كلية الهندسة بشبرا
FACULTY OF ENGINEERING AT SHOUBRA
ERJ
PRINT ISSN 3009-6049
ONLINE ISSN 3009-6022

ENGINEERING RESEARCH JOURNAL (ERJ)
Volume (53),Issue (4)
October 2024, pp:1-12
https://erjsh.journals.ekb.eg

Risk Assessment During Restoration Stage for the Heritage Buildings Rehabilitation in Egypt

Mahitab Magdy [1, *], Mohamed Abdel-Hamid [1], Khaled Abd-Elhady [2], Tareq Attia [3]

[1] Civil Engineering Department, Faculty of Engineering at Shoubra, Benha University, Egypt
[2] Architecture Engineering Department, Faculty of Engineering at Shoubra, Benha University, Egypt
[3] Housing and Building National Research Center (HBRC), Egypt
**Corresponding author*

E-mail address: Mahitab.magdy.asha@gmail.com , Mhamid01@gmail.com, id_abdelhady2@yahoo.com , tarek_attia@yahoo.com

Abstract: The objective of this research is to create a comprehensive risk assessment framework for the restoration stage of heritage building rehabilitation in Egypt. Forty-two primary risk factors were gathered from various sources including literature, site visits, and stakeholder interviews conducted during the restoration stage of the Amr ibn al-Aas mosque and Kom el-Shoqafa Cemetery in Alexandria. An online questionnaire was created, and the data was analyzed utilizing IBM SPSS version 20. The top risk factors identified were collapse of the heritage building due to design/construction errors, falling the labors from heights, falling materials due to the building's structural weaknesses and old artistic components, causing irreparable damage while trying to restore the Heritage building, collapse of scaffolding used, fire accidents of timber buildings, assigning design tasks to unqualified designers, insufficient awareness and lack of qualifications, skills, and experience of the contractor, using inappropriate methods, selecting unsuitable materials, inadequate qualification and supervision of the owner's engineer, lack of skilled labor, poor communication between design team & construction team, poor quality control, lake of installing safety measures, lack of availability of the proper materials, using low quality materials, excavation and using heavy equipment near the rehabilitated building, lack of understanding the project scope and objectives by the contractor, and inability to determine the accurate scope of work.

Keywords: Heritage Buildings, Rehabilitation, Risk assessment, Conservation, Environment Heritage.

1. Introduction

Heritage buildings are structures with substantial cultural significance to society. Developed societies consider existing buildings as cultural heritage due to their cultural value. Generally, the cultural value of a building is often proportional to its age [1]. Heritage buildings are considered unique and valuable assets for the countries they reside in, with a significant emphasis on their conservation and preservation for the benefit of future generations [2]. During the initial design phase of a building project, the design team collaboratively decides on the different engineering aspects of the project, including the building's structure, materials, operating and control systems. This process is guided by the user's requirements and the project's budget [3]. Heritage buildings can be renovated to maintain their cultural significance while gaining a new purpose. Retrofitting these structures is a flexible preservation approach that acknowledges their deterioration and the need for repairs to prevent further damage [4]. The construction industry has significant impacts on the natural environment, economy, and society [5]. Maintaining heritage buildings is a complex task that involves making tough decisions on when and how to intervene. The data gathered during the conservation and rehabilitation of these buildings can provide valuable insights to help stakeholders make informed decisions about efficiently planning maintenance activities throughout the buildings' lifespan [6]. Preserving the original building materials in heritage structures is essential for prolonging their lifespan and preventing frequent replacements. Specialized expertise is necessary to maintain the authenticity of historic buildings and address potential deterioration issues effectively, ensuring that the building elements continue to function as intended while avoiding material decay [7]. International Organization for Standardization (ISO) 31000 defines risk management as systematic actions taken within an organization to manage and regulate risks. This process involves establishing context, assessing risks through identification, analysis, and evaluation, treating risks, monitoring, communicating, and documenting them [8]. The construction industry is deemed risky due to frequent occupational accidents resulting from the dynamic and complex nature of projects. Safety is a global concern in this sector, with a traditional reliance on safety inspections and workers' hazard recognition abilities [9]. The construction sector in developing countries faces a high frequency of occupational accidents due to its labor-intensive and unskilled personnel employment. The construction industry inherently carries more risks compared to others, leading to a high incidence of accidents worldwide, both in terms of frequency and damages [10]. Risk assessment is crucial for effective risk management, enabling decision-makers to understand the impact of each risk on project success. By prioritizing high-priority risks through this process, resources can be appropriately allocated, enhancing the efficiency and effectiveness of risk management practices [11]. Personal factors like poor safety awareness and lower education levels increase safety risks for migrant construction workers. Some migrant construction workers may overlook safety protocols and Personal Protective Equipment (PPE) requirements due to overconfidence, further increasing their vulnerability to accidents [12]. Accurate cost estimation plays a critical role in the success of construction projects. Inaccuracies in cost estimation can have significant and serious consequences for the outcome of these projects [13]. Construction projects frequently encounter cost and time overruns, with poor labor productivity being a key contributor [14, 15]. Sometimes, variations to the works before commencement lead to no unimpacted work period. The Association for the Advancement of Cost Engineering (AACE) International, Inc. (2004) suggests employing schedule analysis techniques to assess project delay and delays to specific activities within the project schedule [16]. In this paper, a comprehensive risk assessment framework for the restoration stage of heritage building rehabilitation in Egypt is conducted. Forty-two primary risk factors were gathered from various sources including literature, site visits, and stakeholder interviews conducted during the restoration of the Amr ibn al-Aas mosque and Kom el-Shoqafa Cemetery in Alexandria. An online questionnaire was created, and the data was analyzed utilizing IBM SPSS version 20. The degree of risk associated with 42 identified risk factors is calculated. Finally, the top risk factors for the heritage buildings rehabilitation during restoration stage in Egypt are identified.

