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Using the Fuzzy Analytic Hierarchy Process (FAHP) for Evaluating the Factors Affecting Building Rehabilitation Cost Management in Iraq

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ABSTRACT

This research aims to evaluate the factors affecting building rehabilitation cost management using the fuzzy analytical hierarchy process (FAHP) model. A literature review, case studies, consultations with experts, and questionnaires were used to identify and categorize fifty-seven factors into six categories. The proposed model has considered twenty factors out of the fifty-seven. The main factor with the highest weight in building rehabilitation cost management in Iraq is the building characteristics, with a weight of 0.298. Design and bill of quantities issues follow this with a weight of 0.204. The next factor is project management Issues with a weight of 0.185. Planning and contract management factors come next with a weight of 0.150. Safety and environmental factors have a weight of 0.104. The element with the lowest weight is economic and financial factors, with a weight of 0.058. This order of elements highlights their importance in affecting cost management.
The prioritization within each category is outlined with due consideration to the weights assigned to the main factors. The significance of required quality standards and site visit to the building under the design and bill of quantities, while planning and contract management prioritize project duration and general and specific contract conditions. Building characteristics prioritize the number of floors in the building and its location, economic and financial factors emphasize fluctuations in currency exchange rates and labor costs, and safety and environmental concerns are anchored by health, safety, awareness and training. Project management emphasizes change orders and a lack of coordination among team.

Keywords: Building rehabilitation, Cost management, Fuzzy analytical hierarchy process, Building characteristics, Project management.

1. INTRODUCTION

Buildings begin to deteriorate gradually over time due to several factors, including environmental influences, improper use of the building, and neglected repairs for damages

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during the building's life span **(Harris, 2001; Kadhim, 2023)**. Building rehabilitation is necessary to maintain the building in a satisfactory condition for its occupants through its operational phase **(Kim et al., 2016)**. Cost management for building rehabilitation is a complicated task, especially when considering Iraq's particular infrastructure and economic difficulties. This study aims to investigate how to evaluate factors that affect building rehabilitation cost management using Fuzzy Analytic Hierarchy Process (FAHP).

FAHP combines fuzzy sets proposed by **(Zadeh, 1965)** with the Analytic Hierarchy Process (AHP) method established by **(Saaty, 1980)**. This integrated approach retains the advantages of AHP and is widely used **(Mardani et al., 2015)**. FAHP was introduced by **(Van Laarhoven and Pedrycz, 1983)** and has been extensively applied to multi-criteria decision-making (MCDM) problems in various fields, e.g., evaluation of urban planning projects **(Kamas et al., 2017),** airport operation situation risk assessment **(Zhang et al., 2019)**, project prioritization and selection **(Shaygan and Testik, 2019)**, decision-making with subjective judgments **(Liu et al., 2020)**, risk assessment **(Lyu et al., 2020)**, information price measurement of commercial concrete **(He et al., 2022)**, prioritization of flexible pavement sections **(Kumar and Suman, 2022)**, supply chain capabilities **(Mistarihi and Magableh, 2023)**, evaluation of slab track quality indices **(Ren et al., 2023)**, public procurement crisis **(Hasan et al., 2024).**

Cost management epitomizes an essential part of management in building rehabilitation projects **(Koroteev et al., 2020; Vigneault et al., 2020)**. Building rehabilitation cost management in Iraq involves coordinated activities to direct and control the financial resources concerning rehabilitation projects. Potential cost reductions, concerns about rising rehabilitation costs, and government efficiency requirements primarily drive the improvement in cost management. However, before considering different contributing factors, it is necessary to analyze, at the national level, the feasibility of the improvement efforts for various sectors of the construction industry. This is especially important for developing countries like Iraq, where, due to the lack of financial resources, it is necessary to channel the available resources into the most promising areas **(Al-Shiblawi and Erzaij, 2017; Jovanović et al., 2015)**.

The FAHP method is used to determine weightings for the evaluation criteria among decision makers **(Khashei-Siuki and Sharifan, 2020)**. FAHP has been applied in various fields. For instance, it has been used to investigate and prioritize the failures of knowledge-based business plans. This research developed a FAHP to prioritize the most important reasons for the failure of knowledge-based business plans. The results of this study assist managers, researchers, and investors in determining the sources of failures in knowledge-based business plans **(Khorramrouz et al., 2019)**. **(Golestani et al., 2022)** focused on the benefits that have to be considered within FAHP. They used FAHP benefits in risk assessment of aseismic capacity. **(Goyal et al., 2021)** used the FAHP for evaluating ranking of failure rates of a complex structure. There have also been comparative sensitivity analyses of some FAHP methods. The literature review covers major studies related to the development of the methods of FAHP and their application in various fields **(Vinogradova-Zinkevič, 2023)**.

The objectives of this research include identifying and categorizing the critical factors influencing cost management in building rehabilitation projects in Iraq, FAHP methodology is applied to prioritize these factors by calculating their weights using a fuzzy pairwise matrix comparison. The methodology employed in this study comprised a general survey involving literature review, case studies, group brainstorming, expert interviews, and questionnaires to identify 57 factors affecting cost management, which were then categorized into six groups. The FAHP method was subsequently used to evaluate and rank the factors based on their relative importance. The findings of this research highlighted significant factors impacting building rehabilitation cost management in Iraq, such as design and bill of quantities, planning and contract management, building characteristics, economic and financial aspects, safety and environmental considerations, and project management. Through the FAHP analysis, factors with high relative importance were identified and weighted, providing insights into key areas for improving cost management practices in building rehabilitation projects.

