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Determining the Essential Criteria for Choosing Appropriate Methods for Maintenance and Repair of Iraqi Healthcare Building Facilities

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Abstract: Today, building maintenance and repair (M&R) is a neglected aspect of the construction business throughout a building's entire life cycle. Selecting appropriate M&R strategies is crucial, particularly for emerging economies like Iraq with severely constrained resources. This study seeks to identify the primary selection criteria for M&R methods of healthcare building facilities (HBFs) in Iraq. A comprehensive desktop literature analysis was undertaken to extract and determine the essential selection criteria for the most suited M&R approaches to buildings in general. Then, two rounds of the Delphi survey were conducted to consolidate the specific selection criteria to suit the circumstances of Iraq and HBFs. A total of 21 sub-criteria were identified and divided into six main groups. The main criteria and the associated sub-criteria were then analyzed and ranked using the fuzzy analytic hierarchy process (FAHP) technique. The ranking of the various main criteria revealed that the "cost" criterion was ranked first in terms of importance, followed by the "human resources" and "quality" criteria. The fourth, fifth, and sixth main criteria are "reliability/flexibility", "safety/risk/environment", and "facilities/technology", respectively. The overall ranking of the sub-criteria placed "optimization and cost reduction" in the first position and "extending the life of the equipment and preserving their initial quality" in the bottom place. It is anticipated that the key findings and effective recommendations of this study will considerably contribute to the improvement of building maintenance and repair management practices in developing nations while enhancing different stakeholders' understanding of the most important selection criteria for M&R methods, particularly with regard to healthcare building facilities in Iraq.

Keywords: selection criteria; maintenance; repair; healthcare building; Delphi survey; fuzzy analytical hierarchy process (FAHP)

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1. Introduction

In the 21st century, sustainable global development requires structural engineers to design durable infrastructures, long-lasting and efficient. This means focusing on creating structures that are resistant to wear and tear, easy to maintain, and capable of withstanding extreme weather conditions. To achieve this, businesses must transition from traditional to electronic maintenance procedures that use advanced technologies such as the Internet of Things (IoT) to monitor and diagnose equipment problems in real time. By adopting new technologies and sustainable development practices, we can create an infrastructure that is efficient, reliable, and eco-friendly, meeting the demands of today's competitive global marketplaces [1].

Maintenance is essential for the safe and efficient operation of healthcare building facilities in Iraq. It helps to proactively identify and address potential issues, extend the lifespan of facilities, and ensure compliance with regulatory and safety requirements. On the other hand, maintenance and repair (M&R) encompass a vast array of operations and are among the numerous construction processes with their unique tasks [2]. Controlling the first phases of demolition and preventing the failure of building components requires M&R techniques. Choosing appropriate solutions will allow for more efficient budget allocation and limit building performance degradation over time. The comparison of maintenance plans depends heavily on performance, minimum quality, service life, and the frequency of maintenance activities [3].

During the life cycle of the building, including planning, design, calculation, execution, and operation, the owners or users of the building must also consider optimal building maintenance; meanwhile, effective building use extends the building's useful life. In general, M&R comprises around 95% of a building's life cycle, beginning with the conception of its construction and continuing until its demise. The current purpose of the maintenance department is to maintain the intended operational levels of machinery, buildings, equipment and devices, buildings, and facilities [4].

Today, companies address the life cycle of their physical assets to better manage costs and maximize asset value, and the physical asset management system is a successful solution in three areas: optimal asset performance, cost reduction, and accident elimination. The maintenance method plays a crucial part in the amount of building operating costs, and by using the system and selecting a suitable maintenance method, large-scale repairs are avoided, resulting in a significant reduction in excessive expenditures [5]. On the other hand, in the absence of a proper maintenance system, structures and equipment deteriorate, resulting in significant problems and costs for reconstruction, unanticipated accidents, a decrease in the number of clients and their trust, and ultimately a decline in the organization's credibility [6].

Buildings are the most valuable national assets because they provide housing and facilities for homes and workplaces. Nevertheless, the enhancement of the life cycle of buildings necessitates implementing M&R procedures, which are essential for maintaining a building's value and quality [7]. In this vein, experts underline the importance of selecting the most appropriate and most efficient maintenance method for public facilities, which should be done by considering several factors, such as (1) the type of building structure; (2) the number of buildings and sections; (3) the density and complexity of mechanical installations; (4) the density and complexity of electrical installations; and (5) the type of use and the nature of the facilities. Consequently, governments spend a significant amount of money yearly on M&R projects, around 50% of the total revenue of the architecture, engineering, construction/facility management (AEC/FM) industry. As a result, researchers have become increasingly focused on determining the proper M&R procedures that can minimize the M&R costs of buildings; this is because using an effective M&R practice significantly reduces M&R expenses [8].

The M&R of buildings is a critical aspect of building management that can significantly affect the lifespan and performance of buildings. In HBFs, M&R is even more crucial due to the impact that it can have on patients' health and safety. On the other hand, healthcare building facilities (HBFs) require a higher level of M&R management than other types of structures due to their nature of use and the requirement to provide a variety of healthcare services continuously and efficiently. However, despite its importance, there is a lack of comprehensive research on primary selection criteria for effective M&R methods. This issue is particularly significant in developing countries such as Iraq, where building maintenance management has not received enough attention. The existing regulations and standards in Iraq only specify the inspection periods for various components based on their usage type and do not address other critical issues. This gap highlights the need for more research to identify the most important selection criteria for M&R approaches in Iraqi HBFs. The current study addresses this existing gap by examining the criteria for selecting the optimal M&R approach in HBFs in Iraq. The study will investigate the specific maintenance needs of healthcare buildings, the factors that influence M&R decision-making, and the most effective M&R approaches for HBFs in Iraq. The findings of this study are expected to contribute significantly to the improvement of HBF maintenance and management practices in Iraq. The results will provide a transparent and clear maintenance philosophy for healthcare buildings, enabling more effective and efficient decision making regarding M&R activities. The study's outcomes will also have broader implications for building management and maintenance practices in developing countries, emphasizing the need for comprehensive research to support effective building maintenance management practices.

2. Building Maintenance and Repair Management in Healthcare Building Facilities

Companies are often operated under a significant amount of pressure to reduce spending on "non-core" tasks such as maintenance and operation as a direct result of increased levels of competition in the business sector. This motivates building owners and users to have higher standards and expectations for the facilities that they use. Facility managers are therefore obliged to reduce operating costs and risks through the effective and efficient design, construction, management, and maintenance of facilities without compromising the operational performance of the facilities themselves. Facilities management (FM) has undergone significant growth over the past three decades, primarily due to the five global trends of development: (1) increased construction costs; (2) a greater recognition of the effects of space on productivity; (3) increased performance requirements by both users and owners; (4) contemporary bureaucratic and statutory restrictions; and (5) recognition of the criticality of the facility's operational performance. As a result, the traditional function of "maintenance managers" has evolved into that of "facility managers", and the practices of FM have been enriched with methodical processes, especially those that are executed with established key performance indicators. The facility manager's decisions regarding the strategic and operational planning of the organization's facilities can affect the organization's overall business performance [9]. This is especially true for HBFs, which are commonly regarded as being among the most complex and challenging types of facilities to manage, maintain, and run.

