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Risk Management of Highly Constrained Construction Projects

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Abstract.

Risk management of highly constrained construction projects is a valuable process to achieve project goals, minimize threats, and improve the performance of the projects. Constraints are the main obstacles to meeting the project targets. Every project has at least one constraint so the case of Constructing a construction project with ideal performance without any constraints is a theoretical case. Existing constraints are positive issues to determine the performance of a system, gradually elevation for them, and improving its performance. This research aims to determine the current risk factors of highly constrained construction projects. Qualitative and quantitative analysis for them using improved questionnaire tools that help in project enhancement. After using a wide literature review, the study listed 34 risk factors divided into nine categories. Then, we designed a questionnaire and distributed it to rank these factors according to their probability and impact on time and cost. Based on two methods in evaluating (Relative Important Index and a modified fuzzy group decision-making approach (FGDMA)), we performed a statistical analysis for all collected data using (Statistical Package for the Social Sciences) SPSS Ver.25 software, Analyzing the reliability, Cronbach’s alpha coefficient, Chi-Square Test, Person correlation, T-test, and using ANOVA analysis to find out the effect of all independent variables on dependent variables.

Keywords: Constraints, Theory of constraints, Risk assessment, qualitative analysis, quantitative analysis, schedule overrun, cost overrun, probability, impact, relative important index, fuzzy logic, response planning, simulation, forecasting, statistical analysis.

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1 Introduction

The construction industry is the most active, risky, and demanding sector. Complexity, restrictions, financial worries, and party conflicts are particularly risky in building projects. Furthermore, they require the engagement of many people with different skills in dealing with hazards through the use of equipment, varied technologies, and applications. Highly constrained construction projects face several constraints that must be identified using the Theory of limitations (TOC) and then managed to assist prevent delays, cost overruns, and poor-quality work (Bhavsar and Solanki 2020).

Risk assessment and management are key concerns. They form the framework for a construction company's decision-making process. Because of the nature of construction business operations, methods, environment, and organization, the construction industry and its customers face significant risks as a result of project delays and cost overruns. As consequently, risk assessment plays an essential role in construction projects(Abdelalim 2018). Owners cause unexpected cost increases and delays in construction projects, contractors, surroundings, and other risk variables that may occur concurrently. Cost overruns and schedule delays have an impact not only on the construction industry but also on the whole economy (Abdelalim 2018), (Abd El-Karim, Mosa El Nawawy et al. 2017) . Because of risks on construction project productivity, performance, quality, and scope, the construction sector tries to find alternative approaches to reduce risks, minimize their consequences, enhance opportunities, and improve their benefits.

This paper uses two methods (Relative importance index (RII) and a modified fuzzy group decision-making approach (FGDMA)) for the risk analysis of highly constrained construction projects and assesses the cost overrun risks and the time overrun risks.

2 Literature Review

Many previous researches have dealt with constraints that affect construction projects and the role of the Theory of Constraints (TOC) in identifying these constraints, categorizing them, and then trying to find solutions to diminish them.(Gupta and Boyd 2008) defined constraint as anything that limits the performance of a system toward its goal.

Also (Bhavsar and Solanki 2020), (Mishra and Moktan 2019)used the Theory of constraints (TOC) to determine the constraints of construction projects and study the reasons behind the occurrence of these kinds of constraints. They provided a specific methodology for identifying and eliminating the system constraints using (TOC) by moving on five focusing steps:

1.Identify the system constraints.
2.Decide how to exploit the system constraints.
3.Subordinate everything else to the above decision.
4.Elevate the system constraints.
5. In the previous steps, go back to step one if the constraint is broken, but do not allow inertia to cause a system constraint.

(Bhavsar and Solanki 2020) made a questionnaire to determine the most effective constraints on projects by data gathering from previous studies and projects. The questionnaire includes 43 limiting factors(constraints), the constraints divided into five main groups:

- Economic constraints.
- Legal constraints.
- Environmental constraints.
- Technical constraints.
- Social constraints.

They received 42 responses from the questionnaire survey and collected data analyzed to find the most effective constraints affecting the construction projects. They applied the Importance Performance Analysis method to the questionnaire. From research, the Legal Constraint and the factors falling under this section responsible for the delay is a major one.

According to (Sharaf and Abdelwahab 2015),(Yousri, Sayed et al. 2023),(Rizk Elimam, Abdelkhalek et al. 2022) risk is the combination of probability of an event and its impacts on project objectives. A positive consequence presents an opportunity, and a negative one poses a threat, meaning its management process is necessary to control project performance. (Abdelalim 2018), (Ahmed Mohamed Abdelalim1 2016) explained that Risk management is a systematic process to define, analyze, and respond to the system's risk. It's a decision-making process that enables the organization to exploit opportunities by increasing the probability and frequency period of desired occurrences and decreasing the negative consequences of undesired occurrences.