2. RESEARCH METHODOLOGY

This research contains two parts: a general survey and the FAHP method. The first part of the research depended on a review of the literature, nine case studies, group brainstorming, expert interviews, and questionnaires. 57 factors affecting cost management were identified. The identified factors were categorized into six groups: design and bill of quantities, planning and contract management, building characteristics, economic and financial, safety and environment, and project management. A total of sixty-three questionnaire forms were returned out of seventy questionnaire forms. The 5-point Likert scale was adopted, where 1 was "not important," 2 was “slightly important," 3 was “moderately important,” 4 was "important," and 5 was “very important," to capture the importance of the factors affecting building rehabilitation cost management in Iraq **(Erzaij and Obaid, 2017; Joshi et al., 2015)**. The scores were then transformed into important indices to determine the relative ranking of the affecting factors **(Chan and Kumaraswamy, 1997; Kometa et al., 1994)**. Factors with high relative importance, from 0.80 to 1, were selected to conduct the second part of this research to evaluate the factors and calculate their weights by using the FAHP method. **Fig. 1** shows the research methodology for this study.

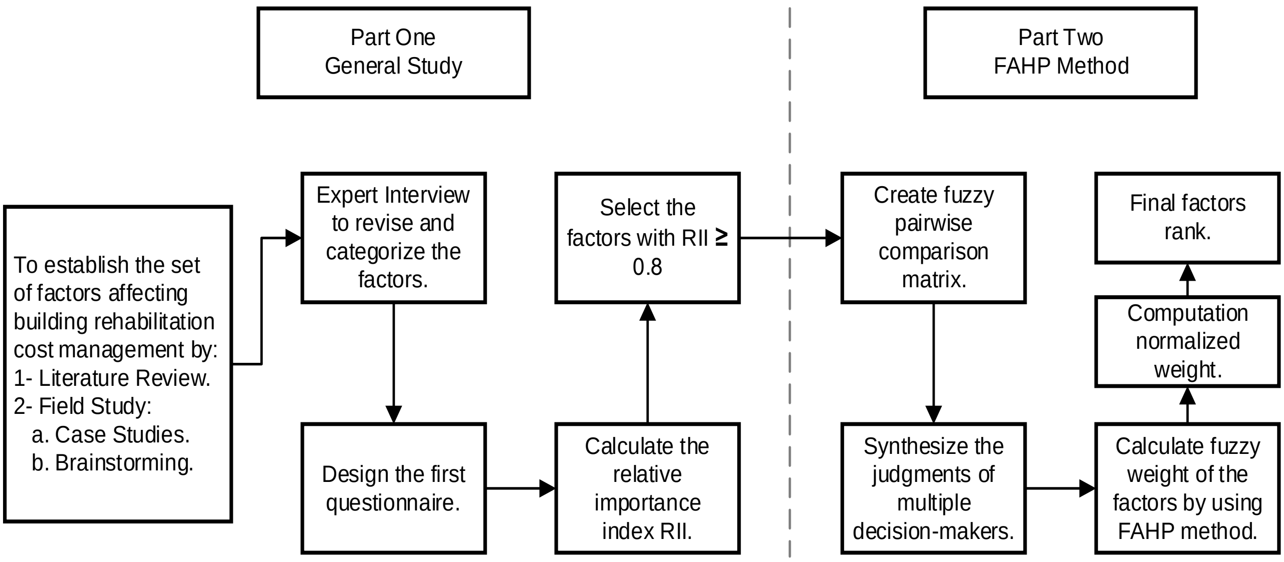

Figure 1. Research methodology for this study

3. FILED WORK

The field work includes:

a) A comprehensive review of both local and international research literature about cost management for building rehabilitation projects was conducted to provide an in-depth understanding of the research topic.

b) Nine case studies were carried out on already completed buildings, including seven from the University of Baghdad, one from the Iraqi Ministry of Education, and another from the private sector. The selection of these specific case studies is intentional, allowing for a focused examination of various cost management strategies, challenges, and outcomes in building rehabilitation projects in Iraq. This study addresses cost management issues related to these projects, including the estimated cost, contractual cost, number of change orders, number of contract amendments, total amount of additional work, total amount of canceled work, final cost, expected duration, contractual duration, actual duration, and completion percentage. These aspects were discussed in brainstorming sessions to identify the factors that influenced cost management.

c) Utilizing the brainstorming technique, two sessions were held in one place with the engineering staff involved in the building projects used as case studies. During these sessions, 65 factors influencing these projects were identified.

d) Interviews were held with construction sector experts with over 20 years of experience in building rehabilitation. As a result of these interviews, some factors were consolidated, removed, or added, resulting in a total of 57 factors, which were then categorized into six groups.

e) A questionnaire was developed based on a five-point Likert scale and divided into three sections. The aim was to ascertain the impact of each factor on the various project phases (initiation and planning; executing, monitoring, and controlling; commissioning, handing over, and closing). This questionnaire was then distributed to engineers in both the public and private sectors. Out of the 70 questionnaires distributed, 63 valid responses were received.

f) The questionnaire responses were analyzed using the statistical software SPSS V26 to determine the relative importance of each factor. The validity and reliability of the questionnaire results were tested and found to be greater than 95%.

g) The relative importance of each factor in each section for the various phases of the project was extracted, then the average importance was taken for the three sections, and the factors with greater than 80% importance were taken to conduct the hierarchical analysis process. **Table 1** shows the twenty factors with relative importance equal to or greater than 80% extracted after the questionnaire analysis process.