Regarding the various aspects that impact healthcare facility management, the literature has much to say. Gallagher [10] cited the following six factors as those that promote the successful adoption of healthcare FM: strategic planning, customer service, market testing, benchmarking, environmental management, and staff development. Amaratunga et al. [11] developed a model to evaluate the impact of organizational FM cultural processes on a healthcare building facility. Allen [12] referred to an important issue and stated that due to the use of less durable materials in some construction facilities, long-term maintenance planning is essential.

Proper M&R management is an essential component of HBF management [13]. Building facility maintenance is an integrated strategy for operating, maintaining, enhancing, and adapting the organization's facilities and infrastructure to create an environment that strongly supports the organization's fundamental objectives. In this regard, a building facility maintenance model has been developed by the International Building Maintenance Association [14]. In the built environment, facility maintenance management is becoming an increasingly important task, particularly for facilities and asset managers working in hospitals, factories, schools, hotels, and other public buildings and services. Considering the condition of the construction industry in both developed and developing nations, it is obvious that the number of buildings and infrastructure facilities that require professional management and maintenance has increased to the same level of significance as new construction projects [15]. In the meantime, building M&R management processes differ depending on the types of construction projects [16].

According to previous studies, HBFs are underfunded and underresourced in some developing countries [17,18]. This trend may negatively impact healthcare providers' non-core tasks and most significantly facility management, such as maintenance management. Ritchie [19] stated that it is possible to improve the performance and quality of healthcare services by focusing as much on the quality of the service as one does on financial concerns. Because public buildings constitute a substantial portion of a nation's real estate wealth, it is necessary to conduct routine maintenance management on these structures to keep them in adequate condition for usage. According to Shohet [20], condition-based maintenance is a prevalent strategy for the maintenance of complex buildings in countries with constrained economic resources. Specifically, he proposed two rating systems for assessing the condition and planned M&R of buildings: one for individual elements and another for the entire structure. The first scale considers the performance, physical condition, use, and preventative maintenance of a variety of building components. The second scale examines ten of the building's key systems.

Shohet and Nobili [21] devised a performance-based contract for the maintenance of public infrastructure by combining a KPI-based performance model, a contracting model, and a procurement model. The application of their proposed model resulted in 20 to 40 percent improvement in the performance-cost effectiveness of maintenance. Its key parameters are the development of a clearly defined procurement model, the incorporation of the performance model for both the owner and the contractor, and performance control of the facilities. This framework, which is primarily based on a condition-based maintenance approach that enables the control of desired maintenance performance levels and costs [22], can generate even better results when paired with an enterprise resource planning (ERP) system [23]. To strengthen the framework given by Shohet and Straub [24], a more comprehensive collection of KPIs for measuring the performance of public buildings is required, and Lai and Man [25] provide a comprehensive list. Even without a ranking, these researchers created a list of 71 factors categorized into five groups: (i) task- and equipment-related, (ii) environmental, (iii) physical, (iv) health, safety, and legal, and (v) financial.

According to Shafiee's [26] review of M&R methods, there is always a variety of criteria to consider when selecting the most appropriate M&R method: "Some of these criteria are quantitative and measurable (such as hardware/software and training costs, equipment reliability/availability), while others are qualitative and difficult to measure (such as safety, flexibility, acceptance by laborers, product quality)." Shafiee [26] classified qualitative and quantitative criteria as follows: economic, technical, social, and environmental. Notably, these four groups are aligned with those of a recent review by Hauashdh et al. [27] on the factors influencing M&R building in Malaysia. In this regard, Besiktepe et al. [28] attempted to prioritize procurement selection criteria for building maintenance projects; the results of the first study indicated that "Health and Safety" was the most important selection criterion, whereas the most important selection criterion for the second study was "Price Competition" among potential suppliers. However, the above study failed to account for several crucial characteristics, including human resources, flexibility, and technical capability, leaving the study incomplete. In addition, none of the studies that attempted to prioritize the M&R technique (e.g., [29,30]) accounted for extremely constrained and unequally distributed resources [31]. As revealed by Vanier et al. [32], selection of M&R techniques is largely dependent on the weights assigned to elements by evaluators, which vary based on culture and organizational necessity.

As previously mentioned, the M&R of buildings is a frequently neglected element of the construction industry. However, maintenance management challenges must be considered in the life cycle of a structure, especially in developing nations. In addition, it is clear from the available information that the maintenance of government facilities (such as health buildings) in Iraq is not in accordance with the proper maintenance management systems [33]. Consequently, it is vital to create the main criteria for the selection of suitable M&R approaches for HBFs in the developing nation of Iraq. This research examines the essential criteria for selecting M&R approaches to gain insights into their applicability in HBFs.

3. Research Methodology

This statement describes the methodology of a study that aims to identify the most appropriate maintenance and repair (M&R) processes for healthcare building facilities (HBFs) in Iraq. The study is conducted in a developing nation context, which means that the researchers need to consider various factors specific to that context, such as resource availability and infrastructure limitations. To achieve the objective of the study, the researchers divided it into three independent steps. Figure 1 provides a visual representation of these sections. In the first and second steps, the most relevant criteria and indicators for selecting M&R processes for HBFs were identified. To do this, a comprehensive review of the existing scholarly literature on the subject was conducted. In the second step, two rounds of the Delphi survey were carried out, which is a structured communication method that aims to reach a consensus among experts on a particular topic. The Delphi survey is particularly useful when confronting complex and uncertain issues. In this case, the researchers used it to gather opinions from a panel of experts on M&R processes for HBFs in Iraq. The Delphi survey allowed the researchers to identify the most relevant criteria and indicators that experts deemed important for selecting M&R processes in this context. Overall, the study provides guidance for decision makers in Iraq on how to select the most appropriate M&R processes for HBFs. By identifying the most relevant criteria and indicators for this purpose, the study can help ensure that HBFs are properly maintained and repaired, which is essential for providing quality healthcare services. Eventually, in the third step, the fuzzy analytic hierarchy process (FAHP) technique was used for the prioritization of identified criteria.

