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Causes of Rework of Building Construction Projects in Egypt

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الملخص العربى :

إعادة العمل هي مشكلة مستمرة في قطاع البناء، مما يؤدي إلى تأخير المشروع وتجاوز التكاليف. لذلك، تهدف هذه الدراسة إلى التحقيق في أسباب إعادة العمل في صناعة البناء المصرية، تم إنشاء استبيان يضم 62 سببا لإعادة العمل وتوزيعه على 120 خبيرا لدراسة أسباب وتأثيرات إعادة العمل على مشاريع البناء في مصر. تم تحليل البيانات التي تم جمعها من الاستبيان باستخدام SPSS V25. تكشف الدراسة أن ظروف الموقع ونقص العمالة الماهرة وضعف الإشراف على الموقع وطلبات التعديل وقلة التصميم هي الأسباب الرئيسية لإعادة العمل في مشاريع البناء المصرية. قد تساعد النتائج أصحاب المصلحة في المشروع في فهم تأثير إعادة العمل على أداء المشروع والتصرف بشكل مناسب لتقليل حدوثه.

الكلمات المفتاحية: إعادة العمل، البناء، الأسباب، تكلفة المشروع، وقت المشروع.

Abstract

Rework is a persistent issue in the construction sector, leading to project delays and cost overruns. Therefore, this study aim to investigate the reasons for rework in the Egyptian building industry, a questionnaire comprising 62 causes of rework was created and distributed to 120 experts to examine the causes and effects of rework on building construction projects in Egypt. The data collected from the questionnaire were analyzed using SPSS V25. The study reveals that site conditions, lack of skilled labor, poor site supervision, modification requests, and lack of design are the primary causes of rework in Egyptian building projects. The results may aid project stakeholders in understanding the impact of rework on project performance and acting appropriately to minimize its occurrence.

Keywords: Rework, Construction, Causes, , Project cost, Project time**.**

1. INTRODUCTION

The term "re-work" is widely used in the construction industry literature and has a significant impact on project performance, both directly and indirectly, by substantially increasing cost and time overruns. Rework expenses often represent 5-25% of the contract value and contribute to 50% of time overruns. However, the project could be expedited, and additional resources allocated to address the time overrun, which may increase project costs [1]. Further research indicates that the cost of rework for commercial, residential, and industrial buildings ranges from 2% to 6% of the contract value [2].

Despite rework's negative effects on project outcomes, it remains inadequately addressed in the Egyptian construction industry. Moreover, the work items and their associated rework causes are still not fully understood. Therefore, the aim of this study is to investigate, evaluate, and analyze the causes of rework and the work items that are most affected by rework in Egyptian building projects.

2. BACKGROUND

Rework is a significant contributor to poor construction project performance, leading to time overruns, additional resource recruitment, delays in the schedule, and reduced efficiency or extension of the project [3]. These issues can result in low benefits, loss of market share and prestige, increased management and staff turnover, lower productivity, and higher expenses [4]. The four primary causes of rework are errors, omissions, alterations, and harm during the design and construction phases [5]. Numerous studies have investigated the causes of rework and their impact on construction project performance in different countries from 2013 to 2021. For instance, in Uganda, Alinaitwe et al. [6] examined the reasons for construction project delays and cost overruns, identifying changes in the scope of operation and powerless supervision and control as the major causes. Meanwhile, in China, Ekambaram et al. [7] analyzed data from 112 building and engineering projects to investigate the causes of rework and found that ineffective communication with the design consultant and a lack of understanding and expertise in the design and construction process were the primary causes. Additionally, Shen et al. [8] evaluated the prefabricated construction (PC) process and analyzed the impacts of rework risk. They found that the frequency of rework, its cost, and time in the design stage was higher than in the other stages.

Moreover, in Nigeria, Ajayi and Oyeyipo [9] investigated the causes of rework in construction projects. The study revealed that limited communication with the design consultant, the use of inferior materials, and poor workmanship were the most common reasons for rework. Eze and Idiake [4] also examined the impact of rework on the time and cost performance of commercial building projects, finding an average 3.53% impact on the initial project cost, 46.60% contribution to cost overrun, and an average 7.35% impact on the initial delivery time.

Furthermore, in Palestine, Mahamid [10] studied the causes of rework in residential building projects, identifying 43 rework causes. Poor quality products, poor site management, and inadequate communication were the most common causes of rework in Palestine. Enshassi et al. [11] analyzed the factors causing rework in construction projects, identifying a set of 57 rework factors categorized under seven groups. The results showed that the main categories affecting project performance were contractors' related rework causes and human resources capability-related rework causes. Mahamid [12] investigated the factors affecting labor productivity, the causes of rework, and the relationship between them in building projects, finding that higher rework costs resulted in lower construction productivity.

In Sweden, Adam et al. [13] studied the consequences and causes of cost and time overruns in large public construction projects, identifying a communication gap between clients and contractors and unexpected ground circumstances as top factors of rework.

In Jordan, Al-Hazm et al. [14] investigated the causes of cost, and time overruns in 40 infrastructure projects, finding that terrain, and weather conditions were the primary causes of project delays and cost overruns.

In Cambodia, Durdyev et al. [15] identified ten key causes of project delays in residential construction projects, with a shortage of materials on-site, unrealistic project scheduling, and delays in shipping materials among the top reasons.

In Spain, Forcada et al. [16] examined the factors affecting rework costs in 40 construction projects, revealing that a local general contract project operated by a single contractor had a higher rework cost than a foreign private contract project managed by a joint venture. The rework cost was found to be 2.75% of the original contract value, attributed to errors and defects reported by the contractors.