Table 1. Factors Affecting Building Rehabilitation Cost Management.

No.	Affecting Factor	Total Mean	RII 1	RII 2	RII 3	RII Mean	Rank
A.	Factors related to Design and Bill of Quantities						
1.	Site visit to the building before the design process and preparation of the bill of quantity.	4.20	0.870	0.838	0.810	0.839	2
2.	Lack/Errors in technical specifications.	4.14	0.794	0.867	0.822	0.828	4
3.	Lack/Errors in architectural, structural, and MEP design.	4.14	0.844	0.848	0.790	0.827	5
4.	The discrepancy between the bill of quantities and technical specifications.	4.11	0.873	0.838	0.756	0.822	6

5.	Availability of materials in the local market.	4.17	0.883	0.829	0.790	0.834	3
6.	Required quality standards.	4.24	0.889	0.867	0.790	0.849	1
B.	Factors Related to Planning and Contract Management						
1.	Project duration.	4.08	0.838	0.851	0.762	0.817	1
2.	Allowed time for bill of quantity preparation.	4.05	0.829	0.841	0.762	0.811	2
3.	General and specific contract conditions.	4.04	0.841	0.832	0.749	0.807	3
C.	Factors related to the building						
1.	Number of floors in the building.	4.28	0.892	0.902	0.771	0.855	1
2.	Building area.	4.17	0.876	0.876	0.752	0.835	4
3.	Building condition.	4.25	0.889	0.898	0.762	0.850	3
4.	Building or project location.	4.27	0.892	0.898	0.771	0.854	2
D.	Factors related to Economic and Financial						
1.	Fluctuations in currency exchange rates.	4.36	0.911	0.898	0.803	0.871	1
2.	Labor costs.	4.33	0.892	0.902	0.806	0.867	2
E.	Factors related to Safety and Environment						
1.	Health and safety requirements.	4.12	0.800	0.892	0.778	0.823	1
2.	Awareness and training.	4.02	0.813	0.854	0.746	0.804	2
F.	Factors related to Project Management						
1.	Change orders.	4.04	0.673	0.905	0.844	0.807	3
2.	Lack of coordination among team members.	4.09	0.854	0.879	0.721	0.818	1
3.	Project team size.	4.08	0.879	0.886	0.679	0.815	2

4. FAHP METHOD

In FAHP, the linguistic variables have been used for pair-wise comparisons of the main factors and the sub-factors. Buckley's method **(Buckley, 1985; Dağdeviren and Yüksel, 2008; Gul et al., 2018)** is adopted to determine the relative importance of the main factors and the sub-factors. The procedure steps are as follows:

Step 1: The fuzzy pairwise comparison matrix $\tilde{D} = [\widetilde{a_{ij}}]$ is constructed as

$$\tilde{D} = \begin{bmatrix} (1,1,1) & \widetilde{a_{12}} & \cdots & \widetilde{a_{1n}} \\ \widetilde{a_{21}} & (1,1,1) & \cdots & \widetilde{a_{2n}} \\ \vdots & \vdots & \ddots & \vdots \\ \widetilde{a_{n1}} & \widetilde{a_{n2}} & \cdots & (1,1,1) \end{bmatrix} \quad (1)$$

where $\widetilde{a_{ij}} \times \widetilde{a_{ji}} \approx 1$ and $\widetilde{a_{ij}} \cong wi / wj , i, j = 1,2,\ldots,n$.

Step 2: The fuzzy geometric mean value $\widetilde{r_i}$, for each criterion *i* is computed as

$$\widetilde{r_i} = \left(\widetilde{a_{ij}} \text{ x } \widetilde{a_{ji}} \text{x} \cdots \text{ x } \widetilde{a_{ji}}\right)^{1/n} \quad (2)$$

Step 3: The fuzzy weight $\widetilde{w_i}$ for each criterion *i* is calculated as

$$\widetilde{w_i} = \widetilde{r_i}\, x\, (\widetilde{r_1} + \widetilde{r_2} + \cdots \text{ x } \widetilde{r_n})^{-1} \quad (3)$$

$where\ \widetilde{r_k} = (l_k , m_k , u_k) and\ (\widetilde{r_k})^{-1} = (1/u_k , 1/m_k , 1/l_k)$.

Step 4: The fuzzy weights $\widetilde{w_i} = (l_i, m_i, u_i)$ are defuzzified by any defuzzification method; here we use the CoA method as follows:

$$\widetilde{w_i} = \frac{l_i, m_i, u_i}{3} \quad (4)$$

Step 5: Computation normalized weight

$$N_i = \frac{\widetilde{w_i}}{\sum_{i=1}^{n} \widetilde{w_i}} \quad (5)$$

5. FAHP MODEL FOR THIS STUDY

Questionnaires were distributed to eleven experts with experience in buildings rehabilitation projects in various fields. The specifications of the targeted sample are shown below.

a) The analysis of the affiliation classification showed that the sample included 37% from the University of Baghdad, 18% from the Ministry of Education, 27% from the Ministry of Construction, Housing, Municipalities, and Public Works, and 18% from a non-government, as shown in **Fig. 2**.