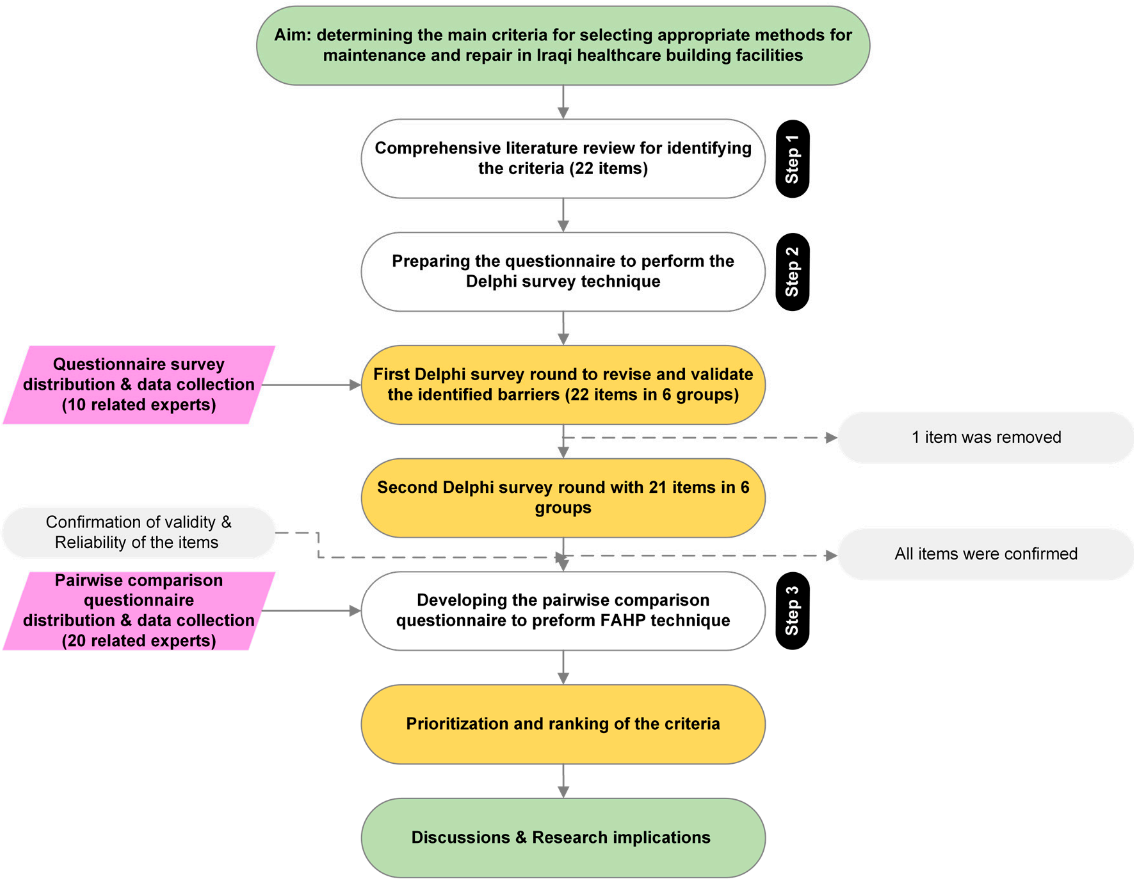

Figure 1. Research flow diagram used in this study.

3.1. Review of Previous Related Studies

To identify a comprehensive set of selection criteria, previous literature was extensively searched and reviewed. Although researchers use various search engine databases, Web of Science, Scopus, and Google Scholar are currently the most widely used databases in the world. However, the Scopus database has attempted to dominate the market for research data [34]; hence, for this study's literature search, the Scopus database was used. Several related articles on construction maintenance management were analyzed to determine relevant criteria for selecting effective M&R solutions. Previous research indicates that a choice must be made between the benefits of the comprehensiveness of findings and the accuracy of identified studies [35]. On the other hand, using research tools (e.g., SPIDER, PICOS) is advantageous for review teams with severely limited resources or time as well as for those who do not want to conduct a full search. In light of the significance of exhaustiveness to this research, the search tools were not used preferentially [36]. Finally, a set of selection criteria were identified that were considered as the basis for the questionnaire of the first round of the Delphi survey. The 22 identified main criteria and their corresponding sub-criteria are listed in Table 1. The identified criteria were grouped into the following six categories: (1) reliability and flexibility, (2) facilities and technology, (3) human resources, (4) safety, risk, and environment, (5) cost, and (6) quality.

Table 1. Evaluation of the main criteria and their corresponding sub-criteria.

Main Criteria (Symbol)	Sub-Criteria (Symbol)	Explanations	Sources
Reliability/Flexibility (RF)	Using different M&R techniques (RF1)	Ability to use different maintenance management techniques	[8,30,37]
	Increasing credibility and satisfaction of users (RF2)	Increasing credibility and satisfaction of patients/users	[8,38,39]
	Increasing productivity capacity (RF3)	By using the selected M&R method, the productivity and efficiency of the system can be increased	[8,29,40]
	Feasibility and ease of implementation (RF4)	The ease of understanding, use, and execution of the selected M&R method by the workforce	[30,37,39,41]
Facilities/Technology (FT)	Registration of information, as built, and technical documents (FT1)	The ease of registration and use of information and technical documents of an M&R method	[8,37,38,41]
	Intelligent control capability—BMS (FT2)	The ability to use intelligent control tools and sensors in the selected M&R method	[30,37,40]
	Information integration—BIM (FT3)	Synchronization of the selected M&R method with building information modeling	[39,41,42]
	Quick access to repair records (FT4)	The ease of access and use of information records related to M&R	[8,37,38,40]
	Quick access to equipment spare parts (FT5)	Coordination and integration with procurement management systems for quick access to equipment spare parts	[30,37,38]
Human Resources (HR)	Employing M&R expert human resources (HR1)	The availability of skilled labor in the field of the selected M&R method	[8,30,37,40],
	Employing workforces during project construction (HR2)	The possibility of employing workforces familiar with the selected M&R methods in the pre-operation stages	[8,37,40]
	M&R executive culture (HR3)	The compatibility and appropriateness of the selected M&R method with the working culture (e.g., teamwork) of the organization's human resources	[8,30,38,39]
	Periodic monitoring of personnel in terms of performance (HR4)	The necessity of periodic monitoring of personnel in terms of performance	[8,30]

Table 1. *Cont.*

Main Criteria (Symbol)	Sub-Criteria (Symbol)	Explanations	Sources
Safety/Risk/Environment (SRE)	Minimizing rework (SRE1)	Having specific and clear procedures to minimize rework	[12,37,39]
	Personnel safety (SRE2)	Reducing the safety risks related to executive personnel applying the selected M&R method	[37,38,40,41]
	Recognizing failure at an early stage (SRE3)	The ability to detect failure in the early stages by using different tactics/techniques of net management	[8,30,39,40]
Cost (CO)	Optimization and cost reduction (CO1)	Having justified costs in using the M&R method	[8,30,41]
	Energy efficiency (CO2)	Improving energy consumption using the selected M&R method	[8,30,37,38]
Quality (QU)	Improve performance and maintain high quality (QU1)	Improving performance and quality by achieving the lowest rate of failure	[37,38,40,41]
	Increasing the life of the equipment and maintaining their initial quality (QU2)	Increasing the life of the equipment using the selected M&R method	[8,30,41]
	Existing specific maintenance instructions (QU3)	The existence of instructions related to the selected M&R method for facilitating the implementation	[8,30,37,38]
	Compliance and maintenance of technical standards (QU4)	The technical standards of the equipment must be observed.	[8,30,41]

3.2. Delphi Survey Technique

Before implementing a decision-making process that considers several criteria, the Delphi method is used to define the significance of criteria and eliminate less significant criteria. The Delphi method is a technique for systematically gathering data to reach conclusions about qualitative issues [37,43,44]. The primary objective of the Delphi method is to obtain the most reliable collection of expert opinions through a series of structured polls with regulated feedback. As a result, the Delphi survey technique was applied in this study to establish and categorize the criteria [45], just as it has in previous studies [46]. For instance, using the Delphi method, Kuo and Chen [43] created performance appraisal indicators for the mobility of the service industries. In another study, Sarvari et al. [41] evaluated risk detection methodologies for public-private partnership (PPP) projects using the Delphi method. Using this technique, which involves the assignment of a group of specialists, researchers can identify and prioritize issues and provide a framework for identifying them. A Delphi survey panel should include enough experts to provide a diverse range of opinions while maintaining a manageable size for efficient communication and analysis [42].