(Bahamid and Doh 2017), (Dziadosz and Rejment 2015) mentioned that many techniques exist for risk identification, such as brainstorming and workshops, checklists and prompt lists, questionnaires, expert interviews, etc. They were sure there was no single "best method" for risk identification.

Risk could be categorized in many different ways, as (Luka and Ibrahim 2015) categorized risk factors related to risks into management, design, financial and economic, material, Labor- and equipment, client, contractor, Consultant. However, (Abdelalim, El Nawawy et al. 2016) categorized risk into environmental, sub-surface, site location, labor, equipment, material, owner, engineering, design, contractor, project management, financial, political, financial.

(Sigmund and Radujković 2014) categorized risks according to their source. They divided risks into two main groups: external and project risks (internal risks). These two groups are defined mainly through their subgroups. Risk categorization for construction projects on existing buildings including external risks refer to table 1 and internal risks refer to table 2.

Table 1: External Risk

External risks					
Legal risks	Political risks	Economic risks	Social risks	Environment risks	Technical risks
• Laws. • The ownership structure. • Work and construction approvals. • Regulations and standards.	• Political elections. • Government shifts. • Meetings.	• Monetary issues. • Financing type changes. • Inflations.	• Strikes • Culture • Seasonal working	• Floods • Earthquakes • Extreme temperatures • Fires	• Not evidenced changes • Historic design • documentation • Past problems register

Table 2: Internal Risk

Internal risks				
Management risks	Design documentation	Human factor	Delivery and logistics	Contractual risks
• Bad control • Not realistic goals • Organization • Arrangements	• Insufficient investigation • Bad design Documentation • Expert estimations	• Omission • Users • Workers Motivation	• Insufficient materials • Not approachable Areas • Not available workers	• Prices • Contract type • Chain of control

Regarding international studies, especially Egyptian studies which mentioned the ranking of the most critical risk factors affecting construction projects in Egypt and other countries due to recent research work,(Sharma and Gupta 2019) identified Critical Risk Factors associated with construction projects along with most top commonly used risk identification techniques and method of classifying risks. The top five identified risks were unavailability of funds, design errors and poor engineering, poor site management and supervision, contractual risks, and changes in laws and regulations.(El-Sayegh, Manjikian et al. 2021)identified and assessed the risks in sustainable construction projects in the UAE.

The top five risks are shortage of client funding, insufficient or incorrect sustainable design information, design changes, unreasonably tight schedules for sustainable construction, and poor scope definition in sustainable construction.(Zou, Zhang et al. 2007)identified key risks present in the construction industry of China. Risks are ranked based on their effect on the project objectives (cost-overrun, time-delays, environment, quality issues, safety, etc.) and the project life cycle. The top 5 identified risks in the Chinese construction industry were the funds problem, lack of contractor experience in proper project management, reimbursement difficulty, no insurance policies taken, and no attention towards construction safety and pollution. (El-Sayegh 2008)examined the risks in the UAE construction industry and determined the top five identified critical ones were price inflation, tight schedule to complete projects, subcontractors' improper management, less productivity, delay and shortage of material, and design changes by owners.(Ameyaw and Chan 2015) evaluated and ranked various risk factors in PPP water supply projects using the fuzzy approach in developing countries. The top five risks found were an unpredicted exchange rate, corruption, bribes, water stealing, delay in payment, and political issues.(Iqbal, Choudhry et al. 2015) studied risk management in construction projects in Pakistan. The top 5 risks in the Pakistan construction industry were payment delays, defective design, lack of funds, construction accidents, and low performance.(Yu, Chan et al. 2018) identified critical risk factors of transnational PPP projects.

The top 5 identified risks were legal risk, tariff risk, cooperation risk between public and private sectors, financing risk, and political risk.(Siraj and Fayek 2019) identified common and top risks in the construction industry. The top identified risks were design errors, inflation rate changes, bad engineering practices, and changes in government laws within the project affecting outcomes.

3 Methods and Techniques

1.1. Research Methodology

The research summarizes its activities, including what constructed and how to do it, and is logically related to the study objectives. The research methodology covers a prior literature review of published work on risk identification and risk sources in highly constrained construction projects. After reviewing and analyzing the existing published work, a structured survey questionnaire was designed and sent out. The acquired data statically analysis was applied using (Statistical Package for the Social Sciences) SPSS Ver.25 software to check the validity and reliability of the questionnaire using (The Pearson correlation coefficient, Cronbach alpha coefficient and chi square test) and to find the effect of all independent variables on dependent variables using (T-test and ANOVA). To evaluate risk according to cost and time impact (Relative importance index approach (RII) and a modified fuzzy group decision-making approach (FGDMA)) applied to score and rank the aspects of risk allocation in construction projects. The authors summarized the methodology as follows:

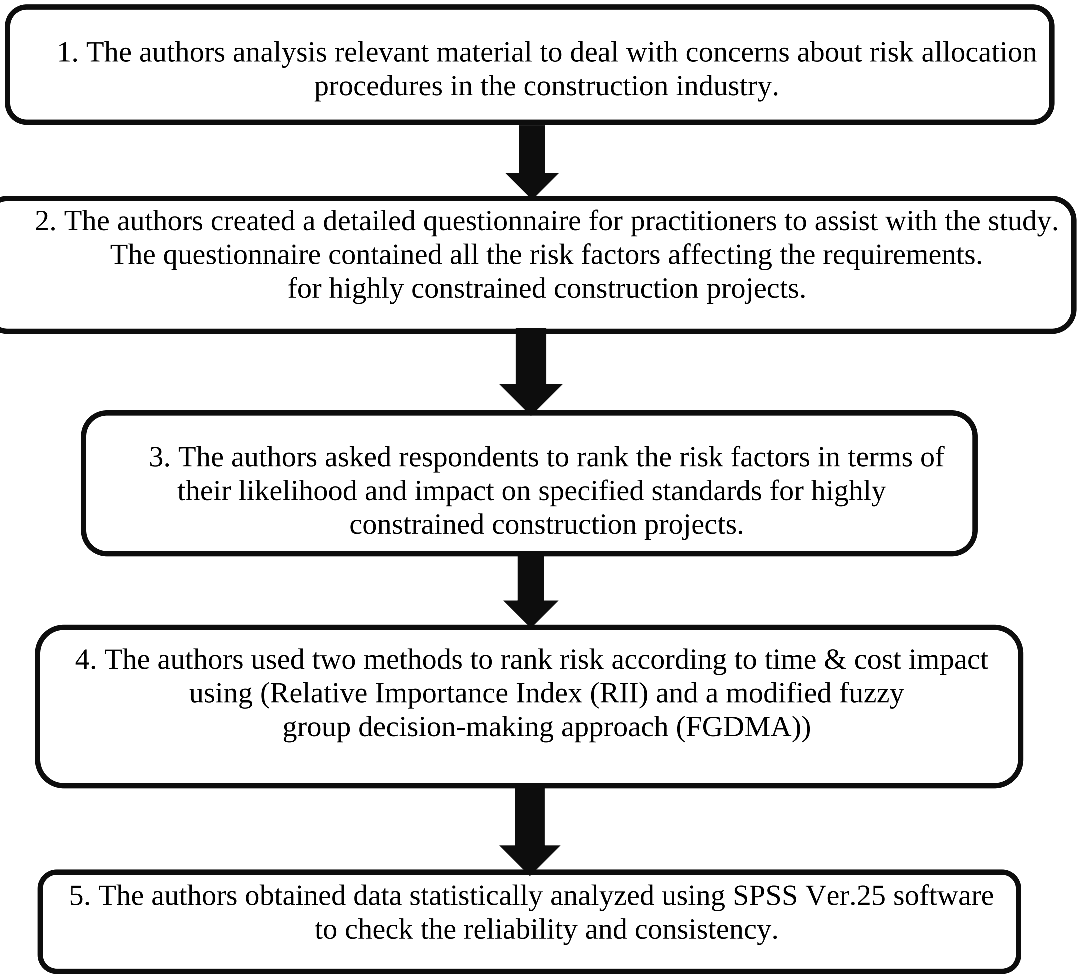

Fig. 1 Research Methodology

1.2. Design of Survey

The questionnaire includes 34 risk attributes divided into nine main groups. It tries to identify the most critical risks to highly constrained construction projects. The writers separated the questionnaire into two parts. The first part contains an overview about practitioners representing their organizations in the building industries. In the second part, respondents were requested to rank risk factors based on a 5-point Likert Scale (1=Very Low, 2=Low, 3=Moderate, 4= High, 5=Very High) in order of probability and cost/time consequences.

The authors created the survey to collect the following sections:

- Risk Factor Probability of Occur.
- The impact of risk on time.
- The impact of risk on cost.

Table 3: Risk factors mentioned in questionnaire.