2. Research Problem

Failure of heritage buildings during the restoration stage in Egypt is associated with the lack of knowledge or understanding in the field of risk assessment for the main factors focused on this stage of rehabilitating these buildings. Also, the selection of inappropriate methods and materials for rehabilitation leads to their failure. There are many risk factors that affect heritage building rehabilitation during the restoration stage in Egypt. There is a scarcity of comprehensive studies specifically addressing the risks associated with the restoration phase of rehabilitation of heritage buildings in Egypt. The current research seeks to bridge this gap and introduces a comprehensive risk assessment associated with the restoration phase of rehabilitating heritage buildings in Egypt. Finally, it identifies the top risk factors during the restoration stage of heritage building rehabilitation in Egypt.

3. Study objectives

The main objective of this research is to develop a comprehensive risk assessment framework for the restoration stage during heritage buildings rehabilitation in Egypt.

The other objectives are the following:

- **Risk Assessment:** Discussion on the degree of risk associated with 42 identified risk factors affecting heritage building rehabilitation during the restoration stage in Egypt.
- **Identification of High-Risk Factors:** Identifying the top high-risk factors affecting heritage building rehabilitation in Egypt during the restoration stage.

These objectives aim to guide the research towards improving the restoration process for heritage buildings in Egypt by effectively managing risks and ensuring the preservation of cultural significance.

4. Research Methodology

To achieve the previous stated objectives, the following methodology is considered:

1. Performing a detailed literature review in the field of risk assessment during restoration stage of heritage building rehabilitation.
2. Identifying and collecting the risk factors effect on heritage building rehabilitation during the restoration stage from relevant literature coupled with face-to-face semi-structured interviews with three academics and three experts (with over 25 years of experience in heritage buildings rehabilitation) and through site visits and interviews with relevant stakeholders during the rehabilitation of Amr ibn al-Aas mosque and Kom el-Shoqafa Cemetery in Alexandria, Egypt.
3. Performing a survey among contractors, consultants, and owners involved in restoration stage of heritage building rehabilitation. A questionnaire was designed to collect points of views of different sources from expert's engineers about these risk factors.
4. Analyze the data collected from the questionnaire using IBM SPSS version 20.
5. Discussion the degree of risk of 42 risk factors that affect heritage building rehabilitation in Egypt during restoration stage.
6. Finally, the risk assessment is conducted to identify the top risk factors during restoration stage of heritage building rehabilitation.

5. Literature Review

Several researchers have identified risk factors in construction projects. The following are some of the published articles in this domain:

Abd Karim et al. (2012) identified the five most important risk factors in construction project including shortage of material, late deliveries of material, insufficient technology, poor quality of workmanship, and cash flow difficulties [17]. Iqbal et al. (2015) revealed that financial issues for projects, accidents on site and defective design are the most significant risks affecting most of construction projects [18]. As further reported by Iqbal et al. (2015), the contractor is responsible for management of most risks occurring at sites during the implementation phase, such as issues related to subcontractors, labour, machinery, availability of materials and quality, while the client is responsible for the risks such as financial issues, issues related to design documents, changes in codes and regulations, and scope of work [18]. Further reported results of the analysis by Iqbal et al. (2015) demonstrate that the production of proper schedule by getting updated data of the project and guidance from previous similar projects are the most effective preventive risk management techniques while close supervision and coordination within projects are the most effective remedial risk management techniques [18]. Mohammed (2016) identified significant risks in construction projects, including owner's inability to finance the project, assigning design tasks to unqualified designers, poor contractor and technical staff qualifications, design errors, inadequate owner's engineer qualifications, delays in test approvals, and inspections [19]. These risks were grouped into owner, management, contractor, and consultant categories. Notably, certain risks significantly affected project cost, duration, and quality [19]. The most critical risks impacting costs were rising material prices, poor cost control, and owner-initiated design changes [19]. Project duration was notably affected by work suspension, inadequate contractor planning, and slow owner decision-making. In terms of project quality, risks like material non-compliance, unqualified designers, and inadequate owner's engineer supervision were highlighted as crucial factors [19]. Suwandari & Riantini (2019) identified the high-risk factors for heritage building maintenance included inaccurate historical information, a lack of skilled personnel for maintenance, absence of maintenance standards, inadequate scheduling, poor quality control, project delays, non-compliance with safety regulations, human error in defining repair scopes, budgetary constraints, and inappropriate materials [20]. Dhivya and Prabu (2019) identified the high-risk factors in construction projects including project delay, accidents on site, design changes, errors in design drawings, adverse impact on project due to climatic conditions, increase of labour costs, wastage of material by workers, improper verification of contract documents, unknown & unforeseen site physical condition, surplus materials handling, change of top management, and poor team work [21]. Suwandari et al. (2020) conducted a study to pinpoint the risk factors affecting building safety, with a specific focus on cultural heritage structures [22]. The research underscored the necessity for heightened oversight of building safety post the damages incurred by these buildings [22]. The study, set in Jakarta, utilized interviews and questionnaires to unearth risks. Risk assessment involved probability and weight matrices, unveiling 23 high-risk factors alongside potential risk mitigation strategies [22]. The research highlighted obstacles to heritage building maintenance, with the most significant barriers being inadequate technical data and inaccurate historical building information [22]. Accurate data was deemed essential in offsetting these risks' adverse effects. Moreover, the analysis identified a scarcity of skilled workers in the cultural heritage sector [22]. El-Sayegh et al. (2021) conducted a study on risks in sustainable construction projects in the UAE [23]. They identified thirty risks across categories such as management, technical, green team, green materials, and regulatory/economic through a literature review [23]. The authors identified the top five risks, including shortage of client funding, insufficient sustainable design information, design changes, tight construction schedules, and poor scope definition [23]. Gürcanlı et al., (2022) conducted a study on the risks associated with restoring historic buildings, highlighting the dangers involved in tasks like cleaning, painting, and engraving performed at elevated heights [24]. The primary risk identified was falls from heights, leading to numerous fatalities [24]. Implementing safety measures such as scaffolding, guardrails, and safety harnesses faced challenges due to compliance issues with health and safety regulations, especially concerning anchorage points and footings [24]. The presence of architectural features made maintaining a standard distance between scaffolding and the building difficult. Installing lifelines was also problematic as it could potentially damage the building. Structural weaknesses and old artistic components in historic buildings posed risks of falling materials like paintings, chandeliers, and roof coverings. Specialized crane systems were necessary for the proper disposal of materials removed from upper parts of the building to ensure worker and public safety [24]. Fire safety emerged as a significant concern as many historic buildings did not meet fire safety regulations, with wooden parts, wood dust, chemicals, and other flammable elements increasing the risk of fire and explosions. Construction activities like welding and cutting near flammable materials further exacerbated the risk [24]. Yousri et al. (2023) identified the high-risk factors in construction projects in Egypt including funding problems from contractors, material price fluctuations, unrealistic estimates of the duration of project activities, and shortages of construction materials in the market [25].