Several criteria have been used regarding selecting experts known as Delphi questionnaire respondents. The criteria depend on the specific research question and the characteristics of the population being studied. In particular, in this case, experts were selected based on their experience and knowledge of M&R processes for HBFs in Iraq. It is essential to note, however, that the quality of the specialists is more significant than their quantity, which is often between 15 and 50 [42]. The number of experts is determined by sample homogeneity, the objective of the Delphi method, the difficulty range, the quality of the decision, the expertise of the research team, internal and external validity, the amount of time required to collect data, and the available resources [43]. In prior contributions of a similar sort, data collection was conducted using the Delphi approach. The targeted snowball strategy is a widely used method for selecting research specialists. It is the procedure through which a qualified participant invites specialists who meet the study standards [47]. For this study, experts who have awareness and knowledge of the construction industry (including project managers, facilities managers, maintenance and repair contractors, construction professionals, and university professors) were invited. Typically, snowball sampling is a steady process that continues until data are collected [48]. Accordingly, two experts were selected, and after data collection, they were tasked with recommending further specialists. When the factors became saturated, the outreach specialists were terminated. Therefore, when no new factors were discovered during data collection, the data were considered saturated [49].

During the Delphi survey study, a questionnaire with two sections was distributed among experts. Section A was related to demographic information. In section B, the panel memvbers were asked to indicate the extent of their agreement with each identified criterion based on the five-point Likert scale of measurement. In addition to rating the criteria, the panel members were also allowed to add new criteria that they thought could affect the selection of appropriate M&R processes for HBFs. This is a common practice in the Delphi survey technique, as it allows experts to provide input and feedback that may not have been considered in the initial questionnaire.

Feedback from the panel members was essential to refine and improve the criteria used in the study. After collecting, analyzing, and averaging the replies of the first round of panelists, it became clear that one of the questionnaire items (Periodic monitoring of personnel in terms of performance (HR4)) had not been approved by experts, and this criterion needed to be eliminated from the survey. During the second round of the Delphi survey, panelists were handed a questionnaire containing 21 sub-criteria divided into six groups. Panelists were asked to comment not only on whether they accepted the criteria but also on which category they considered each criterion to fall under. All 21 of the criteria specified in the questionnaire were confirmed by the panel members according to the findings of this round. After collecting and analyzing the panelists' opinions, it became evident that they were all in accord with the specified criteria and the classes allocated to them.

Validity and Reliability of the Questionnaire

In addition, the validity and dependability of the questionnaire were examined. Since it is possible to add or remove criteria and sub-criteria during the rounds of the Delphi survey technique, it is essential to evaluate the questionnaire's validity and reliability in the closing round of the Delphi survey [50]. The validity of a measuring questionnaire relates to whether the method or questionnaire employed to assess a construct accurately measures the desired attribute. Therefore, validity is the degree to which the conceptual and practical meanings of a variable or construct agree [51].

In this research, the questionnaire content validity was evaluated. The methods proposed by Lawshe [52] were used to determine content validity. The recommended method of Lawshe [52] states that a minimum of four members is required. In addition, the minimum validity coefficient for acceptable validity analysis is 0.60. In addition, at least eight individuals can satisfy this requirement [53]. In this study, ten experts participated in the validation of the questionnaire.

Lawshe [52] proposed the content validity ratio (CVR) metric in 1975. Using the three-part Likert scale "item is necessary", "item is useful but not necessary", and "item is not necessary", the experts decide the significance of each question by analyzing the questionnaire. The CVR is then determined based on Equation (1):

$$\mathrm{CVR} = \frac{\left(n_e - \frac{N}{2}\right)}{\frac{N}{2}}, \tag{1}$$

where N is the total number of experts and n is the number of experts that selected the required option [54]. The lowest admissible value for the CVR with 10 experts is 0.62, based on the number of experts that examined the questions [53]. In addition, to identify the hidden elements (criteria) for each answer to the question, "Is the grouping appropriate?" it was included in the questionnaire so that the specialists could voice their views or make rectification suggestions.

In addition, Waltz and Bausell's approach is used to determine the content validity index (CVI). The "importance", "clarity", and "simplicity" of each topic are determined by experts using a four-point Likert scale. The CVI is computed using Equation (2).

$$\mathrm{CVI} = \frac{\text{The number of experts who rated the item 3 and 4}}{\text{Total number of specialists}} \tag{2}$$

The minimum permissible value for the CVI is 0.79, and if an item's CVI is less than 0.79, it must be eliminated [55]. All test item scores for content validity were reviewed and confirmed.

In addition, using Cronbach's alpha approach, SPSS software was used to evaluate the test reliability. Cronbach established the alpha coefficient statistical approach to determine the reliability of multiple-question exams at Stanford University in 1951. This is the most prevalent internal consistency reliability coefficient employed in most studies, and it shows the suitability of a group of items for measuring a construct. Cronbach's alpha must be at least 0.7 or more for a question to remain in the questionnaire [56]. The results demonstrate that Cronbach's alpha for all items is equal to 0.952, confirming the reliability.

3.3. Fuzzy Analytic Hierarchy Process (FAHP) Technique

The development of computational and mathematical tools to support decision-makers in their subjective evaluation of several performance criteria is the focus of the operations research area known as multi-criteria decision-making (MCDM) [57]. In recent years, numerous studies have used MCDM tools such as the analytic network process (ANP), the analytic hierarchy process (AHP), and the fuzzy analytic hierarchy process (FAHP), as well as applications, to solve area problems such as determining the criteria for making an appropriate decision. These studies have been undertaken in numerous disciplines, including business, science, and engineering. It is feasible to apply the analytic hierarchy process (AHP), an efficient method for solving problems involving the use of many factors in decision making, to the problem of M&R maintenance to gain a scientific and objective perspective of the maintenance schedule [58–60].

