if factor j is "1/q times" as important as factor i, then factor i is "q times" as important as component j. To determine the weights of criteria and attributes for selecting a maintenance contractor, the five criteria and subfactors in each category are compared with each other by the experts using a nine-point scale. Their priorities are calculated, and a matrix is formed resulting from this pairwise comparison. Matrix is shown in Tables 4–9, showing their sub criteria. These matrices are formed after taking the geometric mean of the answers given by the experts.

Table 4. Pairwise matrix of criteria.

Criteria					
	Work Approach	Experience	Past Performance	Personal Record and Resource	Financial and Legal Status
Work Approach	1.000	1.146	0.820	0.517	2.246
Experience	0.873	1.000	0.882	1.647	1.566
Past Performance	1.219	1.134	1.000	1.723	1.216
Personal Record and Resource	1.933	0.607	0.581	1.000	0.739
Financial and Legal Status	0.445	0.638	0.822	1.353	1.000

Table 5. Pairwise matrix of work approach attributes.

Work Approach		
	Proposed Maintenance plan and Approach	Understanding insight of client and Project need
Proposed Maintenance plan and Approach	1.000	0.640
Understanding insight of client and Project need	1.563	1.000

Table 6. Pairwise comparison of experience attributes.

Experience				
	General Work Experience	Experience of similar works	Employee qualification	Availability of technical Staff
General Work Experience	1.000	0.353	1.933	0.381
Experience of similar works	2.831	1.000	1.811	0.529
Employee qualification	0.517	0.552	1.000	0.345
Availability of technical Staff	2.627	1.891	2.901	1.000

4.2. Normalization and Weight Calculation

In normalization, matrix values are normalized to accurately calculate the weights of criteria and attributes. Normalization is applied to make the data comparable or to bring it to a common scale. Normalization involves summing the columns of the matrix, and then each element of the matrix for a given column is divided by the sum of that column [61].

Equations (1) and (2) show an example of the process of normalization for Table 4, resulting in Table 10.

$$X_{1,1} = \frac{1}{1 + 0.873 + 1.219 + 1.933 + 0.445} = 0.183 \quad (1)$$

$$X_{1,2} = \frac{1.146}{1.146 + 1 + 1.134 + 0.607 + 0.638} = 0.253 \quad (2)$$

Table 7. Pairwise comparison of past performance attributes.

Past Performance					
	Past Performance	Performance in similar works	Previous client satisfaction	Work safety record	Previous work quality
Past Performance	1.000	0.223	0.259	0.981	0.266
Performance in similar works	4.481	1.000	1.199	2.034	0.711
Previous client satisfaction	3.861	0.834	1.000	0.654	1.148
Work safety record	1.019	0.492	1.530	1.000	1.448
Previous work quality	3.758	1.407	0.871	0.691	1.000

Table 8. Pairwise comparison of personal record and resource attributes.

Personal Record and Resource		
	Failed Contracts	Inventory in Stock
Failed Contracts	1.000	0.645
Inventory in Stock	1.551	1.000

Table 9. Pairwise comparison of financial and legal status attributes.

Financial and Legal Status				
	Financial Capability	Proposed Price	Availability of required license for work	Litigation and Claim History
Financial Capability	1.000	1.632	0.459	1.919
Proposed Price	0.613	1.000	0.339	1.739
Availability of required license for work	2.180	2.950	1.000	2.420
Litigation and Claim History	0.521	0.575	0.413	1.000

Table 10. Normalized matrix for criteria.