6. Risk Identification

This process aims to thoroughly understand potential risks by studying hazards and vulnerability factors [26]. In this study, primary data was gathered through site visits and interviews with relevant stakeholders during the restoration stage of the rehabilitation of Amr ibn al-Aas mosque and Kom el-Shoqafa Cemetery in Alexandria. The selection of heritage sites in and around Cairo was based on their significance and the ongoing restoration efforts of Amr ibn al-Aas mosque during the study period. Notably, the Mosque of Amr Ibn Al-

Aas and the Kom El-Shoqafa Cemetery were chosen due to their historical importance. Kom el-Shoqafa Cemetery in Alexandria was undergoing restoration, with United States Agency International Development (USAID) involvement, highlighting its value and cultural significance.

7. Significant risk factors that are pertinent during the restoration stage of heritage building rehabilitation

The questionnaire consists of six groups of risk factors identified through a literature review, site visits, and expert interviews related to restoration stage of heritage building rehabilitation. These factors include financial, human resources, technical, organizational, safety, and quality issues. The grouping of these risk factors is detailed in Table1.

8. Questionnaire design

Tan (2012) described the questionnaire survey as a structured technique for gathering information on a subject matter from an identified population of respondents [27]. The questionnaire design process involved extracting variables from literature, site visits, and expert interviews. A five-point Likert scale ranging from 1 "Strongly Disagree" to 5 "Strongly Agree" was utilized to evaluate expert opinions in detail [28]. This scale choice was influenced by its ability to effectively capture nuanced viewpoints [29]. The questionnaire consisted of three parts: an introduction to the research, eight demographic questions, and inquiries about the impact of risk factors during the restoration phase of heritage building rehabilitation.

8.1 Descriptive Terms Impact

The descriptive terms impact for the choices by respondents on five-point Likert scale are shown in Table 2.

8.2 Risk Factor's Impact

By using equation 3 below, Factor's Impact is calculated as follows [31, 32]:

Factor's Impact = (SA x5+A x4+N x3+D x2+SD x1) / {(SA+A+N+D+SD) x 5} -Equation 3

In this study, SA+A+N+D+SD =100

8.3 Validity and reliability of data

The following criteria were considered in order to increase validity and reliability of data in results of questionnaires and interviews:

- Expert Review: The questionnaire questions were reviewed by university experts who had the opportunity to suggest edits or add new questions to ensure their appropriateness and relevance.
- Clear Definitions: The terms used in the questionnaires were accurately defined to avoid any ambiguity or confusion in respondents' interpretations.

Additionally, the results of the questionnaires were analyzed using the Likert scale with the assistance of SPSS software. This allowed for the calculation of the data's validity. The Cronbach's Alpha coefficient, calculated using SPSS, was found to be 0.89. This high value indicates that the collected data from the questionnaires and interviews possess a high level of validity.