It is usually difficult for the maintenance managers/engineers to choose an M&R strategy suitable for a particular machine or a group of units. This challenge in decision making poses a conundrum that must be resolved. It is feasible to find a solution to this issue by employing decision-making approaches such as AHP. The AHP technique also makes it easy to quantify the relative importance of each element, which provides decision makers with a clearer picture of any gaps between the actual and desired conditions. A recent study conducted by Chandrahas [61] indicates that a decision-making technique known as the analytical hierarchy process (AHP) can be applied to solve the problem of determining the optimal machine maintenance plan.

When decision makers are uncertain about how to respond to a survey result, the AHP is incapable of dispelling any ambiguity that may arise. FAHP, on the other hand, can account for this when comparing pairs [62,63]. In reality, fuzzy sets are more compatible with ambiguous explanations and human language, and fuzzy numbers appear to be an effective decision-making technique [45]. Dabiri et al. [64] demonstrated that by applying the FAHP approach to group decisions, the fogginess associated with the common understanding of expert viewpoints could be dispelled. Consequently, this method is suited for analyzing the influence of a phenomenon or concepts influencing features on a more flexible scale. In this study, FAHP was also used to prioritize M&R's selection techniques for HBFs. This strategy employs pairwise comparisons established by the opinions of industry professionals.

In this study, the criteria were evaluated using Chang's FAHP method, and the results were ranked. The likelihood of each criterion is considered in Chang's extension analysis [63,65], which is used for FAHP. The relevant triangular fuzzy values (Table 2) for the linguistic variables are placed on the inquiry form based on the responses, and a pairwise comparison matrix is constructed for a specific level on the hierarchy. Following the computation of subtotals for each row of the matrix, a new set of (l, m, u) values is generated. $l_i / \sum l_i$, $m_i / \sum m_i$, $u_i / \sum u_i$,$(i = 1, 2, \ldots, n)$ values are determined and utilized as the most recent $M_i(l_i, m_i, u_i)$ values to determine the overall triangular fuzzy values for each criterion. This is done so that the overall triangular fuzzy values may be calculated. After that, membership functions are constructed for each criterion, and intersections are found by comparing each pair of criteria individually. In fuzzy logic, the crossing point is determined for each comparison, which is then followed by the membership values of the point that correlate with its weight. This membership value can also be viewed as the probability that the value will be used. Before the normalization process, the weight of a criterion is determined by the minimal degree of the probability of situations in which the value is greater than the others. This minimal degree of probability is associated with a particular criterion. Following the collection of non-core activities performed by healthcare professionals, the ultimate importance degrees or weights for each level of the hierarchy are calculated.

Table 2. Fuzzy nine-point scale for valuating indicators [45].

Definitive Equivalent	Linguistic Variable	Triangular Fuzzy Number
1	So trivial	(1,1,1)
2	So trivial to trivial	(1,2,3)
3	Trivial	(2,3,4)
4	Trivial to mediocrity	(3,4,5)
5	Mediocrity	(4,5,6)
6	Mediocrity to important	(5,6,7)
7	Important	(6,7,8)
8	Important to very important	(7,8,9)
9	Very important	(8,9,9)

In order to apply the technique that is based on this hierarchy, according to the approach known as the extent analysis, each criterion is taken, and an extent analysis is carried out for each criterion individually. Therefore, m extent analysis values for each criterion can be obtained using the following notation: $M^1_{gi}, M^2_{gi}, \ldots, M^m_{gi}$; where gi is the goal set $(i = 1, 2, \ldots, n)$, and all the $M^j_{gi}(j = 1, 2, \ldots, m)$ are triangular fuzzy numbers (TFNs). The steps of Chang's analysis are as follows [66]:

Step 1: The fuzzy synthetic extent value (S_i) with respect to the i^{th} criterion as follows: This involves

$$S_i = \sum_{j=1}^{m} M^j_{gi} \otimes \left[\sum_{i=1}^{n} \sum_{j=1}^{m} M^j_{gi} \right]^{-1} \tag{3}$$

1. Computation of

$$\sum_{j=1}^{m} M^j_{gi} \tag{4}$$

Perform the "fuzzy addition operation" of m extent analysis values for a particular matrix given in Equation (5) below. At the end step of the calculation, a new (l, m, u) set is obtained and used for the next:

$$\sum_{j=1}^{m} M^j_{gi} = (\sum_{j=1}^{m} l_j, \sum_{j=1}^{m} m_j, \sum_{j=1}^{m} u_j) \tag{5}$$

where l is the lower limit value, m is the most promising value, and u is the upper limit value, and to obtain (6):

2. Computation of

$$\left[\sum_{i=1}^{n} \sum_{j=1}^{m} M^j_{gi} \right]^{-1} \tag{6}$$

Perform the "fuzzy addition operation" of M_{gi}^{j} $(j = 1, 2, \ldots, m)$ values given

$$\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j} = \left(\sum_{j=1}^{m} l_i, \sum_{j=1}^{m} m_i, \sum_{j=1}^{m} i\right) \tag{7}$$

Then compute the inverse of the vector in Equation (7). Equation (8) is then obtained, such that

$$\left[\sum_{i=1}^{n}\sum_{j=1}^{m} M_{gi}^{j}\right]^{-1} = \left[\frac{1}{\sum_{i=1}^{n} u_i}, \frac{1}{\sum_{i=1}^{n} m_i}, \frac{1}{\sum_{i=1}^{n} l_i}\right] \tag{8}$$

Step 2: The degree of possibility of $M_2 = (l_2, m_2, u_2) \geq M_1 = (l_1, m_1, u_1)$ is defined in Equation (9):

$$V(M_2 \geq M_1) = sup[\min\,(u_{M1}(x), \min\,(u_{M2}(y))] \tag{9}$$

and x and y are the values on the axis of the membership function of each criterion. This expression can be equivalently written as given in Equation (10) below:

$$V(M_2 \geq M_1) = \begin{cases} 1, if\ m_2 \geq m_1, \\ 0, if\ m_2 \geq m_1, \\ \frac{l_1 - u_2}{(m_2 - u_2) - (m_1 - l_1)} otherwise \end{cases} \tag{10}$$

where d is the highest intersection point $(u_{M1}\ and\ u_{M2})$ (see Figure 2). To compare M_1 and M_2, we need both the values of $V(M_2 \geq M_1)$ and $V(M_1 \geq M_2)$.

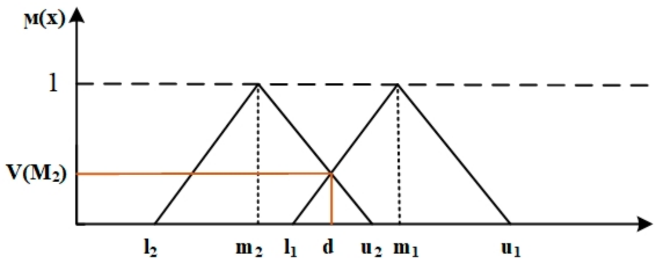

Figure 2. The Distance of Two Triangular Fuzzy Numbers [45].