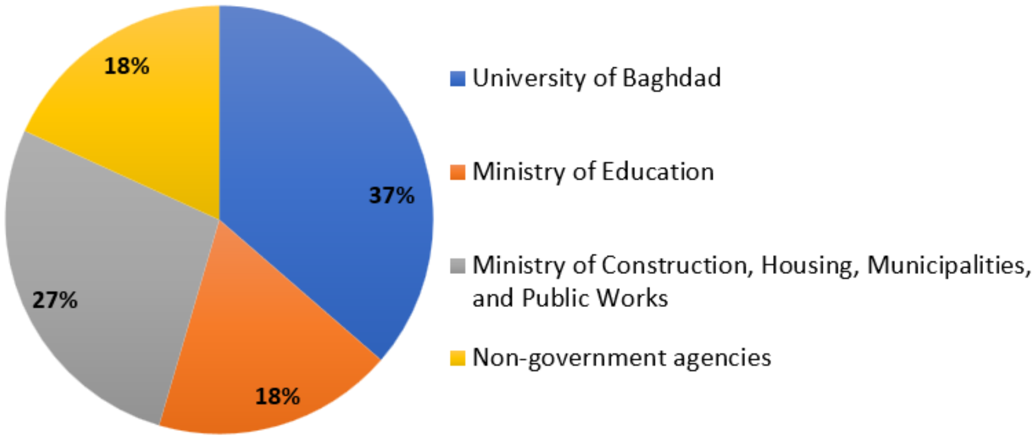

Figure 2. Classification of the affiliation.

b) The analysis of academic qualification showed that the sample is divided into 57% having a bachelor's degree, 27% having a master's degree, and 16% having a doctorate, as shown in **Fig. 3**.

c) The analysis of the respondents' specialty showed that the sample included 55% of a civil engineer, 18% of an architect engineer, 18% of an electrical engineer, and 9% of a mechanical engineer, as shown in **Fig. 4**.

d) The analysis of years of experience in building rehabilitation projects showed that the sample included 18% of a 16- 20 years category, 18% of a 21- 25 years category, 27% of a 26- 30 years category, and 37% of a more than 30 years category as shown in **Fig. 5**.