TABLE 1: Risk factors that are pertinent during the restoration stage [17-25]

No.	Group of risk factors	Risk factors
1	**Financial issues**	F1: Fluctuations in foreign currency exchange rates impacting project cost.
		F2: lack of financial contingency planning.
		F3: Errors in cost estimates.
		F4: Errors in time estimates.
		F5: Stop of works due to lack of funds.
		F6: Weak financial credit of the contractor with banks.
		F7: Contractor poor management of cash flow.
		F8: Price escalations of materials and equipments.
2	**Human resources issues**	F9: Insufficient awareness and lack of qualifications, skills, and experience of the contractor.
		F10: Insufficient resources to fully redevelop the building into an appropriate new use.
		F11: Poor communication between design team & construction team.
		F12: Lack of general manpower.
		F13: lack of skilled labors.
		F14: Inadequate qualification and supervision of the owner's engineer.
		F15: Getting approvals from government.
		F16: Using inappropriate methods for restoration.
		F17: Causing irreparable damage while trying to restore the Heritage building.
		F18: Selecting unsuitable materials for restoration.

3	**Technical issues**	F19: Missing and lack of related documents such as original design drawing and specifications.
		F20: Using project documents without knowing if they are reliable/approved or not.
		F21: Inability to determine the accurate scope of work due to access restrictions at the building site.
		F22: The addition of modern technological systems to the building such as lighting and searchlights that may change the Heritage building external appearance.
		F23: Failing to preserve a building's original external appearance after restoration results in the loss of its visual identity.
		F24: Using low quality materials for restoration.
4	**Organizational issues**	F25: Lack of understanding the importance of the building by the design team.
		F26: Lack of understanding the project scope and objectives by the contractor.
		F27: Weak regulations and government requirements on proper quality measures for rehab projects of Heritage buildings.
		F28: Failure to develop an accurate time estimation.
		F29: Changes to the scope of work during construction phase.
		F30: Lack of availability of the proper materials for restoration.
5	**Safety issues**	F31: Fire accidents during rehabilitation of timber buildings.
		F32: Collapse of buildings surrounding rehabilitated heritage building.
		F33: Collapse of scaffolding used.
		F34: Excavation and using heavy equipment near the rehabilitated building during construction phase.
		F35: Collapse of the heritage building during construction phase. due to design/construction errors.
		F36: Poor quality control during construction phase.
		F37: Failure to provide security on the site.
		F38: Falling the labors from heights during cleaning, painting, and engraving, which are performed at elevated heights.
		F39: Falling materials due to the building's structural weaknesses and old artistic components.
		F40: Lake of installing safety measures like scaffolding, guardrails, and safety harnesses due to compliance issues with safety regulations, especially regarding anchorage points and footings.
6	**Quality issue**	F41: Failure to preserve and careful handling of materials.
		F42: Assigning design tasks to unqualified designers.

TABLE 2: Descriptive Terms Impact

Factor's Impact	Value	Description
Strongly Disagree (SD)	1	No serious influence as a risk factor during construction phase of heritage building rehabilitation.
Disagree (D)	2	Slightly affecting as a risk factor during construction phase of heritage building rehabilitation.
Neutral (N)	3	Moderately this factor effects as a risk factor during construction phase of heritage building rehabilitation.
Agree (A)	4	Significantly this factor affecting as a risk factor during construction phase of heritage building rehabilitation.
Strongly Agree (SA)	5	Catastrophic, where this factor affecting as a risk factor during construction phase of heritage building rehabilitation.

9. Data Collection

A questionnaire was designed to gather diverse opinions from expert contractor, consultant, and owner engineers regarding the significance of 42 risk factors that are pertinent during the restoration stage of heritage building rehabilitation in Egypt.

9.1 Sample Size

Cochran's sample size formula in equation (1) is used to calculate desired survey sample size [30].

$$n_0 = \frac{(t)^2(s)^2}{(d)^2} \quad \ldots\ldots\ldots\ldots\ldots (1)$$

Primary outcome variables of interest are attitudes and beliefs - these are primarily measured on a 7-point scale.

Where t = value for selected alpha level of 0.025 in each tail = 1.96 (the alpha level of .05 indicates the level of risk the researcher is willing to take that true margin of error may exceed the acceptable margin of error.)

Where s = estimate of standard deviation in the population = 1.167 (estimate of variance deviation for 7-point scale calculated by using 7 [inclusive range of scale] divided by 6 [number of standard deviations that include almost all (approximately 98%) of the possible values in the range]).

d = acceptable margin of error for mean being estimated = number of points on primary scale * acceptable margin of error 7*0.03= 0.21 (product of acceptable margin of error = 0.03, and points on survey scale = 7) [error researcher is willing to except]).

Therefore, for a population of 1755, the required sample size is determined to be 119. However, as this sample size surpasses 5% of the population (1755*.05=88), Cochran's (1977) correction formula specified in equation (2) should be used to calculate the final sample size [30].

$$n = \frac{n_0}{(1 + \frac{n_0}{\text{Population}})} \quad \ldots\ldots\ldots\ldots\ldots (2)$$

Rounded up, Equation (2) indicates that 112 participants are needed to have 95% confidence that sample estimates are within ±5% of the population value. The equation variables are defined as follows:

n_0 = sample size needed prior to correction = 119

Population= 1750 (Total number of contractor, consultant, and owner engineers who are working in the field of heritage building rehabilitation in Egypt according the data collecting from the Egyptian Engineers Syndicate, and Building and Construction Contractors Federation).

n = corrected sample size

Based on Cochran's sample size formula and its correction formula as per Cochran (1977), the calculated sample size required for the distributed questionnaire was determined to be 112. These participants were drawn from specialized engineers affiliated with contractors, consultants, and owners involved in heritage building rehabilitation in Egypt.