Criteria					
	Work Approach	Experience	Past Performance	Personal Record and Resource	Financial and Legal Status
Work Approach	0.183	0.253	0.200	0.083	0.332
Experience	0.160	0.221	0.215	0.264	0.231
Past Performance	0.223	0.251	0.244	0.276	0.180
Personal Record and Resource	0.353	0.134	0.141	0.160	0.109
Financial and Legal Status	0.081	0.141	0.200	0.217	0.148

Tables 10–15 show the normalized matrices. After normalization of matrices, the weights of attributes are calculated, considering both their criteria and the overall goal of the study. These weights are known as local weights and global weights, respectively. If an attribute is a sub-criterion, then the local weight of that attribute shows its importance with respect to its specific criteria. After local weights are calculated, the next step is to calculate the weight of the attribute with respect to the main goal. If an attribute is a criteria, then its

global weight is its importance with respect to the main goal of the study. The score for the criteria is given by Equation (3). Equation (4) shows an example of a score calculation for the work approach in Table 10. Similarly, local weights of sub-criteria are calculated. The global weight of a sub-criteria is given by $Score_{criteria} \times Localweight_{sub-criteria}$ [62]. The local and global weights of criteria and attributes are shown in Table 16 in descending order according to weights.

$$Score\ or\ Local\ weight = \frac{\sum Row_{attribute}}{n} \tag{3}$$

$$Score_{work\ appraoch} = \frac{0.183 + 0.253 + 0.2 + 0.083 + 0.332}{5} = 0.210 \tag{4}$$

Table 11. Normalized matrix for work attribute.

Work Approach		
	Proposed Maintenance plan and Approach	Understanding insight of client and Project need
Proposed Maintenance plan and Approach	0.390	0.390
Understanding insight of client and Project need	0.610	0.610

Table 12. Normalized matrix for experience.

Experience				
	General Work Experience	Experience of similar works	Employee qualification	Availability of technical Staff
General Work Experience	0.143	0.093	0.253	0.169
Experience of similar works	0.406	0.263	0.237	0.235
Employee qualification	0.074	0.145	0.131	0.153
Availability of technical Staff	0.377	0.498	0.379	0.444

Table 13. Normalized matrix for past performance.

Past Performance					
	Past Performance	Performance in similar works	Previous client satisfaction	Work safety record	Previous work quality
Past Performance	0.071	0.056	0.053	0.183	0.058
Performance in similar works	0.317	0.253	0.247	0.380	0.155
Previous client satisfaction	0.273	0.211	0.206	0.122	0.251
Work safety record	0.072	0.124	0.315	0.187	0.317
Previous work quality	0.266	0.356	0.179	0.129	0.219

Table 14. Normalized matrix for personal record and resources.

Personal Record and Resource		
	Failed Contracts	Inventory in Stock
Failed Contracts	0.392	0.392
Inventory in Stock	0.608	0.608

Table 15. Normalized matrix for financial and legal status.

Financial and Legal Status				
	Financial Capability	Proposed Price	Availability of required license for work	Litigation and Claim History
Financial Capability	0.232	0.265	0.207	0.271
Proposed Price	0.142	0.162	0.153	0.246
Availability of required license for work	0.505	0.479	0.452	0.342
Litigation and Claim History	0.121	0.093	0.187	0.141

Table 16. Local and Global weightages.

Category	Score	Factors	Local Score	Global Score
Past Performance	0.235	Performance in similar works	0.270	0.063
		Previous work quality	0.230	0.054
		Previous client satisfaction	0.213	0.050
		Work safety record	0.203	0.048
		Past Performance	0.084	0.020
Experience	0.218	Availability of technical Staff	0.424	0.093
		Experience of similar works	0.285	0.062
		General Work Experience	0.165	0.036
		Employee qualification	0.126	0.027
Work Approach	0.210	Understanding insight of client and Project need	0.610	0.128
		Proposed Maintenance plan and Approach	0.390	0.082
Personal Record and Resources	0.180	Inventory in Stock	0.608	0.109
		Failed Contracts	0.392	0.070
Financial and Legal Status	0.157	Availability of required license for work	0.445	0.070
		Financial Capability	0.244	0.038
		Proposed Price	0.176	0.028
		Litigation and Claim History	0.136	0.021

4.3. Consistency Check

For matrices of 3 $\times$ 3 or larger size in AHP, it is important to perform consistency checks to ensure that judgment for decision making is of high consistency [61]. This process starts with calculating λ_{max} value using pairwise comparison data and the final scores of criteria and attributes. The consistency index (CI) is then calculated using the λ_{max}, and then this index is compared with a random index to assess the rationality of the evaluator's pairwise comparisons. The requirement states that the consistency ratio should not be more than 10% or 0.1 [63].