Step 3: The degree possibility for a convex fuzzy number to be greater than k convex fuzzy numbers $M_i (j = 1, 2, \ldots, k)$ can be defined by

$$\begin{aligned} V(M \geq M_1, M_2, \ldots, M_k) &= V[(M \geq M_1)\ and\ (M \geq M_2), \ldots,\ and\ (M \geq M_k)] \\ &= \min V(M \geq M_I), i = 1, 2, \ldots, k \end{aligned}$$

Assume that Equation (11) is

$$d(A_i) = \min V(S_i \geq S_k) \tag{11}$$

for $k = 1, 2, \ldots, n; k \neq i$. Then, the weight vector is given by Equation (12):

$$W_i = (d(A_1), d(A_2), \ldots, d(A_n))^T \tag{12}$$

where $A_i (i = 1, 2, \ldots, n)$ are n elements.

Step 4: Via normalization, the normalized weight vectors are given in Equation (13):

$$W = (d(A_1), d(A_2), \ldots, d(A_n))^T \tag{13}$$

where W represents nonfuzzy numbers. After the criteria have been identified according to Figure 1, a questionnaire has been developed to determine the relative weight of these criteria. To evaluate the questions, respondents merely select the relevant linguistic variable, which is then converted into the following scale, which includes triangular fuzzy numbers, and generalized for such analyses as shown in Table 2 [48]. The questionnaire, including pairwise comparisons, was finally emailed to a total of 20 industry experts. This sample size is comparable to that used in the study by Tamosaitiene et al. [8]. A month was required to complete the distribution and collection of survey materials.

4. Presentation of Analytical Results

The results of the evaluation of the data acquired from the Delphi survey using the FAHP method were then used to rank the criteria and sub-criteria. In the same vein, a questionnaire regarding paired comparisons was delivered to a total of 20 specialists. Table 3 presents the demographic information of the study participants.

Table 3. Description of respondents to the questionnaire of the study.

Characteristics		Frequency (%)
Area of Expertise	Mechanical engineering	9 (45)
	Computer engineering	1 (5)
	Civil engineering	5 (25)
	Academia/Research	1 (5)
	Surveying engineering	1 (5)
	Architecture	1 (5)
	Project management	1 (5)
	Medical engineering	1 (5)
	Total	20 (100)
Level of Education	Ph.D. degree	1 (5)
	Master's degree	3 (15)
	Bachelor's degree	15 (75)
	Diploma	1 (5)
	Total	20 (100)
Working Experience in Construction	≤5 years	0 (0)
	6–10 years	5 (25)
	11–15 years	8 (40)
	16–20 years	4 (20)
	≥20 years	3 (15)
	Total	20 (100)
Working Experience in Maintenance	≤5 years	0 (0)
	6–10 years	11 (55)
	11–15 years	6 (30)
	16–20 years	1 (5)
	≥20 years	2 (10)
	Total	20 (100)
Oorganization Type	Public	14 (70)
	Private (individual)	4 (20)
	Private (organization)	2 (10)
	Total	20 (100)

After receiving the opinions of the experts through the completion of the paired comparison questionnaire, the geometric mean approach was used to calculate the average and generate a merged pairwise comparison matrix. The integration of fuzzy matrices takes the first terms of all comparisons as the geometric mean, the second terms as a group, and the third terms as the geometric mean. The pairwise comparisons are depicted in Table 4. Then, each row's fuzzy numbers are combined (see Table 4).

Table 4. The integrated fuzzy comparison matrix for the main criteria.

	QU			CO			HR			RF			SRE			FT		
QU	1.000	1.000	1.000	0.955	1.264	1.712	0.624	0.830	1.141	1.377	1.766	2.257	0.793	1.062	1.426	1.119	1.469	1.907
CO	0.584	0.791	1.047	1.000	1.000	1.000	0.781	1.019	1.321	0.989	1.270	1.664	1.394	1.871	2.499	1.683	2.270	2.996
HR	0.876	1.204	1.603	0.757	0.981	1.280	1.000	1.000	1.000	1.078	1.467	1.961	1.056	1.481	2.050	1.249	1.785	2.424
RF	0.443	0.566	0.726	0.601	0.787	1.012	0.510	0.682	0.928	1.000	1.000	1.000	1.531	2.071	2.715	0.785	1.050	1.443
SRE	0.701	0.942	1.261	0.400	0.534	0.717	0.488	0.675	0.947	0.400	0.527	0.716	1.000	1.000	1.000	1.596	2.035	2.627
FT	0.524	0.681	0.894	0.334	0.440	0.594	0.413	0.560	0.801	0.693	0.952	1.275	0.381	0.491	0.627	1.000	1.000	1.000

In the subsequent phase, all the numbers from the previous step are added together, and then the process is reversed. In this stage, all fuzzy numbers will be combined and then subtracted. According to Table 4, this inverse is then multiplied by each row of the initial step (each row's total) to yield the normalized integration values of each row. Each line should now be compared to the ones beneath it. For each line to be compared to itself, number one is assigned. Table 5 shows the degree of preference for S*i* over S*k*. The final weights are then derived from the preceding phase. The final weight of each criterion is equal to the minimum value in each column, also known as priority (see Table 5). Each raw weight was divided by the total raw weight to determine the normalized weight. The final column in Table 5 displays the normalization of preferences, also known as the final ranking.

Table 5. Fuzzy sum, fuzzy expansion, and the degree of preference for the main criteria.

	Fuzzy Sum of Each Row			Fuzzy Compound Expansion			Degree of Preference of S_i over S_k					Degree of Preference	Normalization of Preferences
QU	5.868	7.391	9.442	0.116	0.187	0.303	0.893	0.933	1.000	1.000	1.000	0.893	0.2001
CO	6.431	8.223	10.526	0.127	0.208	0.338	1.000	1.000	1.000	1.000	1.000	1.000	0.2240
HR	6.017	7.919	10.318	0.119	0.200	0.332	1.000	0.964	1.000	1.000	1.000	0.964	0.2159
RF	4.869	6.156	7.824	0.096	0.156	0.251	0.813	0.704	0.748	1.000	1.000	0.704	0.1577
SRE	4.585	5.713	7.268	0.091	0.145	0.234	0.735	0.626	0.672	0.924	1.000	0.626	0.1403
FT	3.344	4.125	5.190	0.066	0.104	0.167	0.380	0.277	0.332	0.578	0.655	0.277	0.0619

In addition, it was important to examine the rate of comparison discrepancy. If the incidence of discrepancy is less than 0.1%, the comparability is acceptable. The rate of discrepancy was examined and certified as meeting the criteria.

Figure 3 depicts the order of the criteria. In terms of relevance, the "Cost" criterion 0.2240 ranked first (0.2240), followed by the "Human Resources" criterion (0.2159), and then by the "Quality" criterion (0.2240). (0.2001). Additionally, "Reliability/Flexibility", "Safety/Risk/Environment", and "Facilities/Technologization" were ranked fourth, fifth, and sixth, respectively.