In Afghanistan, Niazi and Painting [17] examined the primary factors causing cost overruns in the construction industry, identifying corruption, delay in progress payment by the owner, and difficulties in financing projects by contractors as top factors in Afghanistan.

Similarly, in Egypt, Zaki et al. [18] investigated the factors contributing to schedule delays and cost overruns in construction projects, with poor labor productivity and insufficient data as top factors causing time overrun, and fluctuations in money exchange rates and escalation of material prices as the top factors causing cost overrun. Kotb et al. [19] conducted an analysis of the factors influencing project cost and cost overrun, categorizing 95 factors into six primary groups, namely technical, economic, financial, political and regulatory, management, project resources, and environment. The study findings indicated that the management risk group had the most substantial impact on cost overrun, followed by economic and financial risks. Abdelbary et al. [20] investigated client-related rework causes and the role of BIM in reducing them in fast-track projects, identifying replacement of materials, change of scope, and financial problems as the top causes. The study also found that rework could be reduced through better communication and accurate cost estimates by using BIM at an early project stage. Mohamed et al. [21] studied the factors affecting production rate and causing rework, identifying incomplete design at the time of bidding, poor planning and coordination of resources, and errors in contract documentation as the main causes.

In India, Jadhav et al. ([22] analyzed the factors causing cost overruns in residential building projects, identifying contractual statements, faulty planning, and additional job problems as top factors.

In Iran, Khalesi et al. [23] used the step-wise weight assessment ratio analysis method and BIM technology to identify and reduce time delays caused by reworks in building projects, detecting design errors, differences between plans and operational requirements, and non-compliance with specifications as top causes. By using BIM and earned value management, working hours were reduced by 4.6%, and the schedule performance index increased by 0.06.

In the United Arab Emirates, Johnson and Babu [24] investigated 30 reasons for time overrun and 20 reasons for cost overrun, with design variation and unrealistic schedules as the primary causes of time overrun, while design variation and poor cost estimation were the primary causes of cost overrun.

Finally, in Texas, El-Sherbiny [25] examined the design error of rework costs in industrial projects. The findings revealed that the mean design error rework cost accounted for 15.5% of the project's value and 62% of the rework cost.

3. RESEARCH METHOGOLOGY

This study's methodology is outlined in **Fig. 1** and is explained in the following steps:

1. A literature review was conducted to identify previous studies related to the causes of rework. The review was supplemented by expert interviews to identify the various reasons that could lead to rework and impact cost and time in construction projects.

2. A questionnaire survey was conducted to determine the most significant reasons for rework in construction projects in Egypt based on the previously identified factors.

3. The collected data and survey questionnaire were analyzed to identify the main causes that lead to rework and affect the cost and time of construction projects. Predictive equations were developed to calculate the expected increase in project costs and time.

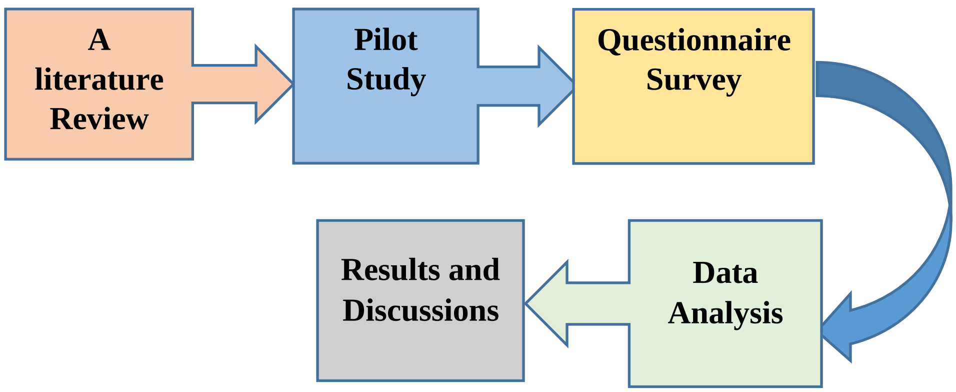

Fig. 1: Questionnaire methodology

3.1. Pilot Study

In this study, a thorough literature review was conducted to identify the causes of rework in building construction projects, resulting in 62 rework causes being identified. A pilot survey was conducted to evaluate the questionnaire's structure and to identify rework causes from experts in the Egyptian construction industry. Based on the experts' opinions, 33 causes were selected from previous studies, and an additional 29 causes were added. These 62 causes were categorized into eight work item categories: excavation and backfilling works, concrete works underground, insulation works, concrete works above ground, building works, carpentry works, electricity works, and sewage works, as presented in **Table 1**.

3.2. Survey of Questionnaire

Following the experts' recommendations, the final questionnaire was adjusted and distributed to 120 construction professionals, including designers, contractors, and project managers. Before receiving the questionnaire, each participant was informed about the research objectives through a phone call, and their consent was obtained. The questionnaire was then delivered either by hand or via email as a soft copy. A total of 100 questionnaires were returned, with the respondents comprising 30% designers, 50% contractors, and 20% project managers, as presented in **Fig. 2**.

The questionnaire required participants to rate the likelihood of occurrence of rework causes and the extent of their impact on project cost and time using a 5-point scale ranging from very low to very high. Additionally, respondents were asked to provide any additional factors that they deemed relevant at the end of the questionnaire. Statistical methods such as Pearson correlation and Cronbach's alpha coefficients were used to analyze the data, followed by calculating the averages and standard deviations to obtain the questionnaire results.