Effect of Risk on Highly Constrained Construction Projects	
Item	Risk type in construction industry
Risk categories in the construction projects	
Category 1: Engineering and design risk	
1.1	Design error
1.2	Unclear project scope
1.3	Many construction phases
1.4	Design changes during construction
Category 2: Construction risk	
2.1	Poor site coordination and errors in site planning
2.2	Geotechnical problems during construction due to improper soil investi-
2.3	Storage and handling problems (poisonous & flammable)
2.4	Site security and safety issues
Category 3: Material risk	
3.1	Late material delivery
3.2	Defective material
Category 4: Equipment risk	
4.1	Low equipment efficiency / productivity
4.2	Breakdown of equipment
4.3	Rareness imported spare parts
4.4	Poor equipment maintenance
Category 5: Labor risk	
5.1	Unavailability of skilled labors
5.2	Labor strikes
5.3	Skilled labor high wage scales
Category 6: Environment risk	
6.1	Earthquakes
6.2	Unpredicted climate change
6.3	pollution (epidemics)
6.4	Non-compliance with environment laws
Category 7: Contractor risk	
7.1	Poor contractor prequalifications
7.2	Lack of ability and experience
7.3	Improper selection of sub-contractors
7.4	Poor quality and rework
Category 8: Owner risk	
8.1	Owner reputations
8.2	Owner financial stability
8.3	Suspension of work by owner
8.4	Repeat delays of payment
Category 9: Political / Economical risk	
9.1	Laws and regulation changes
9.2	Inflation
9.3	Potential of riots & disturbances
9.4	Rises of taxes rate
9.5	Import / Export restrictions

1.3. Sample Size Determination

According to (Hassanen and Abdelalim 2022) the following equations were used to create a representative sample.

$$ss = \frac{z^2 * p * (1-p)}{e^2} \qquad \text{Eq (1)}$$

Where,

SS: (calculated sample size)

Z: value for the confidence level (e.g., 1.64 for 95% confidence level)

Confidence level indicates the probability with which the estimation of the location of a statistical parameter in a sample survey is also true for the population, With a 95 percent confidence interval, you have a 5 percent chance of being wrong.

p = percentage picking a choice, expressed as decimal

(0.2 used for sample size needed)

e = confidence interval, expressed as decimal

(e.g., o.08 = ±8%).

$$ss = \frac{1.64^2 * 0.2 * (1-0.2)}{0.08^2} = 6 \qquad \text{Eq (2)}$$

Another correction equation involving a known population is:

$$SS_{corr} = \frac{ss}{1+\frac{ss-1}{pop}} \qquad \text{Eq (3)}$$

SScorr: corrected sample size.

pop is the population which is considered for this research as the number of engineers in the construction industry in Egypt, the number of pop is 860,000 by using the equation:

$$SS_{corr} = \frac{68}{1+\frac{68-1}{860000}} = 68 \qquad \text{Eq (4)}$$

That means the number of respondents can't be less than 68 engineers. The questionnaire asks the opinions of project management specialists on questions about the project's existing risk effect and the probability of their occurrence. The authors sent this questionnaire to 150 engineers from the target audience and received 102 useful responses in a month and a half, which is more than the minimum number of responses.

Figure 2 shows the respondents' experience. Figure 3 shows the respondents' company type.

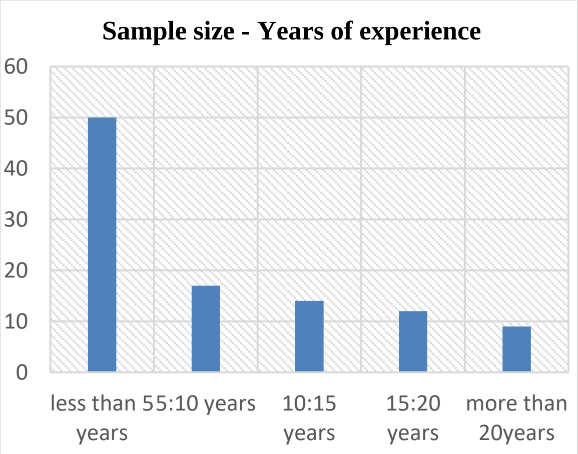

Fig.2 respondent profile; years of experience

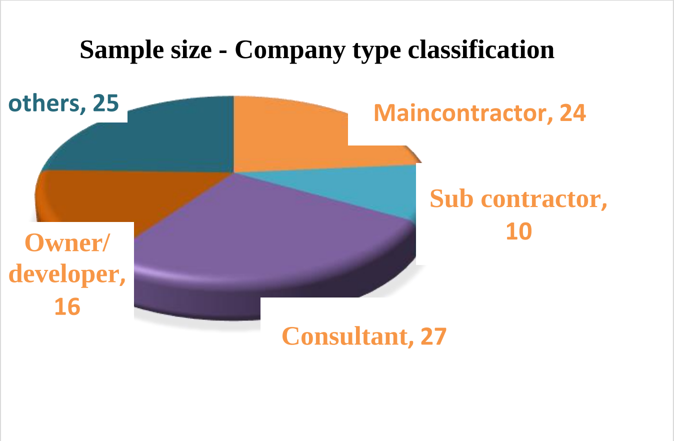

Fig.3 company type classification

1.4. Data Collection and Results Analysis

To carry out this study and analyze the survey results.