9.2 Methods of distribution of questionnaire

The questionnaire was distributed directly through an online Google Form to the experts during the period from March to May 2024. The questionnaire was sent to a sample of 112 specialized engineers from contractors, consultants, and owners who had a minimum of 10 years of experience in heritage building rehabilitation in Egypt across various public and private sectors. A total of 100 contractors, consultants, and owners' engineers responded to the questionnaire, resulting in a response rate of approximately 91%.

10. Data analysis

10.1 Risk Factors' Impacts on heritage buildings rehabilitation

Group No. 1 (Financial issues): F1- F8 Impacts

Table 3 shows the percentage of respondents' opinion at five-point Likert scale about the degree of impact of risk factors from F1 to F8. Also, it presents the calculated risk factor impact by using equation 1.

Group No. 2 (Human resources issues): F9- F14 Impacts

Table 4 shows the percentage of respondents' opinion at five-point Likert scale about the degree of impact of risk factors from F9 to F14. Also, it presents the calculated risk factor impact by using equation 1.

Group No. 3 (Technical issues): F15- F24 Impacts

Table 5 shows the percentage of respondents' opinion at five-point Likert scale about the degree of impact of risk factors from F15 to F24. Also, it presents the calculated risk factor impact by using equation 1.

TABLE 3: Risk factors Impacts of Group (1)

	SD	D	N	A	SA	Impact %
F1	27	22	25	14	12	52.4
F2	18	19	21	23	19	61.2
F3	10	13	25	27	25	68.8
F4	11	14	26	26	23	67.2
F5	10	11	26	26	27	69.8
F6	11	20	19	29	21	54.2
F7	12	15	28	23	22	65.6
F8	7	9	15	28	41	77.4

Group No. 4 (Organizational issues): F25 - F30 Impacts

Table 6 shows the percentage of respondents' opinion at five-point Likert scale about the degree of impact of risk factors from F25 to F30. Also, it presents the calculated risk factor impact by using equation 1.

Group No. 5 (Safety issues): F31 – F40 Impacts

Table 7 shows the percentage of respondents' opinion at five-point Likert scale about the degree of impact of risk factors from F31 to F40. Also, it presents the calculated risk factor impact by using equation 1.

Group No. 6 (Quality issue): F41-F42 Impacts

Table 8 shows the percentage of respondents' opinion at five-point Likert scale about the degree of impact of risk factors from F41 to F42. Also, it presents the calculated risk factor impact by using equation 1.

11. Risk assessment for the restoration stage of heritage buildings rehabilitation

In the current study, Risk assessment during restoration stage for heritage buildings rehabilitation are shown in Table 9.

11.1 High-risk factors identified from the risk assessment

During the restoration phase, specific factors can pose a significant risk to cultural heritage sites, potentially leading to severe structural damage. This damage may jeopardize the stability of the heritage unit, sometimes resulting in partial or complete collapse [8]. Table 10 presents the high-risk factors identified from the risk assessment during the restoration phase of the heritage building rehabilitation process.

TABLE 4: Risk factors Impacts of Group (2)

Factor	SD	D	N	A	SA	Impact%
F9	1	2	5	6	86	94.8
F10	15	18	26	21	20	62.6
F11	3	4	6	9	78	91.0
F12	9	10	25	27	29	71.4
F13	2	3	5	10	80	91.2
F14	2	2	3	10	83	91.6

TABLE 5: Risk factors Impacts of Group (3)

Factor	SD	D	N	A	SA	Impact %
F15	51	26	8	8	7	38.8
F16	2	3	5	10	80	92.6
F17	1	2	4	7	86	95.0
F18	3	4	5	8	80	91.8
F19	5	8	9	26	52	82.4
F20	4	6	8	28	54	84.4
F21	9	3	10	10	68	85.0
F22	49	23	11	10	7	40.6
F23	49	18	15	11	7	41.8
F24	5	3	10	8	74	88.6

TABLE 6: Risk factors Impacts of Group (4)

Factor	SD	D	N	A	SA	Impact %
F25	6	8	10	25	51	81.4
F26	2	4	6	9	79	86.6
F27	9	10	22	27	32	72.6
F28	39	15	19	15	10	47.2
F29	7	8	12	26	47	79.6
F30	5	2	9	10	74	89.2

TABLE 7: Risk factors Impacts of Group (5)

Factor	**SD**	D	N	A	SA	**Impact %**
F31	2	2	3	10	83	93.2
F32	4	7	9	27	53	83.6
F33	1	2	5	6	86	94.8
F34	3	5	11	9	72	88.4
F35	0	2	2	5	91	97.0
F36	2	7	6	9	76	90.0
F37	10	11	24	26	29	70.6
F38	0	2	4	6	88	96.0
F39	1	2	3	5	89	95.8
F40	4	6	5	8	77	89.6

TABLE 8: Risk factors Impacts of Group (6)

Factor	**SD**	**D**	**N**	**A**	**SA**	Impact%
F41	8	9	17	29	37	75.6
F42	2	3	5	8	82	93.0