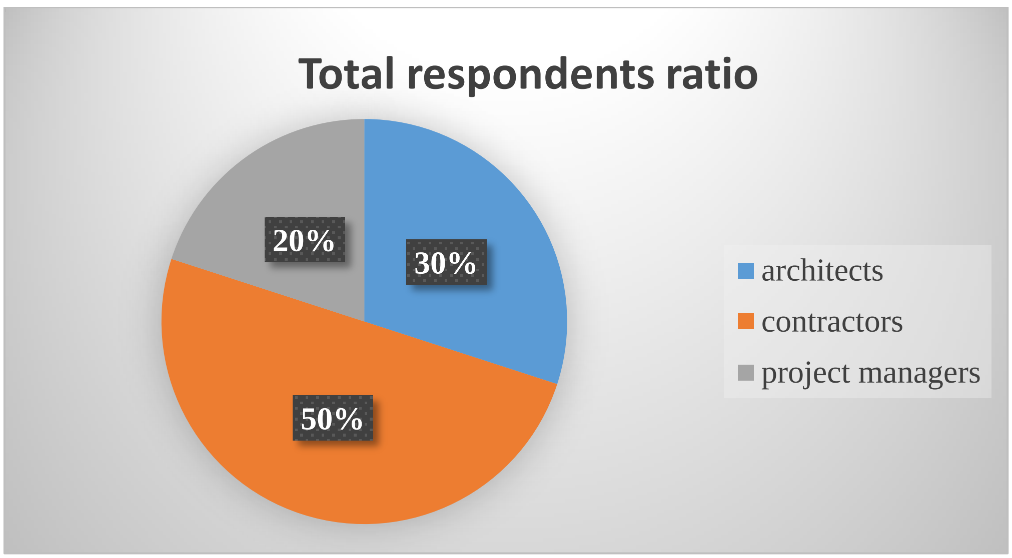

Fig. 2: Total respondents ratio

Table 1: Rework causes of building construction projects in Egypt

Groups	Type of work	Rework causes	Main sources
Underground works	A. Excavation and backfilling works	A.1 Omission of the uncertainty of the location stake out.	Kotb et al. [19], Elsherbiny [25]. Mohamed et al. [21].
		A.2 Errors caused by the wrong construction method such as failure to conduct a soil test.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		A.3 Bad work such as failing to support the sides of the excavation.	Eze & idiake [4].
		A.4 Uncertainty about the existence of work obstacles such as drainage lines or electricity lines.	Added (pilot study)
		A.5 Omission of activities such as neglecting the positioning of the columns.	Kotb et al. [19], Elsherbiny [25], Mohamed et al.

			[21].
		A.6 Damages of concrete erosion because of backfilling with loamy soil.	Eze & idiake [4], Kotb et al. [19].
		A.7 Creating tanks or orchards below the foundation level.	Added (pilot study)
		A.8 Lack of consideration of the underground water table.	Added (pilot study)
	B. Concrete works	B.1 The use of cement or materials that don't conform to specifications	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		B.2 Lack of consideration of the Egyptian code in the implementation of concrete structures.	Added (pilot study)
		B.3 Use of poor-quality foundation type.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		B.4 Lack of consideration for the construction joints' works.	Added (pilot study)
		B.5 Poor implementation of the construction joints according to the specification of the patch.	Eze & idiake [4], Elsherbiny [25].
		B.6 The presence of concrete honeycombing due to the lack of compaction during casting.	Added (pilot study)
		B.7 Lack of application of the concrete industry technology.	Khalesi et al. [23], Elsherbiny [25].
		B.8 The emergence of underground water.	Added (pilot study)
		B.9 Design mistakes in the thickness of the foundations.	Khalesi et al. [23], Elsherbiny [25], Mohamed et al. [21].
		B.10 Modifications of the concrete structure.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
	C. Insulation works	C.1 Defects of lack of cleanliness of the insulation surface.	Kotb et al. [19], Elsherbiny [25], Mohamed et al. [21].
		C.2 Use of local materials that allow pores and water penetration.	Alinaitwe et al. [6], Adam et al. [13].
		C.3 Lack of usage of materials such as epoxy and fiber.	Added (pilot study)
		C.4 Poor professional supervision on the implementation of isolation.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		C.5 Poor workmanship such as failure to adjust the mixing proportions of insulating materials.	Ajayi & Oyeyipo [9], Kotb et al. [19], Jadhav et al. [22].
Above-ground works	D. Concrete works	D.1 Pouring the columns from a height of more than 3 m at once, and the existence of honeycombing in the concrete.	Added (pilot study)
		D.2 Nonconformity of the reinforcement works to engineering specifications.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		D.3 Using hardened cement due to weather conditions.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		D.4 Poor engineering supervision and follow-up, which leads to nonconforming work.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		D.5 The decline and cracking of the buildings as a result of increased	Added (pilot study)