$$\lambda_{max} = \frac{\sum \frac{\text{weighted sum}}{\text{weighted score}}}{\text{no of factors in matrix(n)}} \tag{5}$$

$$CI = \frac{\lambda_{max} - n}{n - 1} \tag{6}$$

$$CR = \frac{CI}{IR} \tag{7}$$

where:

CI = Consistency Index
CR = Consistency Ratio
IR = Index Random Consistency
λ_{max} = Maximum eigenvalue
n = Number of elements in criteria/sub-criteria

IR values are given by Saaty [64]. When n equals 1 and 2, the reciprocal index (RI) value is 0. As n increases, RI varies with values such as 0.58 for n = 3, 0.89 for n = 4, 1.12 for n = 5, 1.24 for n = 6, 1.32 for n = 7, 1.41 for n = 8, and 1.45 for n = 9. The consistency ratio of the criteria matrix and sub-criteria matrices of pairwise comparison are all checked based on Equations (5)–(7). CR is within the range, i.e., less than 0.1.

The consistency ratio of the criteria matrix is shown in Table 17 and Equation (12). The weighted sum and eigenvalue are calculated for each criteria/sub-criteria as shown in Equations (8)–(11) [62,65]. In a similar manner, the CR of sub-criteria is calculated with local scores as their weighted scores.

$$Weighted\ Sum_{attribute} = \sum_{i=1}^{n} \left(X_{(attribute\ row,i)} \times Weighted\ score_i \right) \quad (8)$$

$$\lambda = \frac{Weighted\ sum}{Weighted\ score} \quad (9)$$

$$\begin{gathered} Weighted\ Sum_{work\ approach} \\ = (1 \times 0.21) + (1.146 \times 0.218) + (0.820 \times 0.235) + (0.517 \times 0.18) + (2.246 \times 0.157) = 1.1 \end{gathered} \quad (10)$$

$$\lambda_1 = \frac{1.1}{0.21} = 5.2 \quad (11)$$

Table 17. Consistency check for criteria using eigenvalue.

	Work Approach	Experience	Past Performance	Personal Record and Resource	Financial and Legal Status	Weighted Score	Weighted Sum	λ
Work Approach	1.000	1.146	0.820	0.517	2.246	0.21	1.1	5.2
Experience	0.873	1.000	0.882	1.647	1.566	0.218	1.2	5.3
Past Performance	1.219	1.134	1.000	1.723	1.216	0.235	1.2	5.3
Personal Record and Resource	1.933	0.607	0.581	1.000	0.739	0.18	1.0	5.4
Financial and Legal Status	0.445	0.638	0.822	1.353	1.000	0.157	0.8	5.3

From Equations (5)–(7), CR is less than 0.1.

$$\lambda_{max} = \frac{5.2 + 5.3 + 5.3 + 5.4 + 5.3}{5} = 5.288$$

$$CI = \frac{5.288 - 5}{5 - 1} = 0.072$$

$$CR = \frac{0.072}{1.12} = 0.064 < 0.1 \quad (12)$$

4.4. Substantiation Strategies

To help in the evaluation of attributes, the study also gives substantiation guidelines for the above attributes. The evaluation strategies have been identified through a survey questionnaire with seven experts. The evaluation strategies will help the decision makers assign scores to attributes easily and make the selection process more reliable and time-saving. The evaluation strategies for all 17 attributes are given in Table 18.

Table 18. Substantiation strategies.