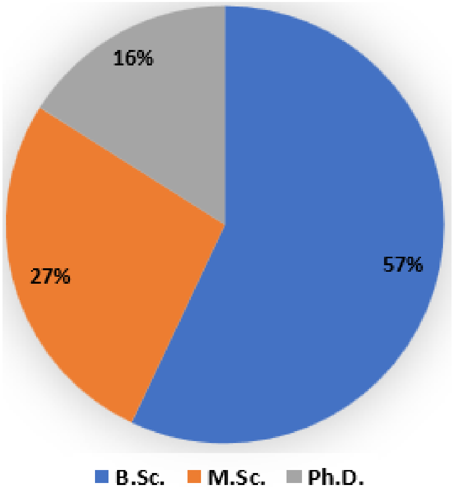

Figure 3. Qualification level

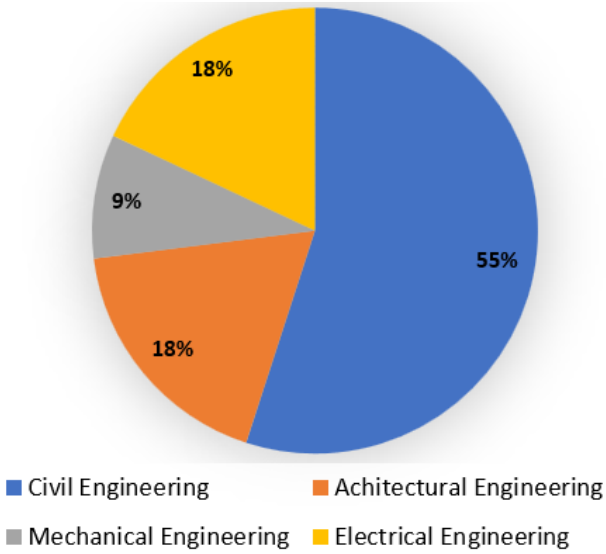

Figure 4. Specialty

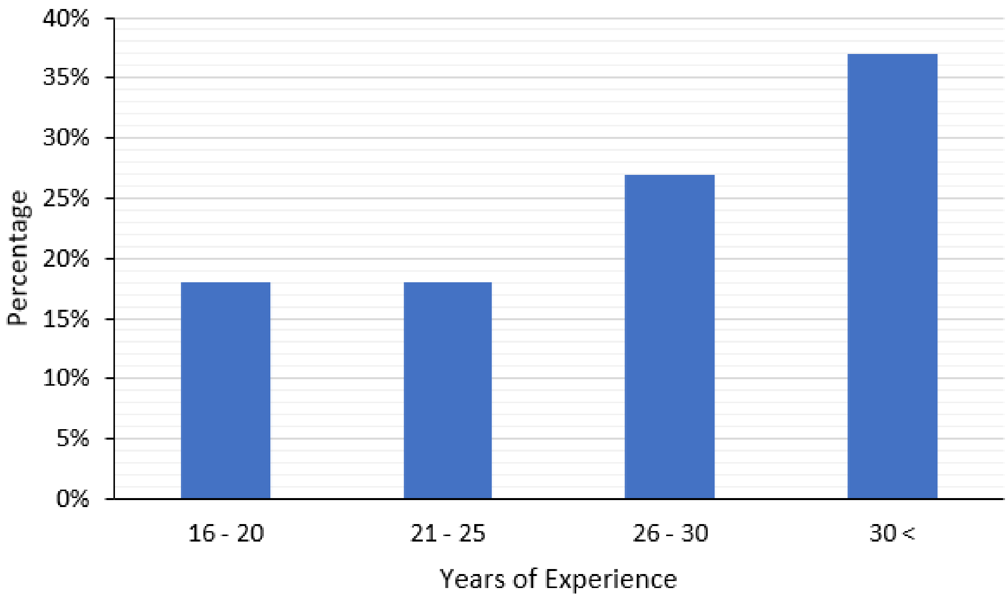

Figure 5. Experience in buildings rehabilitation projects.

The FAHP model for this study has three levels, as shown in **Fig. 6**. The first level represents the goal of the model, which is (factors affecting the cost management), The second level covers the six main factors, and the third level consists of 20 subfactors. During the questionnaire matrix design, the relative weights of levels 2 and 3 are compared in a fuzzy pairwise comparison matrix on a 1–9 fuzzy scale **(Cheng and Mon, 1994)**. **Table 2** shows the 1–9 pair-wise analysis fuzzy scale.

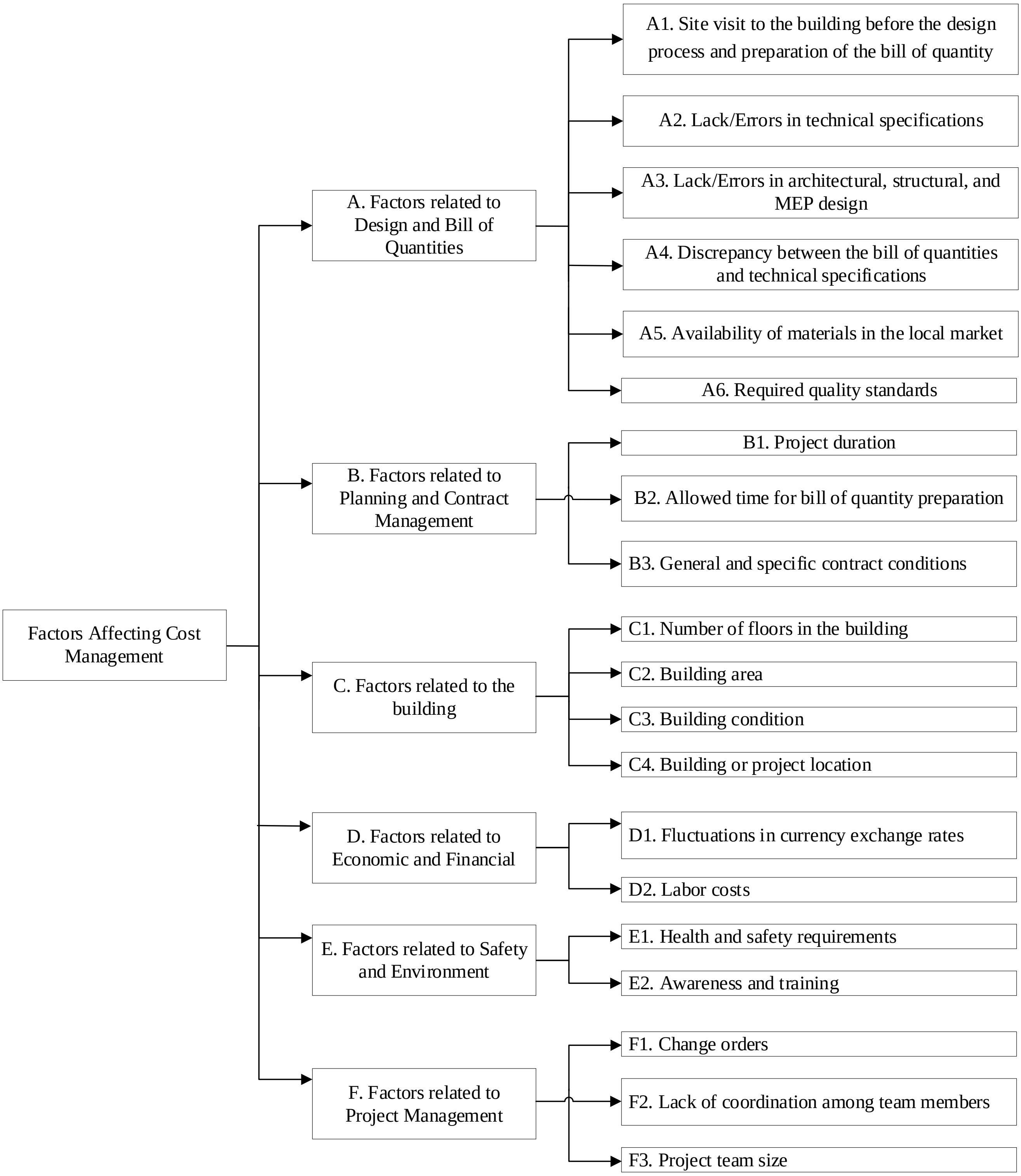

Figure 6. The three levels of the factors.