TABLE 9: Risk assessment for risk factors during the restoration stage

Risk assessment	**Impact**
High	≥ 85%
Moderate	65% - 85%
Low	< 65%

TABLE 10: High-risk factors identified from the risk assessment

No.	**Risk factors**	**Risk Impact**	**Arrangement**
F35	Collapse of the heritage building during rehabilitation due to design/construction errors.	97 %	1
F38	Falling the labors from heights during cleaning, painting, and engraving, which are performed at elevated heights.	96 %	2
F39	Falling materials due to the building's structural weaknesses and old artistic components.	95 .8 %	3
F17	Causing irreparable damage while trying to restore the Heritage building.	95%	4
F33	Collapse of scaffolding used.	94.8%	5
F31	Fire accidents during rehabilitation of timber buildings.	93.2%	6
F42	Assigning design tasks to unqualified designers.	93%	7
F9	Insufficient awareness and lack of qualifications, skills, and experience of the contractor.	92.8%	8
F16	Using inappropriate methods for restoration.	92.6%	9
F18	Selecting unsuitable materials for restoration.	91.8%	10
F14	Inadequate qualification and supervision of the owner's engineer.	91.6%	11
F13	lack of skilled labors.	91.2%	12

F11	Poor communication between design team & construction team.	91%	13
F36	Poor quality control during construction phase	90%	14
F40	Lake of installing safety measures like scaffolding, guardrails, and safety harnesses due to compliance issues with safety regulations, especially regarding anchorage points and footings.	89.6%	15
F30	Lack of availability of the proper materials for restoration	89.2%	16
F24	Using low quality materials for restoration	88.6%	17
F34	Excavation and using heavy equipment near the rehabilitated building during construction phase.	88.4%	18
F26	Lack of understanding the project scope and objectives by the contractor.	86.6%	19
F21	Inability to determine the accurate scope of work due to access restrictions at the building site.	85%	20

12. Discussion of results

The research introduces a detailed risk assessment framework for heritage building rehabilitation during the restoration phase. It involved primary data collection via literature review, site visits and stakeholder interviews at the Amr ibn al-Aas mosque and Kom el-Shoqafa Cemetery in Alexandria, Egypt. A hundred questionnaires, each containing 42 risk factors, were distributed to participants to identify the most significant risk factors impacting heritage building rehabilitation during restoration phase. The impact of each factor was assessed using a formula based on respondent agreement levels. This process helped rank the risk factors by their impact and ultimately determine the main risk factors affecting during restoration stage of heritage building rehabilitation.

To compare the questionnaire results and outcomes with other studies, Table 11 summaries and highlighting the similarities and differences between them.

TABLE 11: Comparison between high-risk factors identified from questionnaire results and other studies

<table>
<tr><th>The most important risk factors according to questionnaire results</th><th>The most important risk factors in other studies</th><th>Similarities</th><th>Differences</th></tr>
<tr><td rowspan="2">1. Collapse of the heritage building due to design/construction errors.
2. Falling the labors from heights.
3. Falling materials due to the building's structural weaknesses and old artistic components.
4. Causing irreparable damage while trying to restore the Heritage building.
5. Collapse of scaffolding used.
6. Fire accidents of timber buildings.
7. Assigning design tasks to unqualified designers.
8. Insufficient awareness and lack of qualifications, skills, and experience of the contractor.
9. Using inappropriate methods.
10. Selecting unsuitable materials.
11. Inadequate qualification and supervision of the owner's engineer.
12. Lack of skilled labor.
13. Poor communication between design team & construction team.
14. Poor quality control.
15. Lake of installing safety measures.</td><td>1. Shortage of materials.
2. Late deliveries of materials.
3. Insufficient technology.
4. Poor quality of workmanship.
5. Cash flow difficulties. [17]</td><td>1. Shortage of material.
3. Insufficient technology.
4. Poor quality of workmanship.</td><td>Other factors.</td></tr>
<tr><td>1. Financial issues for projects.
2. Accidents on site.
3. Defective design.
4. Inaccurate execution plan/schedule.
5. Poor performance of subcontractors. [18]</td><td>2. Accidents on site.
3. Defective design.
5. Poor performance of subcontractors.</td><td>Other factors.</td></tr>
</table>

16. Lack of availability of the proper materials. 17. Using low quality materials. 18. Excavation and using heavy equipment near the rehabilitated building. 19. lack of understanding the project scope and objectives by the contractor. 20. Inability to determine the accurate scope of work.	1. Owner's inability to finance the project. 2. Assigning design tasks to unqualified designers. 3. Poor contractor and technical staff qualifications. 4. Design errors. 5. Inadequate owner's engineer qualifications. 6. Delays in test approvals, and inspections. [19]	2. Assigning design tasks to unqualified designers. 3. Poor contractor and technical staff qualifications. 4. Design errors. 5. Inadequate owner's engineer qualifications.	Other factors.
	1. Inaccurate historical information. 2. Lack of skilled personnel for maintenance. 3. Absence of maintenance standards. 4. Inadequate scheduling. 5. poor quality control. 6. project delays. 7. Non-compliance with safety regulations. 8. Human error in defining repair scopes. 9. Budgetary constraints. 10. Inappropriate materials.[20]	1. Inaccurate historical information. 2. Lack of skilled personnel for maintenance. 5. poor quality control. 7. Non-compliance with safety regulations. 8. Human error in defining repair scopes. 10.Inappropriate materials.	Other factors.
	1. Project delay. 2. Accidents on site. 3. Design changes. 4. Errors in design drawings. 5. Adverse impact on project due to climatic conditions. 6. Increase of labour costs. 7. Wastage of material by workers. 8. Improper verification of contract documents. 9. Unknown & unforeseen site physical condition. 10. Surplus materials handling. 11. Change of top management. 12. Poor team work. [21]	2. Accidents on site. 4. Errors in design drawings. 7. Wastage of material by workers. 12. Poor team work.	Other factors.
	1. Inadequate technical data. 2. Inaccurate historical building information. 3. A scarcity of skilled workers. [22]	2. Inaccurate historical building information. 3. A scarcity of skilled workers.	Other factors.
	1. Shortage of client funding. 2. Insufficient sustainable design information. 3. Design changes. 4. Tight construction schedules. 5. Poor scope definition. [23]	2. Insufficient sustainable design information. 5. Poor scope definition.	Other factors.
	1. Falling the labors from heights. 2. Lake of installing safety measures. 3. Installing lifelines that could potentially damage the building. 4. Falling materials due to the building's structural weaknesses and old artistic components. 5. Fire accidents of wooden parts, wood dust, chemicals, and other flammable elements. [24]	1. Falling the labors from heights. 2. Lake of installing safety measures. 4. Falling materials due to the building's structural weaknesses and old artistic components. 5. Fire accidents of wooden parts, wood dust, chemicals, and other flammable elements.	Other factors.
	1. Funding problems from contractors. 2. Material price fluctuations. 3. Unrealistic estimates of the duration of project activities. 4. Shortages of construction materials in the market. [25]	4. Shortages of construction materials in the market.	Other factors.