Factors	Ways to Substantiate
Proposed maintenance approach and plans	Bid documents, code compliance, proposed methodology, technical bid evaluation.
Understanding insight of clients and project needs	Follow-up meetings, tender docs, method statement, proposed methodology
General work Experience	Project list, contractor profile, similar-cost projects, completion certificates.
Experience of similar works	Similar projects list, contractor portfolio, completion certificates for analogous projects.
Employee qualification	Employee CVs, Employee resume, contractor profile, experience certificates
Availability of technical skilled/Trained staff	Certificates, experience of staff, list of engineers, supervisors, technicians, labor
Past performance	Quality assurance reports, completion records, project inspections, prior approvals, and awards.
Performance In similar project	Quality assurance reports, completion records, project inspections, prior approvals, and awards for similar projects.
Previous Client satisfaction/Reputation earned.	Client satisfactory report, Quality assurance report, previous approvals and awards.
Safety of work/Accidents Record	Contractor HSE plan, level of safety in previous projects, accidents and nature of accident report.
Previous work Quality	Performance certificates from client, client satisfactory report, project completion report
Failed contracts	List of failed contracts with reasons, documents provided by contractor, checking blacklisting of company
Inventory in stock/Resources	Contractor profile, list of equipment and resources available.
Financial Capability/stability	Bank statement, audit reports, bank guarantee, enlistment slips with client
Proposed Price	Bid price, tender amount, financial proposal of contractor
Availability of required licenses to perform maintenance.	Copy of required licenses from registering body, work department
Litigation and claims history	Non litigation certificate

4.5. BV-Substantiated Framework

The final model represents the criteria along with attributes and their percentage weights, along with substantiation strategies, as illustrated in Figure 3. It has been observed that the criteria "Past Performance" is the most significant, holding 23.5% weight. This highlights that a maintenance contractor's previous work is a major deciding factor in the selection process, suggesting that contractors should emphasize their past project successes to stand out in competitive bids. Among its sub-criteria, performance in a similar type of project holds 6% of the weight. Limiting the past performance evaluation to maintenance projects of similar scale and complexity ensures a more relevant assessment of the contractor's capability for the current project. Refining past performance evaluation by assessing previous work quality, client satisfaction, and work safety record establishes specific sub-criteria, enhancing the assessment. Following past performance, the second most important criteria in the selection of a maintenance contractor is "Experience", which holds 21.8% of the total weightage. Experience includes general work experience, availability of technical staff, experience of similar works, and employee qualification. Among the experience sub-criteria, the availability of technical staff holds the most importance at 9%, showing that the importance of skilled technical labor and employees is the most important factor to consider for maintenance work. General experience holds 4%, similar project experience holds 6%, and employee qualification holds 7%. "Work Approach" is the third, with 21% of the total weightage. Having attributes like a proposed maintenance plan and understanding client and project needs shows how important it is to understand the work to formulate a proper execution plan.