- Rank the factors according to time & cost impact using (RII) & (FGDMA).
- Conducting reliability analysis (Cronbach's alpha coefficient) to ensure study assumptions are valid.
- Calculate Pearson correlation to determine the strength of the factors' correlation.
- Calculate Pearson Chi-Square Asymp.
- Calculate Pearson correlation coefficient for probability, time and cost impact.
- Conduct a T-test and ANOVA analysis to assess the influence of independent variables (organization type, size, and experience years) on dependent variables (probability, time, and cost impact).

Ranking Risk factors

The Relative Importance Index (RII) rates factors based on their importance levels. Table (3) shows the Factors of Importance Index Levels for attribute probability, time impact, and cost impact. The categorization factor can be calculated using the table (3).Where X is the lowest index, Y is the highest index, and D is the difference between the highest and smallest RIIs, as shown in the table (4) below.

Table 4: Relative Importance Index (RII) Ranking

<table>
<tr><td rowspan="5">(Probability)</td><td colspan="2">Importance</td><td>Very low</td><td>Low</td><td>Moderate</td><td>High</td><td>Very high</td></tr>
<tr><td colspan="2">From</td><td>0</td><td>20%</td><td>40%</td><td>60%</td><td>80%</td></tr>
<tr><td colspan="2">To</td><td>Up to 20%</td><td>40%</td><td>60%</td><td>80%</td><td>100%</td></tr>
<tr><td rowspan="2">``RII Value</td><td>From</td><td>X</td><td>X+2D+1</td><td>X+4D+1</td><td>X+6D</td><td>X+8D+1</td></tr>
<tr><td>To</td><td>X+2D</td><td>X+4D</td><td>X+6D</td><td>X+8D</td><td>Y</td></tr>
<tr><td rowspan="5">(Cost and Time Impact)</td><td colspan="2">Importance</td><td>Very low</td><td>Low</td><td>Moderate</td><td>High</td><td>Very high</td></tr>
<tr><td colspan="2">From</td><td>0</td><td>20%</td><td>40%</td><td>60%</td><td>80%</td></tr>
<tr><td>To</td><td></td><td>Up to 20%</td><td>40%</td><td>60%</td><td>80%</td><td>100%</td></tr>
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<tr><td>To</td><td>X+2D</td><td>X+4D</td><td>X+6D</td><td>X+8D</td><td>Y</td></tr>
</table>

Ranking Risk Factors by using Fuzzy Group Decision Making Approach (FGDMA)

Fuzzy Group Decision Making Approach used to assess risk factors of highly constrained construction projects and identify cost overrun & time overrun risks affecting those kinds of projects.

According to (Islam, Nepal et al. 2019) the (FGDMA) method is as follows.

1- The linked linguistic phrase's fuzzy triangular number (FTN) is derived from the situation and description in Table (4). Triangular fuzzy numbers are extremely useful for decision makers since they provide a three-point estimate (0.5, 0.7, and 0.9) rather than exact risk assessments. It provides for the carrying out of appropriate risk management measures during the project's execution phases.

Table 5: Linguistic variables and the associated fuzzy numbers

Level of risk of risk Probability / consequences	Fuzzy triangular number (FTN)	Defuzzied number range	Description
Very high	0.7, 0.9, 1	0.7 to < 0.9	There is a significant probability of the risk event occurring, with the most major consequence involving cost and time overrun.
High	0.5, 0.7, 0.9	0.5 to < 0.7	There is a substantial probability of a risk event occurring, which brings significant value to cost and time overrun.
Moderate	0.3, 0.5, 0.7	0.3 to < 0.5	The risk event is likely to occur, with a somewhat large chances of cost and time overrun.
Low	0.1, 0.3, 0.5	0.1 to < 0.3	The risk event is unlikely to occur and has little impact on cost and time overrun.
Very low	0, 0.1, 0.3	0.025 to < 0.1	Very rare chance of the risk event occurring, and very little significance to cost and time overrun

2- Using the FTN, the following equation provides a fuzzy decision matrix (FDM) for risk proba bility (p) or consequence (C) of cost or time overrun for each risk factor (f):

$$FDM^{f}_{\frac{p}{c}} = \begin{bmatrix} L_1 & M_1 & U_1 \\ .. & .. & .. \\ L_n & M_n & U_n \end{bmatrix} \quad \text{Eq (5)}$$

where L, M, and U represent the low, medium, and higher values of a risk's likelihood or consequence either on cost or time, and n represents the number of domain experts evaluating the risks.