		levels of salts and sulfates in the soil or iron rust.	
		D.6 Falling of the ceiling due to weak reinforcement.	Added (pilot study)
		D.7 F Poor implementation of construction joints in accordance with the specifications of the ceiling.	Eze & idiake , Elsherbiny [4].
		D.8 Failure to take into account the application of concrete industry technology.	Khalesi et al. [23], Elsherbiny [25].
		D.9 Mandatory architectural modification.	Jadhav et al. [22], Mohamed et al. [21], Elsherbiny [25].
	E. Building works	E.1 Poor workmanship in building walls.	Kotb et al. [19], Jadhav et al. [22], Elsherbiny [25].
		E.2 Failure to adjust the wall verticality and use of plumb bobs.	Added (pilot study)
		E.3 Not taking into account that the joints are not on top of each other.	Added (pilot study)
		E.4 Not spraying the bricks with water before construction.	Added (pilot study)
		E.5 Failure to make thresholds that match the specifications.	Added (pilot study)
		E.6 Lack of consideration of the industry principles.	Added (pilot study)
		E.7 The existence of an architectural modification.	Jadhav et al. [22], Elsherbiny [25], Mohamed et al. [21].
	F. Carpentry works	F.1 Use of defective wood.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		F.2 The wooden formwork is not designed to withstand ceiling loads.	Added (pilot study)
		F.3 Failure to observe the vertical and horizontal settings.	Added (pilot study)
		F.4 Uncertainty about the horizontality of the wooden ceiling.	Added (pilot study)
		F.5 Weak attachment of door frames with concrete.	Added (pilot study)
		F.6 The presence of inclinations in the door frames.	Added (pilot study)
		F.7 Neglecting to put thresholds for doors and windows.	Added (pilot study)
	G. Electricity works	G.1 Use of poor-quality of wires and hoses.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		G.2 Failure to make electrical plans and employing engineers outside of their specialty.	Ajayi & Oyeyipo [9], Kotb et al. [19].
		G.3 Damage of undistributed loads in a professional engineering method, which leads to short circuit work and breakdown of switches.	Eze & idiake [4], Kotb et al. [19].
		G.4 Not placing the hoses in the roof during the casting process.	Added (pilot study)
		G.5 Use of poor quality cables.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		G.6 Placing electrical panels for each floor in inappropriate places.	Added (pilot study)
	H. Sewage works	H.1 Lack of the required isolation.	Added (pilot study)
		H.2 Misplacing the sanitary devices in their correct places.	Added (pilot study)
		H.3 Defects such as breakage in the plumbing installations under the floors.	Eze & idiake [4], Kotb et al. [19], Mohamed et al. [21].
		H.4 Damage of failure to adjust the water pipes which leads to	Eze & idiake [4],

		leaking in the welds.	Kotb et al. [19].
		H.5 Failure to observe public spending rates upon incorporation.	Added (pilot study)
		H.6 The use of unapproved and nonconforming pipes.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		H.7 Sink heights aren't taken into account.	Added (pilot study)
		H.8 Making changes in the design during implementation by the owner.	Jadhav et al. [22], Khalesi et al. [23], Elsherbiny [25].
		H.9 The diameter of the executed pipes is in violation of the drawings.	Added (pilot study)
		H.10 Ignoring the importance of plumbing and considering it sanitary works as a secondary matter.	Jadhav et al. [22], Elsherbiny [25], Mohamed et al. [21].

4. DATA ANALYSIS

4.1. Coefficients of Validity and Reliability

To establish the reliability of the questionnaire, a Cronbach's reliability coefficient approach was utilized. Cronbach (1951) suggested that a coefficient between 0.6 and 0.8 indicates acceptable reliability, while a coefficient greater than 0.8 indicates preferable reliability. As presented in Table 2, all of Cronbach's α coefficients were greater than 0.8, indicating good reliability for all items.

Table 2: The Coefficients of validity and reliability values for the questionnaire

phases	Study variables	Number of Phrases	Cronbach's Alpha coefficient values	Validity's coefficient
Underground works	Excavation and backfilling works	8	0.855	0.924
	Concrete works	10	0.879	0.937
	Insulation works	5	0.879	0.937
	Underground works	23	0.866	0.930
Above ground works	Concrete works	9	0.886	0.941
	Building works	7	0.845	0.919
	Carpentry works	7	0.866	0.930
	Electricity works	6	0.883	0.939
	Sewage works	10	0.872	0.933
The final result		62	0.881	0.938

To sort the rework causes in descending order according to their impact on project cost and time according to participants' opinions (**Table 3** and **Table 4**).

- The frequency of occurrence of rework causes (F) was computed according to Equ (1) (Mahamid [10]):
  $F = \Sigma a(n/N) * 100 / 5$,   Equ.1

  Where a: represents a constant that indicates the weight assigned to each response, which ranges from 1 (very low) to 5 (very high). n refers to the frequency of the responses, while N represents the total number of responses.

- The impact index on project cost (IC) and the impact index on project time (IT) were calculated according to Equ (2) and Equ (3):
  $IC = \Sigma a(n/N) * 100 / 5$,   Equ.2

  $IT = \Sigma a(n/N) * 100 / 5$,   Equ.3

  Where a: represents a constant that indicates the weight assigned to each response, which ranges from 1 (very low) to 5 (very high). n refers to the frequency of the responses, while N represents the total number of responses.

- The expected impact index on project cost (EIC) and the expected impact index on project time (EIT) were calculated as a function of both frequency and impact indices according to Equ (4) and Equ (5):
  $EIC = F(\%) * IC / 100$,   Equ.4

  $EIT = F(\%) * IT / 100$,   Equ.5

- The expected total impact index (ETI) on both project cost and time was calculated as a function of both the expected impact index on project cost and the expected impact index on project time according to Equ (6):
  $ETI = [W1 * EIC + W2 * EIT]/100$ Equ.6

  Where W1, W2 represent a constant; ($0 \leq W \leq 1$), weighted based on participants' opinion.