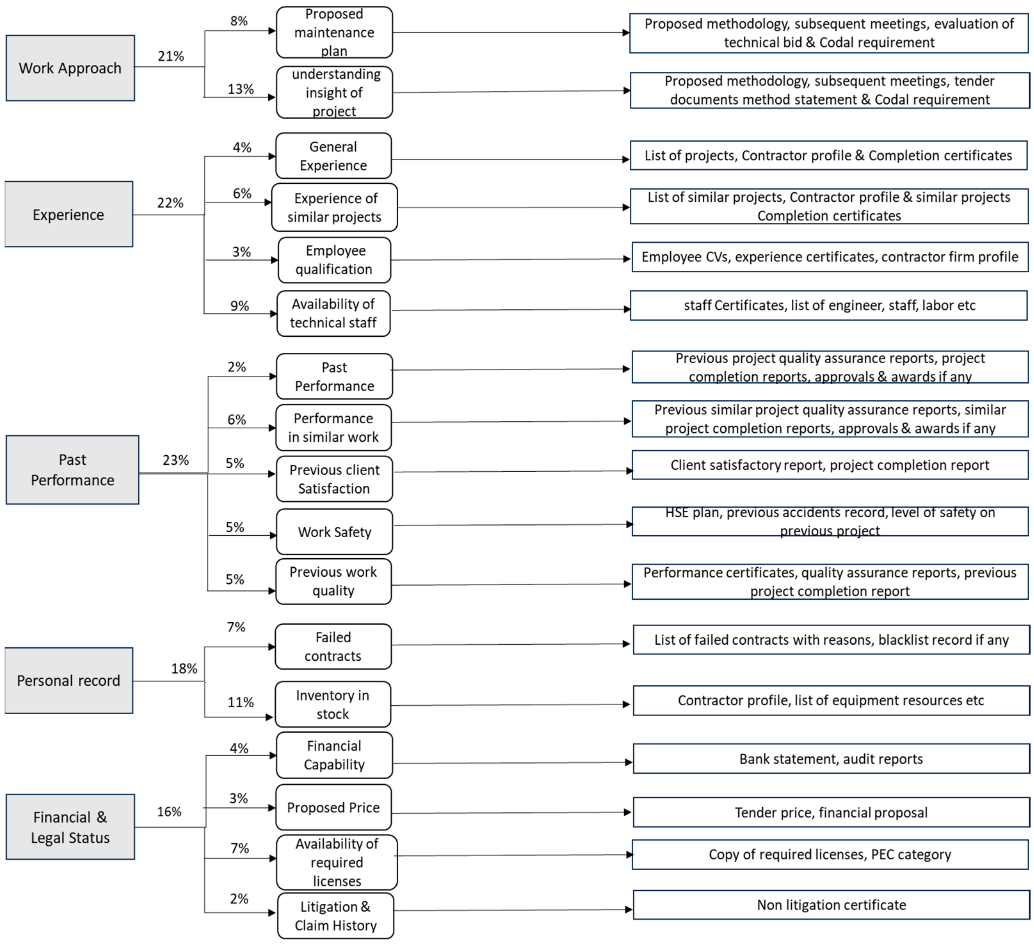

Figure 3. Best value framework.

According to the global weights of attributes shown in Figure 3, the attribute 'Understanding of Client and Project Needs' holds the highest importance at 13% of the total weightage. This shows that understanding the project requirements and client requirements is significant to proceed further accordingly. Following this, having inventory in stock for maintenance work is crucial. Having the required machinery, equipment, and supplies not only saves cost but also time. The third key attribute is the availability of technical staff, which has a global weight of 11%. It emphasizes the need for skilled personnel to carry out the work efficiently and safely. To assist in evaluating these attributes, the study provides guidelines developed through a questionnaire survey with experts. The evaluation strategies will help the decision makers assign a specific score to attributes and make the selection process more reliable and time-saving. The final framework shows the documents that will help in the substantiation of attributes in front of each attribute along with their percentages, e.g., for attribute "understanding client need", the documents required to be evaluated are "tender documents and technical proposal" along with subsequent meetings. This approach helps in assessing the contractor's grasp of project requirements. Similarly, the "experience" of a contractor can be assessed through a list of completed projects. This documented evidence helps evaluators accurately assign scores to contractors in the AHP selection model. Overall, these substantiation strategies simplify the adoption of the best value criteria model, making it more practical for selecting maintenance contractors. Figure 4 shows the global weights of attributes.