3- Experts' judgements of a given phenomenon (and thus its consistency) vary for a range of reasons and must be weighed accordingly. These are a product of their years of experience (YE) and the number of years their firm has worked in the construction industry (YF), which are together referred to as their professional skills(Jung, Kim et al. 2016). To improve data reliability, the level of professional skill of one expert must be integrated into the risk analysis. (Kabir, Sadiq et al. 2016). (Aboshady, Elbarkouky et al. 2013) calculate the weight of an expert's professional skill as follows:

$$W_i^{Ind} = (W_{YE} + W_{YF}) \qquad \text{Eq (6)}$$

4- To evaluate the experts' skill as professionals, the criteria weights (i.e. W_{YE} , W_{YF}) are considered to be equal. (Ameyaw, Chan et al. 2015) calculates the global weight of an expert's professional skill (W_i^g)

$$W_i^g = \frac{W_I^{Ind}}{\sum_{i=1}^{n} W_i^{Ind}} \;\; ; \;\; \sum_{i=1}^{n} W_i^g = 1 \qquad \text{Eq (7)}$$

Here, as indicated in Table (5). (Jung, Kim et al. 2016), To meet the criteria that the greatest level of the fuzzy score is 1, the global weights of all experts must add up to one.

5- The FDM for each risk factor (f) of a project is converted into a weighted FDM (WFDM).

$$(WFDM_{p/c}^{f}) = (FDM_{p/c}^{f}) * W_i^g$$

$$= \begin{bmatrix} L_1 & M_1 & U_1 \\ .. & .. & .. \\ L_n & M_n & U_n \end{bmatrix} * \begin{bmatrix} W_1^g \\ .. \\ W_n^g \end{bmatrix}$$

$$= \begin{bmatrix} L_1 W_1^g & M_1 W_1^g & U_1 W_1^g \\ ... & ... & ... \\ L_n W_n^g & M_n W_n^g & U_n W_n^g \end{bmatrix} \qquad \text{Eq (8)}$$

6- The fuzzy score (FS) for risk probability (P) or consequence (C) on cost or time is derived by adding the various columns of the [Eq. (8)] matrix by

$$\left(FS_{P/C}^{f}\right) = \left[\sum_{i=1}^{n} L_i W_i^g \;, \sum_{i=1}^{n} M_i W_i^g \;, \sum_{i=1}^{n} U_i W_i^g\right] \qquad \text{Eq (9)}$$

7- Defuzzification is required to specify the critical level (i.e., low to very high), and follows(Abdelgawad and Fayek 2010)

$$(FRS_f)_{Deff.} = \frac{(FRS_f)_L + 4*(FRS_f)_M + (FRS_f)_U}{6} \qquad \text{Eq (10)}$$

8- The fuzzy risk score (derived by risk probability and impact on cost and time) is determined by Eq. (11) and is adapted from (Xu, Yeung et al. 2010)'s fuzzy synthetic evaluation approach for risk assessment.

$$(FRS_f)_{L,M,U} = \left(\sqrt{(FS_P^f) * (FS_C^f)}\right)_{L,M,U} \qquad \text{Eq (11)}$$

Where (FS_P^f), (FS_C^f) are fuzzy risk scores for probability and consequences on both cost and time. The fuzzy technique determines risks based on risk probability and impact in terms of cost and time, as well as standard fuzzy if-then rules. However, fuzzy if-then rules have been criticised for failure to deal with subjective errors (Novák 2012),forcing us to try a different method proposed by (Xu, Yeung et al. 2010).

Reliability Analysis

The Reliability Scale assessment is a measurement of the internal consistency of the created items in this study to evaluate the reliability of each factor Cronbach's alpha coefficient and using item-total correlation. Cronbach’s alpha coefficient measures the internal consistency, or reliability, of a set of survey items. Use this statistic to help determine whether a collection of items consistently measures the same characteristic. Cronbach’s alpha quantifies the level of agreement on a standardized 0 to 1 scale. Higher values indicate higher agreement between items. The value of Cronbach’s alpha for acceptable reliability is 0.8. Also, any factor Corrected Item-Total Correlation below 0.3 would be rejected(Hassanen and Abdelalim 2022), (elsamadouny, Abdelalim et al. 2020),(Afifi, Abdelalim et al. 2020).
The analysis shows that Cronbach’s Alpha value in Table (6) of all factors is (0.984) higher than 0.8.

Table 6: Cronbach’s Alpha Value

Cronbach's Alpha	Number of Items
0.984	106

Chi-Square Test

The authors used the Chi-Square test to determine the relationship between the independent ordinal variables' years of experience, organization type, and size. It represents the relationship between each pair of ordinal variables. Table (6) shows the outcomes.

The values of the second relation (Sig. (2-sided)) between years of experience and size of organization less than (α (Level of significance) = 0.05), which reflects a statically significance relation between both in the aspect of the items of probability, time impact and cost impact.

Table7: Chi-square results

Couple independent ordinal variables		Pearson Chi-Square Asymp. Sig. (2-sided)
Years of experience	Organization type	0.270
Years of experience	Organization size	0.000
Organization size	Organization type	0.294

Pearson Correlation

The Pearson correlation coefficient will be employed in connection with the (SPSS) software to evaluate the validity of the questionnaire structure. The authors developed a coefficient of correlation (R) between the main categories and all questionnaire fields for probability, time, and cost impact. The data indicate that:

Pearson Correlation for Items of Probability

The best relations according to Pearson correlation between the following items of probability are between (Non-compliance with environmental laws) and (pollution (epidemics)), with R= 0.614, between (Improper selection of subcontractors) and (Poor site coordination and errors in site planning), with R = 0.612, and between (Improper selection of subcontractors) and (Unavailability of skilled labor) with R = 0.622. To allow the best risk monitoring and controlling process, considering these relations and be followed through the project life cycle.