Table 2. Linguistic Variables for Pairwise Comparison of Each Factor **(Abdullah and Najib, 2014; Kannan et al., 2013).**

Linguistic Variables	Triangular Fuzzy Scale	Triangular Fuzzy Reciprocal Scale
Equally strong	(1, 1, 1)	(1, 1, 1)
Moderately strong	(2, 3, 4)	(1/4, 1/3, 1/2)
Strong	(4, 5, 6)	(1/6, 1/5, 1/4)
Very strong	(6, 7, 8)	(1/8, 1/7, 1/6)
Extremely strong	(9, 9, 9)	(1/9, 1/9, 1/9)
Intermediate values	(1, 2, 3)	(1/3, 1/2, 1)
	(3, 4, 5)	(1/5, 1/4, 1/3)
	(5, 6, 7)	(1/7, 1/6, 1/5)
	(7, 8, 9)	(1/9, 1/8, 1/7)

6. FAHP RESULTS AND DISCUSSION

6.1 Main Factors

In this section, a practical example of the FAHP calculation process is presented. **Table 3** shows the pairwise comparisons specified by eleven experts for six main factors. Each expert was requested to respond in linguistic terms (see **Table 2**) by comparing each factor against other factors for its importance in effecting building rehabilitation cost management. The linguistic terms were converted into an appropriate fuzzy scale and then geometric mean values of eleven responses were used to develop **Table 3**. **Table 4** exhibits the fuzzy geometric mean value and the fuzzy weight for each main factor.

Table 3. Pairwise Comparison and Reciprocal Matrices for the Evaluation of Main Factors.

Main Factor	DBQ			PCM			BC			EF			SE			PM		
DBQ	1	1	1	2	3	4	1/3	1/2	1	2	3	4	1	2	3	1	1	1
PCM	1/4	1/3	1/2	1	1	1	1/3	1/2	1	3	4	5	1	2	3	1	1	1
BC	1	2	3	1	2	3	1	1	1	3	4	5	2	3	4	1	2	3
EF	1/4	1/3	1/2	1/5	1/4	1/3	1/5	1/4	1/3	1	1	1	1/3	1/2	1	1/4	1/3	1/2
SE	1/3	1/2	1	1/3	1/2	1	1/4	1/3	1/2	1	2	3	1	1	1	1/3	1/2	1
PM	1	1	1	1	1	3	1/3	1/2	1	2	3	4	1	2	3	1	1	1

Table 4. Fuzzy Weight

Main Factor	Fuzzy geometric mean value			Fuzzy Weight		
DBQ	1.05	1.44	1.91	0.109	0.210	0.390
PCM	0.79	1 .05	1.40	0.083	0.152	0.286
BC	1.35	2.14	2.85	0.140	0.311	0.584
EF	0.31	0.39	0.55	0.032	0.057	0.113
SE	0.46	0.66	1.07	0.048	0.096	0.219
PM	0.93	1.20	1.82	0.097	0.174	0.372

Table 5 shows the de-fuzzified weights and normalized weights after completing the FAHP analysis for the main factors.

Table 5. De-fuzzified and normalized weights for the main factors.

No.	Main Factor	De-fuzzified weights	Normalized Weights
A.	Design and Bill of Quantities	0.236	0.204
B.	Planning and Contract Management	0.174	0.150
C.	Building Characteristics	0.345	0.298
D.	Economic and Financial	0.067	0.058
E.	Safety and Environment	0.121	0.104
F.	Project Management	0.214	0.185

There are significant variances in the factors affecting the cost management of building rehabilitation projects when weights are compared. The factors associated with building characteristics, weighting 0.298, are at the top of the list, signifying their precedence in cost management decisions. This predominance can be attributed to the inherent complexities and unique aspects of each building, such as age, structural condition, and historical value. These characteristics often necessitate specialized techniques and materials, thereby driving up costs. Understanding the specific attributes of buildings allows for more accurate cost estimations and tailored rehabilitation strategies, ultimately leading to more effective cost management.

Other factors include design and bill of quantities issues with a weight of 0.204, emphasizing the need for careful planning and precise quantity takeoff. Design complexities, inaccuracies in quantity estimates, and changes during construction can lead to significant cost overruns. Managing these issues through a comprehensive design review and accurate quantity surveying can reduce risks and ensure budget compliance. The emphasis on this factor indicates that investments in the early stages of project planning can deliver substantial cost savings.

Project management issues carry a weight of 0.185, indicating their substantial impact on project outcomes. This underscores the significance of leadership, project management experience, and mature practices in cost control. Ineffective project management can result in time lags, expense escalations, and the waste of resources. Additionally, planning and contract management elements have a significance of approximately 0.150. This weight means that it is crucial to plan well, and have those expectations managed very clearly in the form of a watertight contract. Good upstream planning means that all of the different pieces of a project come together nicely, and strong contract management can give some legal framework to enforce accountability as well as at least minimum performance standards. These practices can also help eliminate uncertainties and ultimately lead to better project management. While safety and environmental factors contribute about 0.104 points towards proper prioritization, suggesting room for improvement, these factors are integral to sustainable construction practices. Improving safety protocols and environmental protections can prevent costly accidents and fines, as well as promote a positive project reputation. Lastly, economic and financial issues account for about 0.058, but their influence should not be overlooked given their weight. These weights are crucial in identifying which factor has the most impact on building rehabilitation cost management.