- To calculate the effect of underground and above-ground works on the probability of rework occurrence and cost and time, the group index was computed by taking the average of the causes in each group, as shown in Eqn (7) (Mahamid [10]):
  $\textbf{Mean} = \sum^{n} Xi/n$ Equ.7

  Here, Xi is the sum of the severity of cause i in the group, while n represents the number of causes in the group.

5. RESULTS AND DISCUSSION

After analyzing the questionnaire, the results of the questionnaire were divided into two parts:

5.1. The Factors contributing significantly to Rework in Egyptian Building Projects

Table 3: Overall cause ranking

Causes	F (%)	IC (%)	IT (%)	EIC (%)	EIT (%)	ETI (%)	verall rank
H.10 Ignoring the importance of plumbing and considering it sanitary works as a secondary matter.	70.09	72.73	73.33	50.98	51.40	51.19	1
H.1 Lack of the required isolation.	68.78	72.91	71.14	50.15	48.93	49.54	2
B.8 The emergence of underground water.	73.86	65.52	66.52	48.39	49.13	48.76	3
G.3 Damage of undistributed loads in a professional engineering method, which leads to short circuit work and breakdown of switches.	64.32	75.41	75.73	48.50	48.71	48.61	4
D.4 Poor engineering supervision and follow-up, which leads to nonconforming work.	66.67	71.95	72.18	47.97	48.12	48.05	5
H.4 Damage of failure to adjust the water pipes which leads to leaking in the welds.	64.14	73.51	73.77	47.15	47.32	47.24	6
D.5 The decline and cracking of the buildings as a result of increased levels of salts and sulfates in the soil or iron rust.	62.84	76.09	74.02	47.81	46.51	47.16	7
H.3 Defects such as breakage in the plumbing installations under the floors.	64.94	72.82	72.15	47.29	46.85	47.07	8
G.2 Failure to make electrical plans and employing engineers outside of their specialty.	67.57	69.33	68.68	46.85	46.41	46.63	9
C.4 Poor professional supervision on the implementation of isolation.	72.66	63.15	62.25	45.88	45.23	45.56	10
D.9 Mandatory architectural modification.	67.43	66.44	68.64	44.80	46.28	45.54	11
A.4 Uncertainty about the existence of work obstacles such as drainage lines or electricity lines.	70.29	62.17	65.38	43.69	46.96	44.83	12
H.8 Making changes in the design during implementation by the owner.	67.58	67.30	65.07	45.48	43.97	44.73	13
C.2 Use of local materials that allow pores and water penetration.	65.86	68.71	66.35	45.25	43.69	44.47	14
G.5 Use of poor quality cables.	62.56	71.39	70.42	44.66	44.05	44.36	15
A.2 Errors caused by the wrong construction method such as failure to conduct a soil test.	62.72	69.89	71.06	43.84	44.57	44.21	16
B.6 The presence of concrete honeycombing due to the lack of compaction during casting.	72.89	61.56	59.12	44.87	43.09	43.98	17
B.3 Use of poor-quality foundation type.	58.70	73.91	75.32	43.39	44.21	43.80	18
D.1 Pouring the columns from a height of more than 3 m at once, and the existence of honeycombing in the concrete.	67.04	65.84	62.95	44.14	42.20	43.17	19
B.1 The use of cement or materials that don't conform to specifications.	60.22	71.83	70.64	43.26	42.54	42.90	20
F.2 The wooden formwork is not designed to	60.24	71.57	70.71	43.11	42.60	42.86	21

withstand ceiling loads.							
G.1 Use of poor-quality of wires and hoses.	60.68	71.28	69.74	43.25	42.32	42.79	22
A.8 Lack of consideration of the underground water table.	62.59	67.64	67.83	42.34	42.45	42.40	23
E.7 The existence of an architectural modification.	65.89	62.59	64.94	41.24	42.79	42.03	24
H.5 Failure to observe public spending rates upon incorporation.	59.74	70.00	70.26	41.82	41.97	41.90	25
C.5 Poor workmanship such as failure to adjust the mixing proportions of insulating materials.	67.83	62.07	60.45	42.10	41.00	41.55	26
H.7 Sink heights aren't taken into account.	64.98	63.95	62.82	41.55	40.82	41.19	27
D.3 Using hardened cement due to weather conditions.	56.32	73.33	72.05	41.30	40.58	40.94	28
A.3 Bad work such as failing to support the sides of the excavation.	59.22	69.36	68.84	41.07	40.77	40.92	29
H.6 The use of unapproved and nonconforming pipes.	60.61	67.44	66.84	40.88	40.51	40.70	30
F.1 Use of defective wood.	61.90	65.48	63.33	40.53	39.20	39.87	31
G.6 Placing electrical panels for each floor in inappropriate places.	62.04	63.56	64.59	39.43	40.07	39.75	32
B.7 Lack of application of the concrete industry technology.	68.22	58.84	56.55	40.14	38.58	39.36	33
D.6 Falling of the ceiling due to weak reinforcement.	53.03	73.95	74.25	39.22	39.37	39.30	34
B.10 Modifications of the concrete structure.	54.79	71.95	71.01	39.42	38.91	39.17	35
E.1 Poor workmanship in building walls.	61.90	61.88	63.49	38.30	39.30	38.80	36
C.3 Lack of usage of materials such as epoxy and fiber.	64.04	61.15	59.07	39.16	37.83	38.50	37
C.1 Defects of lack of cleanliness of the insulation surface.	67.42	57.05	56.55	38.46	38.13	38.30	38
E.6 Lack of consideration of the industry principles.	62.65	61.19	60.71	38.34	38.03	38.19	39
D.8 Failure to take into account the application of concrete industry technology.	62.25	63.61	61.95	39.60	36.56	38.08	40
E.2 Failure to adjust the wall verticality and use of plumb bobs.	62.40	60.70	61.15	37.88	38.16	38.02	41
F.3 Failure to observe the vertical and horizontal settings.	58.23	64.15	65.06	37.35	37.88	37.62	42
B.9 Design mistakes in the thickness of the foundations.	55.06	70.23	69.53	36.67	38.28	37.48	43
B.5 Poor implementation of the construction joints according to the specification of the patch.	58.89	64.22	62.44	37.82	36.77	37.30	44
B.2 Lack of consideration of the Egyptian code in the implementation of concrete structures.	58.89	62.64	63.44	36.89	37.36	37.13	45
B.4 Lack of consideration for the construction joints' works.	60.87	61.09	60.86	37.19	37.05	37.12	46
A.5 Omission of activities such as neglecting the positioning of the columns.	55.20	66.38	67.53	36.64	37.28	36.96	47
F.4 Uncertainty about the horizontality of the wooden ceiling.	57.14	64.00	64.63	36.57	36.93	36.75	48
A.1 Omission of the uncertainty of the location stake out.	53.41	66.32	70.11	35.42	37.45	36.44	49
H.9 The diameter of the executed pipes is in	52.89	67.53	69.49	35.72	36.75	36.24	50