The consistency ratio (CR) is calculated by dividing the consistency index (CI) by the random index (RI). If the result is less than 0.1, the matrix is consistent and can be used to evaluate data. If both the CRm and CRg indices are greater than 0.1, the decision maker is encouraged to reevaluate the prioritization. The fuzzy matrix is compatible if both indices are less than 0.1; it is incompatible if both indices are more than 0.1. The median (or border) of the fuzzy verdicts needs to be adjusted by the decision-maker if the CRm (or CRg) is the only one that is greater than 0.1 [67,68]. According to the criteria, both of these indices have values lower than 0.1 (CRm = 0.032051 and CRg = 0.09903), which is the upper limit for acceptable values.

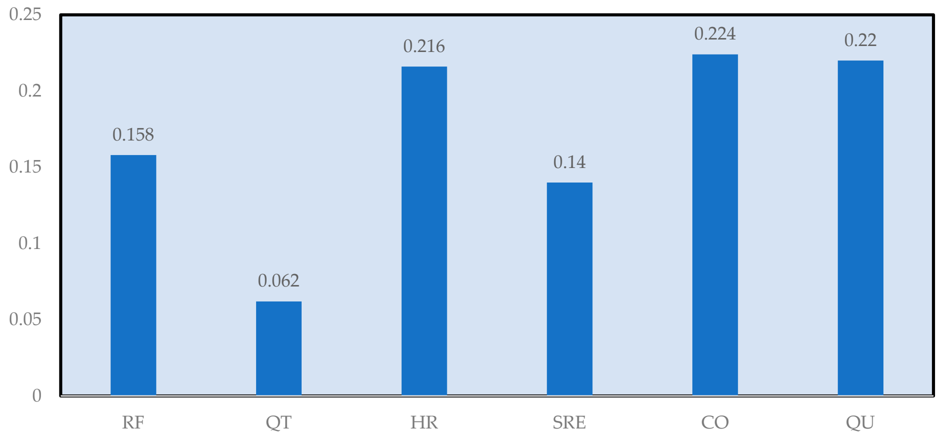

Figure 3. The ranking of the main criteria using the FAHP method.

Using the FAHP approach, the relative importance of sub-criteria within each category was determined. Table 6 displays the results and weights associated with the sub-criteria. According to Figure 4, sub-criteria RF2 and RF3 rated first and second, respectively, in terms of importance for the RF group. Moreover, RF1 and RF4 were ranked third and fourth, respectively. FT1 sub-criteria rated first, FT5 sub-criteria ranked second, and FT4, FT3, and FT2 sub-criteria placed third through fifth for the FT group, respectively. In terms of relevance, sub-criteria HR1 and HR2 ranked first and second in the HR group, respectively, while sub-criteria HR3 ranked third. The ranking of the group of SRE criteria revealed that the SRE3 sub-criteria rated highest, followed by the SRE1 and SRE2 sub-criteria, in that order. The CO1 and CO2 sub-criteria were also placed first and second for the CO group. The ranking of the QU group reveals that sub-criteria QU2 and QU4 ranked first and second, respectively, followed by sub-criteria QU1 and QU3 in third and fourth ranks, respectively. Figure 4 depicts the overall ranking of the criteria and sub-criteria. In a comparison of all sub-criteria, the CO1 sub-criteria ranked highest, while the FT2 sub-criteria ranked lowest.

Table 6. Determination of the final priority of main criteria and sub-criteria using the FAHP technique.

Main Criteria	CR^m	CR^g	Weight	Sub-Criteria	Weight	Rank within the Category	Final Weight	Overall Rank
Reliability/Flexibility (RF)	0.02146	0.05725	0.1577	RF1	0.241	3	0.038	13
				RF2	0.266	1	0.042	11
				RF3	0.263	2	0.041	12
				RF4	0.230	4	0.036	15
Facilities/Technology (FT)	0.00840	0.02575	0.0619	FT1	0.235	1	0.015	17
				FT2	0.136	5	0.008	21
				FT3	0.200	4	0.012	20
				FT4	0.204	3	0.013	19
				FT5	0.224	2	0.014	18
Human Resources (HR)	0.00138	0.00358	0.2159	HR1	0.398	1	0.086	3
				HR2	0.302	2	0.065	5
				HR3	0.300	3	0.065	6
Safety/Risk/Environment (SRE)	0.00145	0.00451	0.1403	SRE1	0.350	2	0.049	9
				SRE2	0.259	3	0.036	14
				SRE3	0.391	1	0.055	8
Cost (CO)	Not applicable	Not applicable	0.2240	CO1	0.564	1	0.126	1
				CO2	0.436	2	0.098	2
Quality (QU)	0.03338	0.09792	0.2001	QU1	0.226	3	0.045	10
				QU2	0.364	1	0.073	4
				QU3	0.100	4	0.020	16
				QU4	0.311	2	0.062	7

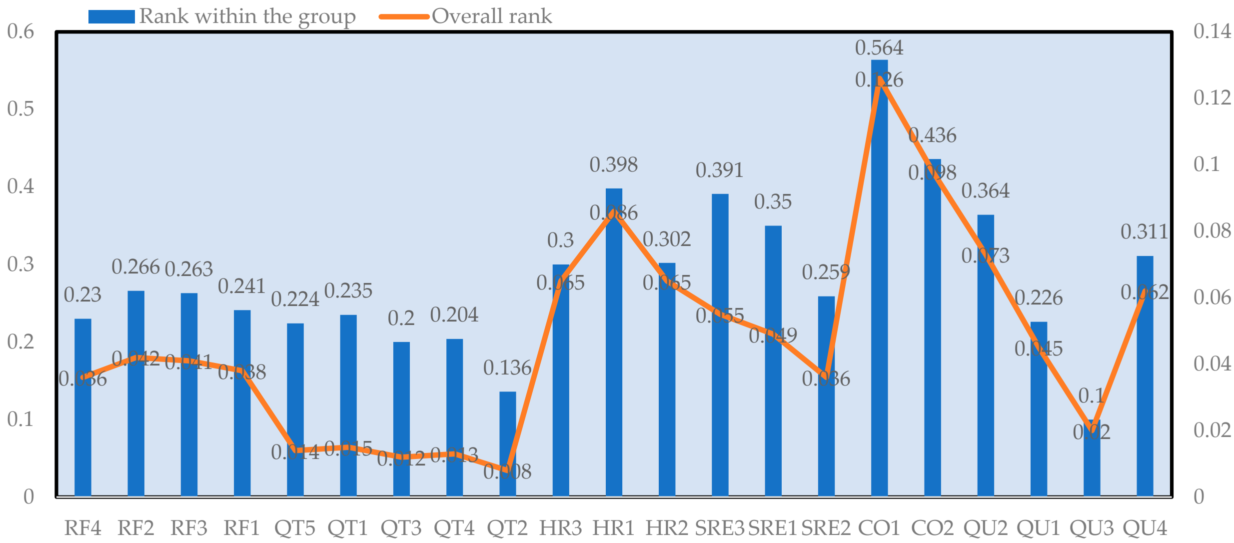

Figure 4. The ranking of the sub-criteria using the FAHP method.