The results of this comparison shows that the current research covered the research gap in previous research work and achieved the required results. Also, the results of this research were identical to the results of previous research and even covered some important factors that were not addressed by previous research work.

The questionnaire results indicate that the top five risk factors are collapse of the heritage building due to design/construction errors, falling the labors from heights, falling materials due to the building's structural weaknesses and old artistic components, causing irreparable damage while trying to restore the Heritage building and collapse of scaffolding used.

Finally, in personal interviews, there was almost a consensus that design errors are among the most dangerous factors because they lead to the collapse of the building during restoration stage of heritage building rehabilitation.

13. CONCLUSION

The risk assessment conducted for the restoration stage of heritage building rehabilitation in Egypt has identified the top high-risk factors. These factors encompass various risk aspects such as collapse of the heritage building due to design/construction errors, falling the labors from heights, falling materials due to the building's structural weaknesses and old artistic components, causing irreparable damage while trying to restore the Heritage building, collapse of scaffolding used, fire accidents of timber buildings, assigning design tasks to unqualified designers, insufficient awareness and lack of qualifications, skills, and experience of the contractor, using inappropriate methods, selecting unsuitable materials, inadequate qualification and supervision of the owner's engineer, lack of skilled labor, poor communication between design team & construction team, poor quality control, lake of installing safety measures, lack of availability of the proper materials, using low quality materials, excavation and using heavy equipment near the rehabilitated building, lack of understanding the project scope and objectives by the contractor, and inability to determine the accurate scope of work. By considering these factors and employing risk mitigation measures, stakeholders can minimize damage, preserve historical value, and contribute to Egypt's cultural heritage conservation.

14. Recommendations for Future Research Work

Efforts are still needed to bridge the gap in the following topics:

1. Developing a decision support system for selecting the proper method and material to be used during restoration stage of heritage building rehabilitation projects in Egypt.
2. Expand the available risk assessment and generate a risk assessment in which all the available risk factors are considered.
3. Focus on the collection of additional responses and developing a comprehensive risk assessment model to be employed by contractors faced with selecting the most appropriate method and material compatible with the specific project characteristics and owner's requirements.

Limitation of the Research

The findings of the research are specific to the context of Egypt and may not be directly applicable to heritage buildings in other regions or countries.

ACKNOWLEDGMENTS

The authors express their gratitude to the laboratory staff for their assistance and cooperation in conducting this work.

References

[1] Santos, S. P., Modena, C., Vientzileou, E., Tomazevic, M., Lourenço, P., Capozucca, R., ... & Jaeger, W. (2010). Guide for the structural rehabilitation of heritage buildings. CIB Publication 335.

[2] Al-Sakkaf, A., Ahmed, R., & Afifi, M. (2021). Risk Assessment Model for Heritage Buildings: Case Study of Yemen. Journal of Architectural Engineering, 27(2), 04021009.

[3] Almufarrej, A. M., & Erfani, T. (2023). Climate, buildings' envelope design and energy patterns: improving energy performance of new buildings in Kuwait. Engineering, Construction and Architectural Management, 30(1), 172-188.

[4] Norazman, N., Salleh, N. M., Mohd Nashruddin, S. N. A., & Wan Ismail, W. N. (2023). Strategic planning of sustainable maintenance in heritage school buildings: Malaysia perspectives. International Journal of Building Pathology and Adaptation, Emerald; Emerald Publishing Limited.

[5] Gounder, S., Hasan, A., Shrestha, A., & Elmualim, A. (2023). Barriers to the use of sustainable materials in Australian building projects. Engineering, Construction and Architectural Management, 30(1), 189-209.

[6] Prieto, A. J., Macías-Bernal, J. M., Chávez, M. J., Alejandre, F. J., & Silva, A. (2019). Impact of maintenance, rehabilitation, and other interventions on functionality of heritage buildings. Journal of Performance of Constructed Facilities, 33(2), 04019011.