The authors connected the highest probability item to all other 33 items having probability with the very high correlation being the probability item (Owner reputations), and the highest probability item connected to all other 33 items having probability with the high correlation being the probability item (Potential of riots and disturbances).

Pearson Correlation for Risk According to Time Impact

The strongest relations between items of time impact according to Pearson correlation value are between item (Potential of riots and disturbances) and item (laws and regulation changes), with R = 0.720, between item (Rareness imported spare parts) and (Low equipment efficiency/productivity), with R = 0.697, and between item (Labor strikes) and (Poor equipment maintains), with R = 0.67

To allow the most reasonable risk monitoring and controlling process, consider these relations, and follow through the project life cycle.

The highest time impact item connected to all other 33 factors with the very high correlation is the time impact item (Repeat delays of payment), and the high time impact item linked to all other 33 items with a high correlation is (Storage and handling problems).

Pearson Correlation for Risk According to Cost Impact

The strong relations between items of impact on cost according to Pearson correlation value are between item (Geotechnical problems during construction due to improper soil investigation) and item (Defective material), with R = 0.697, between item (Owner financial stability) and (Repeat delays of payment), with R = 0.667, and between item (Earthquakes) and (Rises of taxes rate), with R = 0.667.

To allow reasonable risk monitoring and controlling processes, considering these relations, and following through the project life cycle. The highest impact cost item connected to all other 33 factors with the very high correlation is impact on cost item (Repeat delays of payment), and the high impact on cost item linked to all other 33 items with a strong correlation is (Many construction phases).

T-Test

The T-test is used to explore the effect of one independent factor on dependent variables.

The Independent-Sample T Test is used to conduct the T-test, and the test parameters are:

1- Test Variables (dependent variables): All major risk indicators, including probability, time impact, and cost impact.

2- Grouping variables (independent variables) include years of experience, organisation type, and size.

Additionally, this test was performed three times. The first focused on years of experience (an independent variable) and risk probabilities (a dependent variable). The second focused on organization type (another independent variable) and risk attribute time impact (dependent variable), while the third focused on organization size (another independent variable) and risk attribute cost (impact dependent variable). Refer to tables 8, 9, and 10, correspondingly.

Table 8: - Independent Samples Test for Factor R 1.1

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Design error [Probability]	Equal variances assumed	.990	.328	-.429	29	.671	-.155	.363	-.897	.586
	Equal variances not assumed			-.437	29.000	.665	-.155	.356	-.883	.572

Table 9: - Independent Samples Test for Factor R 1.3

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Many construction phases [Impact on time]	Equal variances assumed	.004	.947	.081	38	.936	.021	.256	-.497	.539
	Equal variances not assumed			.081	31.302	.936	.021	.258	-.506	.547

Table 10: - Independent Samples Test for Factor R 1.2

		Levene's Test for Equality of Variances		t-test for Equality of Means						
		F	Sig.	T	df	Sig. (2-tailed)	Mean Difference	Std. Error Difference	95% Confidence Interval of the Difference	
									Lower	Upper
Unclear project scope [Impact on cost]	Equal variances assumed	.024	.878	-.119	36	.906	-.045	.383	-.823	.732
	Equal variances not assumed			-.119	32.796	.906	-.045	.382	-.823	.732

Analysis of Variance (ANOVA)

To investigate the effect of one or more independent factors on dependent variables, the authors used the ANOVA test to determine whether there are any significant differences between Means. For this study, One-Way ANOVA examines the effect of independent factors (years of experience, organization size, and organization type) on the top-ranked significant risk attributes (probability, time impact, and cost impact). Before proceeding with (One-Way ANOVA) analysis, we should first investigate the homogeneity of variables for independent variables using the Levene statistic test, which checks the homogeneity of variances; if any variable has a Levene value less than 0.05, ANOVA analysis cannot be performed on it.