The sub-criteria were evaluated similarly to the primary criteria. For the sub-criteria, the integration of pairwise comparisons, fuzzy sum, fuzzy expansion, the degree of the preference of S*i*. over S*k*., the degree of preference, and the normalization of preferences for comparisons were calculated. In addition, the consistency ratio for the sub-criteria was examined and confirmed (see Table 6).

5. Discussion of Analytical Results

Both industrialized and developing nations yearly contribute billions of dollars to the development of the construction industry. This budget includes cash for maintenance and repair efforts. M&R has therefore always been necessary and will continue to be so in the future. Despite recognizing the importance of maintenance, the industry is experiencing escalating maintenance costs. However, the budgeted amount influences the quality of maintenance tasks. For a building's maintenance procedures to be effective and to maintain an acceptable quality level, sufficient manpower and financial resources are necessary [69]. In order to obtain the intended results, maintenance stakeholders such as building managers, building owners, and clients must make informed decisions regarding acceptable and optimal M&R practices and prioritize the allocation of maintenance resources.

Existing structures require various decision-making M&R technique consideration factors. HBFs demand a larger degree of M&R management than other buildings due to the nature of their usage and the obligation to provide various health services around the clock. The distribution of resources to healthcare services is underinvested in many countries, and this tendency may have a detrimental influence on the noncore activities of healthcare providers, particularly maintenance and operations connected to facilities management. Therefore, it is essential to determine the best M&R approach for HBFs. The outcomes of this study indicate that cost, human resources, quality, reliability/flexibility, safety/risk/environment, and facilities/technology are among the variables that must be addressed while choosing the right methods for Iraqi HBFs. When we consider that the market for building maintenance management lacks information on how to handle common building problems, these results are important [70]. Developing and implementing a proper building maintenance program reduces the frequency and severity of breakdowns and facilitates their repair.

According to the presented results, the main criteria for selecting M&R methods are as follows: CO, HR, QU, RF, SRE, and FT. In this regard, Lam et al. [71] found that safety and cost were the most important considerations in M&R evaluations. The rating of the current study is partially consistent with what they discovered after analyzing the results of 110 M&R management firms in Hong Kong.

In contrast, the results of the current investigation are roughly consistent with the classification offered by Shafiee [26]. This holds true when examining the classification. While this scholar proposed dividing M&R evaluation criteria into (i) economic, (ii) technical, (iii) social, and (iv) environmental, this work proposes dividing them into six groups. A comparison of the two classifications demonstrates a relationship between the two economic and technical terms; the environmental theme of Shafiee [26] is present in the SRE classification, while the social theme can be considered part of the HR variable. The classification in the current study, in contrast to Shafiee [26], concentrates on the internal components of an organization that might perform M&R operations. In actuality, while the proposed classification appears exhaustive of all internal aspects of the organization but not of any external ones, Shafiee's [26] categorization appears to include a portion of both internal and external elements without being exhaustive of either.

As shown in Table 7, even though the cost criterion is one of the most significant criteria in most countries, comparing the prioritization of the main criteria between developed and developing countries reveals several disparities. For example, contrary to the results of the current study, the findings of the study conducted by Besiktepe et al. [72] advocated that "Health and Safety", "Code Compliance", and "Condition" generate a larger impact in industrialized nations when picking M&R ways (i.e., U.K.). While in this study, it has been determined that CO is the most important criterion, Sodangi et al. [73] discovered that the most important criterion in Malaysia was maintenance staff training and expertise—equivalent to the HR category of this work; however, this result contradicts the one by Chua et al. [74], who identified "price competition" as the most important criterion for the procurement of M&R in Malaysia. Ali [75] discovered in Malaysia that the important factors that building managers consider when distributing maintenance costs are funding availability, customer demand, and economic conditions. Amani et al. [76] acknowledged the maintenance cost as the main criterion for selecting M&R techniques for wastewater system maintenance in Iran.

Table 7. A comparison of the most important criteria for selecting M&R techniques between developed and developing countries.

Main Selection Criteria	Developed Countries		Developing Countries		
	United Kingdom [72]	Hong Kong [71]	Malaysia [73–75]	Iran [8,26,76]	Iraq [Current Study]
Reliability/Flexibility				✓	
Facilities/Technology	✓				
Human Resources			✓		
Safety/Risk/Environment	✓	✓			
Cost		✓	✓	✓	✓
Quality					✓

Because of these inequalities, it is obvious that there is no general homogeneity of criteria between developed and developing nations, but there appears to be some commonality between studies undertaken in Iraq and other developing nations. In practice, for decision makers in emerging countries, but especially in Iraq, where results appear to be converging (see [76]), the cost of maintenance is the most important factor in selecting the M&R methods for a building structure. In any case, a comparison of this study's findings with previously published literature reveals that the relative importance of the criteria is influenced by cultural considerations.. As a result, external factors, which were not examined in this and other studies, are likely the cause of discrepancies in criteria ranking. To establish these variances and similarities, cross-national research studies are necessary and timely.

6. Conclusions and Implications of the Study

This study aimed to identify and rank the evaluation criteria for HBFs to establish suitable M&R processes that can satisfy overlapping requirements. A total of 21 essential criteria were selected, categorized into six categories, and ranked using the FAHP technique. Cost, human resources, quality, reliability/flexibility, safety/risk/environment, and facilities/technology were placed first to sixth, respectively. The results revealed that optimization and cost reduction (CO), increasing the life of the equipment, and maintaining their initial quality (QU2) are the most to the least important sub-criteria for M&R operations of HBFs in Iraq.

In terms of practical ramifications, this study attempts to inform M&R decision-makers of the following: First, managers responsible for M&R method selections should examine the expenses associated with M&R techniques since the initial building development analysis. The evaluation of these costs must adhere to the principles of sustainable development and account for the energy embodied in the materials and construction as well as initial and continuing maintenance. To accomplish this, numerous budgeting approaches for M&R operations have been developed; they can be classified as (1) plant value methodologies; (2) other formula-based methodologies; (3) life-cycle cost methodologies; and (4) condition evaluation methodologies. Second, it is recommended and noted that all six types of selection criteria are essential for M&R decision making. These categories should be systematically evaluated when making M&R decisions; if the management fails to do so, the chosen M&R process will lead to overlooking other critical variables (e.g., risks) that, if not analyzed, can result in catastrophically poor outcomes. In this regard, multicriteria approaches must be used. The context-specific nature of a criterion's weight should be considered by managers responsible for selecting appropriate M&R methodologies. Therefore, it is proposed that future research may investigate the implications of the crucial elements (main criteria and sub-criteria) in other countries and regions, both developed and developing, as well as in other economic sectors.

The two fundamental limitations of this study are the small number of survey respondents (20) and their country of origin based in a single developing nation (Iraq), as well as the incompleteness of the disclosed criteria to contain all relevant significant factors for selecting and assessing various M&R methods pertaining to healthcare building facilities.

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