[7] Marzouk, M., ElSharkawy, M., Elsayed, P., & Eissa, A. (2020). Resolving deterioration of heritage building elements using an expert system. International Journal of Building Pathology and Adaptation, 38(5), 721-735.

[8] Romão, X., Paupério, E., & Pereira, N. (2016). A framework for the simplified risk analysis of cultural heritage assets. Journal of Cultural Heritage, 20, 696-708.

[9] Dobrucali, E., Demirkesen, S., Sadikoglu, E., Zhang, C., & Damci, A. (2024). Investigating the impact of emerging technologies on construction safety performance. Engineering, Construction and Architectural Management, 31(3), 1322-1347.

[10] Yılmaz, F. (2023). Analysis of the interaction between safety measures and workers' safety awareness from the construction workers' perspective. Engineering, construction and architectural management, 30(1), 41-55.

[11] Cevikbas, M., Okudan, O., & Işık, Z. (2024). Identification and assessment of disruption claim management risks in construction projects: a life cycle-based approach. Engineering, Construction and Architectural Management, 31(1), 1-27.

[12] Guan, Z., Yiu, T. W., Samarasinghe, D. A. S., & Reddy, R. (2024). Health and safety risk of migrant construction workers–a systematic literature review. Engineering, Construction and Architectural Management, 31(3), 1081-1099.

[13] Sayed, M., Abdel-Hamid, M., & El-Dash, K. (2020). Improving cost estimation in construction projects. International Journal of Construction Management, 23(1), 135-143.

[14] Abdel-Hamid, M., & Abdelhaleem, H. M. (2022). Impact of poor labor productivity on construction project cost. International Journal of Construction Management, 22(12), 2356-2363.

[15] Abdel-Hamid, M., & Abdelhaleem, H. M. (2023). Project cost control using five dimensions building information modelling. International Journal of Construction Management, 23(3), 405-409.

[16] Lee, J. S. (2023). Quantifying costs of the productivity loss due to schedule changes in construction projects. Engineering, Construction and Architectural Management, 30(1), 56-73.

[17] Abd Karim, N. A., Rahman, I. A., Memmon, A. H., Jamil, N., & Azis, A. A. A. (2012, December). Significant risk factors in construction projects: Contractor's perception. In 2012 IEEE Colloquium on Humanities, Science and Engineering (CHUSER 2012), December 3-4, Kota Kinabalu, Sabah Malaysia, pp. 347-350.

[18] Iqbal, S., Choudhry, R. M., Holschemacher, K., Ali, A., & Tamošaitienė, J. (2015). Risk management in construction projects. Technological and Economic Development of Economy, 21(1), 65–78.

[19] Mohammed, A. J. (2016). A study for significant risks and their effects on construction projects in Erbil city. Journal of Engineering and Sustainable Development, 20(4). 96-115.

[20] Suwandari, Y. D., & Riantini, L. S. (2019, April). Development of operational standards for risk-based cultural heritage office building maintenance procedures that the building safe and comfortable to use (Study case heritage office building PT. X). In Journal of International Conference Proceedings, Vol. 2, No. 1, p. 114.

[21] Dhivya, B., Prabu, V. (2019). Analysis of Risk in Construction Projects. International Research Journal of Multidisciplinary Technovation (IRJMT), 1(1), 64-69.

[22] Suwandari, Y. D., Amin, M., & Primatama, M. A. (2020). Risk Analysis of Heritage Building in Jakarta. International Journal of Applied Business and International Management (IJABIM), 5(2), 91-97.

[23] El-Sayegh, S. M., Manjikian, S., Ibrahim, A., Abouelyousr, A., & Jabbour, R. (2021). Risk identification and assessment in sustainable construction projects in the UAE. International Journal of Construction Management, 21(4), 327-336.

[24] Gürcanlı, G. E., Uzun, İ. M., & Öztürk, D. (2022). Managing health and safety risks in restoration/renovation of historic buildings. Journal of Construction Engineering, Management & Innovation, 5(3), 181-193.

[25] Yousri, E., Sayed, A. E. B., Farag, M. A., & Abdelalim, A. M. (2023). Risk identification of building construction projects in Egypt. Buildings, 13(4), 1084.

[26] Jigyasu, R. (2010). Risk Assessment of World Cultural Heritage: Tools & Methodology. Risk Assessment in Heritage: A Need or a Luxury.

[27] Tan, W.C.K. (2012). Practical Research Methods. 4th Edition, Pearson Prentice Hall, Real estate business, 273 pages.

[28] Likert, R. (1932). A Technique for the Measurements of Attitudes. New York: The Science Press, Archives of Psychology, 140 (22), 55 pages.

[29] Ekanayake, L. L., & Ofori, G. (2004). Building waste assessment score: design-based tool. Building and environment, 39(7), 851-861.

[30] Cochran, W. G. (1977). Sampling Techniques, 3rd Ed. John Wiley & Sons, New York, USA, 448 Pages, ISBN: 9780471162407.

[31] Elziny, Y. A. (2020). Developing Decision System to Select the Project Delivery System, Tending Method, and Type of Contract, Ph. D. thesis, Port Said University, Port Said, Egypt.

[32] Elziny, Y. A., Mohamadien, M. A., Essawy, A. Sh., Hassan, H. M., Mahdi, I. M. (2020). Developing Decision Support System to Optimize the Delivery System, Tendering Method, and Type of Contract. American Journal of Engineering Research, 9(8), 176-185.