violation of the drawings.							
G.4 Not placing the hoses in the roof during the casting process.	51.32	70.81	69.07	36.34	35.45	35.90	51
D.2 Nonconformity of the reinforcement works to engineering specifications.	56.67	56.67	69.44	32.11	39.35	35.73	52
H.2 Misplacing the sanitary devices in their correct places.	55.13	64.94	64.10	35.80	35.34	35.57	53
D.7 F Poor implementation of construction joints in accordance with the specifications of the ceiling.	57.20	61.63	62.30	35.25	35.64	35.45	54
A.6 Damages of concrete erosion as a result of backfilling with loamy soil.	55.30	63.11	64.40	34.89	35.61	35.25	55
F.5 Weak attachment of door frames with concrete.	58.75	57.14	57.95	33.57	34.05	33.81	56
F.6 The presence of inclinations in the door frames.	59.67	55.95	56.54	33.39	33.74	33.57	57
E.5 Failure to make thresholds that match the specifications.	59.39	52.94	52.33	31.44	31.08	31.26	58
A.7 Creating tanks or orchards below the foundation level.	51.63	60.24	60.00	31.10	30.98	31.04	59
E.3 Not taking into account that the joints are not on top of each other.	53.64	55.12	55.53	29.67	29.79	29.73	60
E.4 Not spraying the bricks with water before construction.	61.63	48.71	46.74	30.02	28.81	29.42	61
F.7 Neglecting to put thresholds for doors and windows.	48.78	59.01	57.32	28.79	27.96	28.38	62

Table 4: Overall items ranking

Items	F (%)	IC (%)	IT (%)	EIC (%)	EIT (%)	ETI (%)	Overall rank
H. Sewage works	62.89	69.31	68.90	43.59	43.33	43.46	1
G. Electricity works	61.41	70.29	69.71	43.17	42.81	42.99	2
D. Above ground concrete works	61.05	69.26	68.64	42.28	41.90	42.09	3
C. Insulation works	67.56	62.42	60.94	42.17	41.17	41.67	4
B. Underground concrete works	62.24	66.17	65.54	41.18	40.79	40.99	5
A. Excavation and backfilling works	58.79	65.63	66.89	38.58	39.32	38.95	6
F. Carpentry works	57.82	62.47	62.22	36.12	35.98	36.05	7
E. Building works	61.07	57.58	57.84	35.16	35.32	35.24	8