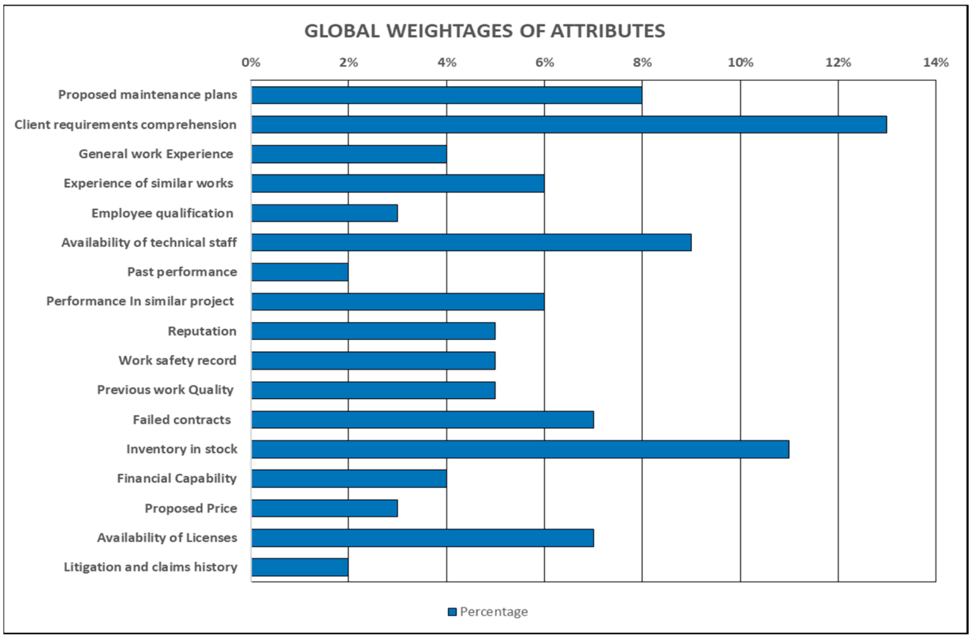

Figure 4. Global weightages.

The developed framework for maintenance contractor selection, employing the Analytic Hierarchy Process (AHP), presents a systematic decision-making approach. The identified criteria, encompassing past performance, experience, work approach, personal record, and financial/legal considerations, collectively contribute to a comprehensive evaluation process. In addition to their direct application in the selection process, this framework's findings have the potential to influence broader industry practices. By establishing benchmarks, improving risk mitigation strategies, underscoring the significance of client–contractor relationships, and promoting transparency and accountability, the framework becomes a valuable tool for organizations seeking enhanced decision making in contractor selection processes. It contributes to the ongoing discourse on effective decision making within industry.

5. Conclusions

Maintenance plays an important role in prolonging the life of buildings and their facilities. Proper maintenance not only keeps a building in good condition but also prevents major issues down the line. It acts as a preventative measure against gradual degradation that can compromise a building's functionality and safety. In extreme cases, a lack of maintenance can result in the premature failure of building components. By periodically maintaining a building, we can mitigate the risk of costly and unforeseen repairs. To ensure proper maintenance, choosing the right maintenance contractor is essential.

Therefore, this study proposed a contractor selection framework that identified the attributes required in contractor selection and assigned weights to them through the process of AHP. The proposed framework uses a best-value selection approach and considers wider criteria like experience, past work, and cost-effectiveness. This study has made the following contributions: (1) Identification of the factors influencing the selection criteria of maintenance contractors. (2) Developed a framework for employing maintenance contractors. (3) Devised strategies to aid owners in substantiating factors in the best-value process.

In conclusion, the framework presented in this study offers a comprehensive and reliable approach for selecting maintenance contractors. The application of the Analytical

Hierarchy Process (AHP) in the maintenance contractor selection process, informed by a comprehensive literature review, not only refines the understanding of best-value criteria but also provides a framework that can be adapted and extended to similar decision-making contexts. It ensures an optimal balance of cost, experience, and performance while bringing clarity into the process. The proposed framework holds practical utility for project managers, procurement professionals, and decision makers involved in maintenance contractor selection. The detailed substantiation strategies derived from expert judgments and the emphasis on past performance criteria offer tangible guidance for practitioners. This approach not only enhances the decision-making process but also ensures a more informed and strategic selection of maintenance contractors, optimizing both value and efficiency, ultimately contributing to the longevity and sustainability of building projects.

However, there are limitations to using the Analytical Hierarchy Process (AHP) for maintenance contractor selection. The study relies heavily on having access to good and reliable data, which can be challenging due to the dynamic and sometimes unpredictable nature of project-related information. Recognizing how quickly the construction industry changes with new technologies, regulations, and project needs is important. This could make the proposed framework difficult to stay relevant and effective over time. In the future, there is a need to establish a systematic process for continuous refinement of the framework. Continuously evaluating and updating the criteria and parameters of the AHP-based model will ensure its adaptability to the changing construction industry landscape. This iterative approach will ensure that the framework remains relevant and effective over time. Additionally, the framework has not been applied in any case studies in the proposed paper. This presents an opportunity for future research to explore and work on this aspect.

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