6.2 Factors Related to Design and Bill of Quantities

In this category, several sub-factors are highlighted as crucial. One of the key steps is conducting a comprehensive on-site visit before design and proper preparation of bills of quantities (weight: 0.263) to avoid expensive revisions and delays. Moreover, inadequate technical documentation (weight: 0.100) can result in misunderstandings, rework, and eventually cost overruns during construction, underscoring the importance of precise specifications. Additionally, errors in design elements (weight: 0.199) can affect project timelines and budgets, necessitating strong quality assurance measures. Furthermore, discrepancies between the bill of quantities and technical specifications (weight: 0.091) could create ambiguities and extra costs during procurement and construction, thereby emphasizing the need for consistency and accuracy. Material availability (weight: 0.060) directly influences procurement lead times and costs, necessitating proactive sourcing strategies to mitigate potential supply chain disruptions and ensure materials are available when needed according to schedule. Lastly, adherence to quality standards (Weight: 0.286) is vital for the long-term serviceability of projects, with violations resulting in rework or delays in previously set completion dates due to failure to meet established standards. Prioritizing quality assurance measures allows for effective cost management while maintaining project quality standards. **Table 6** displays the weights for the factors related to design and bill of quantities.

Table 6. Weights results for the factors related to design and bill of quantities.

No.	Factor	Normalized Weight
1.	Site visit to the building before the design process and preparation of the bill of quantity.	0.263
2.	Lack/Errors in technical specifications.	0.100
3.	Lack/Errors in architectural, structural, and MEP design.	0.199
4.	Discrepancy between the bill of quantities and technical specifications.	0.091
5.	Availability of materials in the local market.	0.060
6.	Required quality standards.	0.286

6.3 Factors Related to Planning and Contract Management

Based on **Table 7**, it's evident that the duration of the project (0.607) significantly influences resource allocation and the project's total cost. Adequate time for the preparation of the bill of quantities (0.121) ensures accurate cost estimation and risk mitigation. Concurrently, well-defined contract conditions (0.273) aid in reducing conflicts and enhancing cost certainty. Considering these factors allows all involved parties to optimize cost management strategies, leading to successful projects within budget constraints.

Table 7. Weights results for the factors related to Planning and Contract Management.

No.	Factor	Normalized Weight
1.	Project duration.	0.607
2.	Allowed time for bill of quantity preparation.	0.121
3.	General and specific contract conditions.	0.273

6.4 Factors Related to The Building Characteristics

From **Table 8**, it's clear that the number of floors in a building (weight: 0.508) significantly correlates with the complexity of the project and the usage of materials. Multi-story structures are often more costly to build due to these factors. Likewise, other variables such as the area of the building (weight: 0.140), the condition of the building (weight: 0.140), and the location of the building or project (weight: 0.211) determine the distribution of resources, the intensity of labor, and compliance with regulations, all of which similarly impact the overall cost of the project. Therefore, considering these elements is essential for stakeholders when developing effective rehabilitation plans. This allows for the maximization of efforts within the available resources while minimizing cost uncertainty, leading to the successful implementation of building rehabilitation initiatives. These initiatives contribute positively to improving the energy efficiency of aging building stocks and extending their operational lifespan, thus enhancing the inhabitants' habitability levels.

Table 8. Weights results for the factors related to building characteristics.

No.	Factor	Normalized Weight
1.	Number of floors in the building.	0.508
2.	Building area.	0.140
3.	Building condition.	0.140
4.	Building or project location.	0.211

A. Factors Related to Economic and Financial

Based on the data in **Table 9**, it's evident that currency and exchange rate fluctuations significantly impact project costs as they affect the price of imported materials and equipment, with a weight of 0.742. Concurrently, labor costs, which are a substantial part of project expenditures, account for 0.258 percent and are influenced by factors such as wage levels and labor market trends. Among the crucial measures, it's essential to have strategies for managing currency risks and optimizing manpower. These strategies are necessary for counteracting the adverse effects of economic factors on project finances and ensuring cost-effective results in rehabilitation.

Table 9. Weights results for the factors related to economic and financial.

No.	Factor	Normalized Weight
1.	Fluctuations in currency exchange rates.	0.742
2.	Labor costs.	0.258

B. Factors Related to Safety and Environment

Table 10 depicts the weight of 0.644 assigned to health and safety requirements and 0.356 to the factor of awareness and training. It's vital to take these two factors into account during the planning and execution stages of a project to prevent incidents and optimize cost-effectiveness in building rehabilitation projects.

Table 10. Weights results for the factors related to safety and environment.

No.	Factor	Normalized Weight
1.	Health and safety requirements.	0.644
2.	Awareness and training.	0.356

C. Factors Related to Project Management

Table 11 indicates that the factor of change orders carries a weight of 0.580, making it the most influential factor in this category. The factor of lack of coordination among team members weighs 0.251, and the project team size is weighted at 0.169. This underscores the importance of effective change order management in controlling costs.

Table 11. Weights results for the factors related to project management.