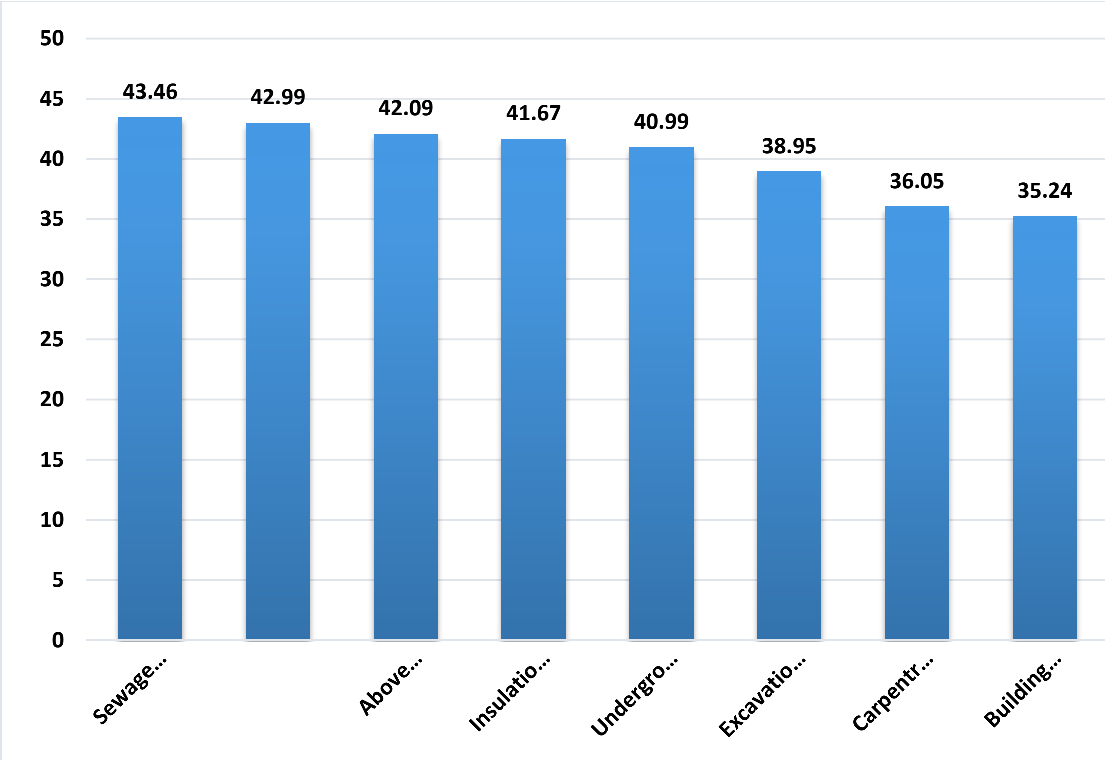

Fig. 3: Ratios of overall items ranking

As shown in **Table 3**, the top five causes that contribute to rework in Egyptian building projects are incompetent sewer workers (group H; sewage works). Lack of pipes insulation (group H; sewage works). The emergence of underground water (group B; underground concrete works). Improper distribution of loads (group G; electricity works) and poor supervision of concrete works (group D; above-ground concrete works).

- Seven causes of rework in group A (Excavation and backfilling works), with the most significant cause being "Uncertainty of underground obstacles," ranking 12th among all rework causes. In group B (Underground concrete works), there are nine causes of rework, with the most important cause is the "Emergence of underground water," ranking 3rd among all rework causes. Previous research by Adam et al. [13] and Al Hazm et al. [14] also identified ground conditions as a primary cause of rework in construction projects.

- In addition, there are five causes of rework in group C (Insulation works), with the most significant cause being the "Lack of competent insulation workers," ranking 10th among all rework causes. In group H (Sewage works), there are nine causes of rework, with the most important cause being "Incompetent sewer workers," ranking 1st among all rework causes.

Previous research by Zaki et al. [18], Khalesi et al. [23], and Mahamid [21] have also identified a lack of labor and poor productivity as top causes of rework in construction projects.

- Nine causes of rework in group D (Above ground concrete works), with the most significant cause being "Poor supervision of concrete works," ranking 5th among all rework causes. Previous research by Kotb et al. [19], Johnson et al. [24], Jadhav et al. [22], and Mahamid [21] also identified poor site management and supervision as a top cause of rework in construction projects.

- Five causes of rework in group E (Building works), with the most significant cause being "Architectural modifications of building works," ranking 23rd among all rework causes. Previous research by Zaki et al. [18], Kotb et al. [19], Abdelbary et al. [20], and Mohamed et al. [21] also identified modification requests as a top cause of rework in construction projects.

- Six causes of rework in group F (Carpentry works), with the most significant cause being "Lack of design of formwork," ranking 21st among all rework causes. In group G (Electricity works), there are five causes of rework, with the most important cause being "Improper distribution of loads," ranking 4th among all rework causes. Previous research by Mohamed et al. [21] also identified a lack of design or errors as a top cause of rework in construction projects.

6. SUMMERY AND CONCLUSION

The objective of this study was to identify the principal causes of rework in building construction projects in Egypt and their impact on project cost and time. To achieve this aim, a comprehensive literature review was conducted to identify the various causes of rework, and semi-structured interviews with experts were conducted to determine the most appropriate reasons for rework on Egyptian construction projects. Based on the above findings and discussions, the following conclusions can be drawn:

1) Sewage works, electricity works, insulation works, and concrete works are common areas that are susceptible to rework in the context of building projects in Egypt.
2) The top five causes of rework identified are incompetent sewer workers, lack of pipes insulation, the emergence of underground water, improper distribution of electric loads, and poor supervision of concrete works.

3) In general, the top causes of rework are related to site conditions, lack of competent labor, poor site supervision, modification requests, and design issues.
4) The results of the study demonstrate that the causes of rework in concrete works carry the greatest significance and have a considerable impact on project cost and time.
5) These findings can aid project stakeholders in comprehending the causes of rework and their effects on building construction projects in Egypt, enabling them to implement necessary measures to prevent or mitigate their impact on project performance.

For future research, it is recommended to develop a user-friendly tool for evaluating the impact of rework causes on a project. Additionally, exploring the feasibility of using Building Information Modelling (BIM) to minimize the occurrence of rework and enhance project performance is suggested.

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CONFLICT OF INTEREST

The authors have no financial interest to declare in relation to the content of this article.

REFERENCES

[1] Hwang, B. G., Zhao, X., & Yang, K. W. (2019). Effect of BIM on rework in construction projects in Singapore: status quo, magnitude, impact, and strategies. Journal of Construction Engineering and Management, 145(2), 04018125.

[2] Fayek, A. R., Dissanayake, M., & Campero, O. (2004). Developing a standard methodology for measuring and classifying construction field rework. Canadian journal of civil engineering, 31(6), 1077-1089.

[3] P.E. Love, D.J. Edwards, Forensic project management: The underlying causes of rework in construction projects, Civil Engineering and Environmental Systems. (2004) Sep 1; 21(3):207-28. https://doi.org/10.1080/10286600412331295955

[4] E.C. Eze, J.E. Idiake, Impact of rework on building project and organisation performance: A view of construction professionals in Nigeria, International Journal of Sustainable Construction Engineering and Technology. (2018) Mar 20; 9(1):29-43. https://doi.org/10.30880/ijscet.2018.09.01.003

[5] P.E. Love, P. Mandal, J.Smith, H. Li, Modelling the dynamics of design error induced rework in construction, Construction Management and Economics. (2000) Jul 1; 18(5):567-74. https://doi.org/10.1080/014461900407374

[6] H Alinaitwe, R. Apolot, D. Tindiwensi, Investigation into the causes of delays and cost overruns in Uganda's public sector construction projects, Journal of Construction in Developing Countries. (2013) Jul 1; 18(2): 33.
[7] P. Ekambaram, P.E. Love, M.M. Kumaraswamy, T.S. Ng, Causal ascription of rework in building and civil engineering projects, Engineering ,Construction and Architectural Management. (2014) Jan 14. https://doi.org/10.1108/ECAM-04-2010-0029

[8] K. Shen, X. Li, X. Cao, Z. Zhihui, Research on the rework risk core tasks in prefabricated construction in China, Engineering, Construction and Architectural Management. (2021) Jan 11. https://doi.org/10.1108/ECAM-07-2020-0521
[9] O. Ajayi, O. Oyeyipo, Effect of rework on project performance in building project in Nigeria, International Journal of Engineering Research & Technology (IJERT). (2015) Feb; 4(02):294-300.
[10] I .Mahamid, Analysis of rework in residential building projects in Palestine, Jordan Journal of Civil Engineering. (2016); 10(2). https://doi.org/10.14525/JJCE.10.1.3536
[11] A. Enshassi, M. Sundermeier, M.A. Zeiter, Factors contributing to rework and their impact on construction projects performance, International Journal of Sustainable Construction Engineering and Technology. (2017) May 3; 8(1):12-33. https://doi.org/10.11113/ijbes.v5.n1.246
[12] I. Mahamid, Study of relationship between rework and labor productivity in Building Construction Projects, Revista de la construcción. (2020) Apr; 19(1):30-40. https://doi.org/10.7764/rdlc.19.1.30-41
[13] A. Adam, P.E. Josephson, G. Lindahl , Aggregation of factors causing cost overruns and time delays in large public construction projects, Engineering, construction and architectural management. (2017) May 15. https://doi.org/10.1108/ECAM-09-2015-0135
[14] N. Al-Hazim, Z.A.Salem, H. Ahmad, Delay and cost overrun in infrastructure projects in Jordan, Procedia Engineering. (2017) Jan 1; 182:18-24. https://doi.org/10.1016/j.proeng.2017.03.105
[15] S. Durdyev, M. Omarov, S. Ismail, Causes of delay in residential construction projects in Cambodia, Cogent Engineering. (2017) Jan 1; 4(1):1291117. https://doi.org/10.1080/23311916.2017.1291117
[16] N. Forcada, M. Gangolells, M. Casals, M. Macarulla, Factors affecting rework costs in construction, Journal of Construction Engineering and Management. (2017) Aug 1; 143(8):04017032. https://doi.org/10.1061/(ASCE)CO.1943-7862.0001324
[17] G.A. Niazi, N. Painting, Significant factors causing cost overruns in the construction industry in Afghanistan, Procedia Engineering. (2017) Jan 1; 182:510-7. https://doi.org/10.1016/j.proeng.2017.03.145
[18] A. Zaki, A.M. Elalim, A. El Samadony, Factors Affecting Schedule Delay and Cost Overrun in Egyptian Construction Projects, InProceedings of the 2nd International

Conference Sustainable Construction and Project Management-Sustainable Infrastructure and Transportation for Future cities, Aswan, Egypt (2018) Dec (pp. 16-18).

[19] M.H. Kotb, A.S. Aly, E.K. Muhammad, Risk Assessment of Time and Cost Overrun Factors throughout Construction Project Lifecycle, Life Sci. J. (2019); 16:78-91. https://doi.org/10.14419/ijet.v7i3.20.22980

[20] M. Abdelbary, A. Edkins, E.M. Dorra, Reducing CRR in fast-track projects through BIM, (2020), ITcon, 25, 140-160. https://doi.org/10.36680/j.itcon.2020.009

[21] H. H. Mohamed, A. H. Ibrahim, A. A. Soliman, Factors Affecting Upstream Production Rate and Causing Reworks in Downstream Activities due to Activities Overlapping, American Journal of Civil Engineering and Architecture, (2021), 9(1), 1-8. https://doi.org/10.12691/ajcea-9-1-1

[22] D. Jadhav, B.A. Konnur, S. Patil, Analysis of Factors Causing Cost Overruns in Residential Building Construction Projects, International Journal of Research in Engineering, Science and Management.(2020) Jul 27; 3(7):308-11.

[23] H. Khalesi, A. Balali, A.Valipour, J. Antucheviciene, D. Migilinskas, V. Zigmund, Application of Hybrid SWARA–BIM in Reducing Reworks of Building Construction Projects from the Perspective of Time, Sustainability. (2020) 12(21), 8927. https://doi.org/10.3390/su12218927

[24] R. M. Johnson, R. I. I. Babu, Time and cost overruns in the UAE construction industry: a critical analysis, International Journal of Construction Management. (2020)20(5), 402-411. https://doi.org/10.1080/15623599.2018.1484864

[25] A. Elsherbiny, Prediction of Design Error Rework Cost in Epc Industrial Projects (Doctoral dissertation, The George Washington University), (2021).