No.	Factor	Normalized Weight
1.	Change orders.	0.580
2.	Lack of coordination among team members.	0.251
3.	Project team size.	0.169

Table 12 depicts the final weight allocated to each factor and its corresponding rank. When the weight of the factor is multiplied by the weight of the main factor, it becomes clear that the factor of the number of floors in the building takes precedence, with a weight of 0.152. This is followed by the factor of change orders, which carries a weight of 0.107, and then other factors.

Table 12. Weights results for the factors related to project management.

Main Factor	Main Factor Weight	Sub-Factor	Sub-Factor Initial Weight	Sub-Factor Final Weight	Rank
A. Design and Bill of Quantities	0.204	A1	0.263	0.054	2
		A2	0.100	0.020	4
		A3	0.199	0.041	3
		A4	0.091	0.019	5
		A5	0.060	0.012	6
		A6	0.286	0.058	1
B. Planning and Contract Management	0.150	B1	0.607	0.091	1
		B2	0.121	0.018	3
		B3	0.273	0.041	2
C. Building Characteristics	0.298	C1	0.508	0.152	1
		C2	0.140	0.042	3
		C3	0.140	0.042	3
		C4	0.211	0.063	2
D. Economic and Financial	0.058	D1	0.742	0.043	1
		D2	0.258	0.015	2
E. Safety and Environment	0.104	E1	0.644	0.067	1
		E2	0.356	0.037	2
F. Project Management	0.185	F1	0.580	0.107	1
		F2	0.251	0.047	2
		F3	0.169	0.031	3

7. CONCLUSIONS

The research conclusion concerning the building rehabilitation cost management in Iraq using the FAHP technique exemplifies the factors, which are building characteristics, design and bill of quantities matters, project management, planning and contract management, the economic and financial factor, and safety and environment, have a direct influence on the cost management of building rehabilitation projects. The stakeholder can make rational decisions on how to address and accord priority to these factors, as revealed through the FAHP analysis, to improve the efficiency and effectiveness of the building rehabilitation cost management practices in Iraq. The research issues will secure leads into future actions and knowledge used to remedy ailing projects. It will result in several beneficial practices that guarantee the successful delivery of building rehabilitation projects in the region.

Following the FAHP analysis, several and outstanding factors have been introduced as well as the ones mentioned above must be considered when dealing with the costs and costs management of rehabilitation of build projects given the issues specific to Iraq's infrastructure and economic setting. Therefore, due to its in-depth and multifaceted basis, encompassing literature reviews, case studies, expert questioning, and a survey response check, the study ensured the field's comprehensive overview.

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Credit Authorship Contribution Statement

Ayad Abbas Obaid Al-Shiblawi undertook this research as part of his Ph.D. study at the College of Engineering/ University of Baghdad. This included the factors affecting building rehabilitation cost management. He also prepared the bulk of the manuscript .
Hatem Khaleefah Breesam contributed to the development, revision, and refinement of the manuscript.

Declaration of Competing Interest

The authors declare that they have no known competing financial interests or personal relationships that could have appeared to influence the work reported in this paper.

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استخدام عملية التحليل الهرمي الغامض (FAHP) لتقييم العوامل المؤثرة على إدارة تكاليف إعادة تأهيل المباني في العراق

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الخلاصة

يهدف هذا البحث إلى تقييم العوامل المؤثرة على إدارة تكاليف إعادة تأهيل المباني باستخدام نموذج عملية التحليل الهرمي الضبابي (FAHP). تم استخدام مراجعة الأدبيات، حالات دراسية، المشاورات مع الخبراء، استبيانات لتحديد وتصنيف سبعة وخمسين عاملاً إلى ست فئات. وقد أخذ النموذج المقترح في الاعتبار عشرين عاملاً من السبعة وخمسين عاملاً. العامل الرئيسي ذو الوزن الأعلى في إدارة تكاليف إعادة تأهيل المباني في العراق هو خصائص المبنى بوزن 0.298. تليها قضايا التصميم وجداول الكميات ذلك بوزن 0.204. العامل التالي هو قضايا إدارة المشروع بوزن 0.185. تأتي بعد ذلك عوامل التخطيط وإدارة العقود بعد ذلك بوزن 0.150. عوامل السلامة والبيئة لها وزن 0.104. أما العنصر الأقل وزنا فهو العوامل الاقتصادية والمالية بوزن 0.058. يسلط ترتيب العناصر هذا الضوء على أهميتها في التأثير على إدارة التكاليف. يتم تحديد الأولويات ضمن كل فئة مع مراعاة الأوزان المخصصة للعوامل الرئيسية. تبرز أهمية معايير الجودة المطلوبة وزيارة الموقع للمبنى تحت التصميم وجداول الكميات، في حين أن التخطيط وإدارة العقود تعطي الأولوية لمدة المشروع وشروط العقد العامة والخاصة. تعطي خصائص المبنى الأولوية لعدد الطوابق في المبنى وموقعه، وتؤكد العوامل الاقتصادية والمالية على التقلبات في أسعار صرف العملات وتكاليف العمالة، وترتكز المخاوف المتعلقة بالسلامة والبيئة على الصحة والسلامة والتوعية والتدريب. تؤكد إدارة المشروع على أوامر التغيير ونقص التنسيق بين الفريق.

الكلمات المفتاحية: إعادة تأهيل المباني، إدارة التكاليف، عملية التسلسل الهرمي التحليلي الغامض، خصائص البناء، إدارة المشاريع.