For the first test, it was tested between one independent factor, which is organization type, and risk dependent variables (34), which are risk attribute probabilities. Some Sig. values exceed α = 0.05, indicating no significant differences in risk attribute probabilities based on the independent factor (organization type). and some Sig. are less than α = 0.05, which means that there are statistically significant differences between Means of (15) risk attributes probabilities according to independent factor (Type of organization) which are (Design error ,Many construction phases, Design changes during construction, Poor site coordination and errors in site planning, Storage and handling problems, Skilled labor high wage scales, Improper selection of sub-contractors, Owner reputations, Owner financial stability, Repeat delays of payment, laws and regulation changes, Inflation, Potential of riots and disturbances, Rises of taxes rate, Import / Export restrictions)

The second test was conducted between one independent factor, organization size, and all risk dependent variables (34) which are risk attributes time impact. It was indicated that some Sig. are higher than α = 0.05, which means that there are no statistically significant differences between Means of these risk attributes impact on time according to independent factor (Type of organization), and some Sig. are less than α = 0.05, which means that there are statistically significant differences between Means of (27) risk attributes impact on time according to independent factor (Type of organization).which are Design error, Unclear project scope, Many construction phases, Design changes during construction, Poor site coordination and errors in site planning, Geotechnical problems during construction due to improper soil investigation, Storage and handling, Late material delivery, Defective material, Breakdown of equipment, Poor equipment maintains, Skilled labor high wage scales, Earthquakes, Unpredicted climate change, Poor contractor prequalification, Lack of ability and experience, Improper selection of sub-contractors, Poor quality and rework, Owner reputations, Owner financial stability, Suspension of work by owner, Repeat delays of payment, laws and regulation changes, Inflation, Potential of riots & disturbances, Rises of taxes rate, and Import / Export restrictions.

4 Conclusions

The study searches into a methodology for managing risks in highly constrained construction projects by highlighting previous construction risk management studies, including limited studies on highly constrained projects, and listing attributes that represent common risks associated with cost and time overruns. The questionnaire was linked to construction experts to select the most valuable attributes relevant to the study. The authors classified risks into nine different groups and listed 34 risk factors that influence time and cost in construction projects. The authors created and distributed a comprehensive survey to assess risk based on time and cost effect, employing relative importance index (RII) and a modified fuzzy group decision-making technique (FGDMA). Then, the statistical analysis using SPSS Ver.25, such as (Reliability analysis, Cronbach's alpha coefficient, Chi-Square Test, Pearson Correlation, T-Test and ANOVA Test). According to the (RII) and (FGDMA) approach, the top 20 risks impact time and the top twenty risks impact cost were determined and tabulated in the table (11) & (12) below.

Table 11: Top 20 Risk Factors affecting time and cost according to (FGDMA)

Top 20 Risk Factors affecting time			Top 20 Risk Factors affecting cost		
NO.	Risk Attribute on Time	Risk Score	NO.	Risk Attribute on Cost	Risk score
1	Inflation	0.5324	1	Inflation	0.5417
2	Import / Export restrictions	0.5020	2	Rises of taxes rate	0.5103
3	Repeat delays of payment	0.4941	3	Repeat delays of payment	0.5069
4	Owner financial stability	0.4919	4	Import / Export restrictions	0.5047
5	Poor quality and rework	0.4896	5	Owner financial stability	0.5046

6	Rises of taxes rate	0.4871	6	Poor quality and re-work	0.4973
7	Design changes during construction	0.4757	7	Design changes during construction	0.4771
8	Lack of ability and experience	0.4697	8	Lack of ability and experience	0.4698
9	Late material delivery	0.4673	9	Improper selection of sub-contractors	0.4692
10	Poor equipment maintenance	0.4671	10	Poor equipment maintenance	0.4658
11	Improper selection of sub-contractors	0.4649	11	Many construction phases	0.4650
12	Suspension of work by owner	0.4638	12	Poor contractor prequalification	0.4617
13	Geotechnical problems during construction due	0.4620	13	laws and regulation changes	0.4600
14	Many construction phases	0.4599	14	Late material delivery	0.4593
15	Poor contractor prequalification	0.4592	15	Suspension of work by owner	0.4582
16	Skilled labor high wage scales	0.4590	16	Skilled labor high wage scales	0.4578
17	Unavailability of skilled labor	0.4547	17	Geotechnical problems during construction due	0.4567
18	Low equipment efficiency / productivity	0.4516	18	Unavailability of skilled	0.4561
19	Breakdown of equipment	0.4467	19	Breakdown of equip-ment	0.4527
20	laws and regulation changes	0.4461	20	Low equipment effi-ciency	0.4502

Table (12) Top 20 Risk Factors affecting time and cost according to (RII)

Top 20 Risk Factors affecting time			Top 20 Risk Factors affecting cost		
NO.	Risk Attribute on Time	Impact on time im-portance index	NO.	Risk Attribute on Cost	Impact on cost im-portance index
1	Owner financial stability	86.21	1	Owner financial stability	84.90
2	Late material delivery	82.55	2	Repeat delays of payment	80.20
3	Repeat delays of payment	82.35	3	Inflation	78.85
4	Lack of ability and experience	77.25	4	Poor quality and rework	76.27

5	Unavailability of skilled labors	76.08	5	Defective material	75.10
6	Improper selection of sub-contractors	75.49	6	Design changes during construction	74.51
7	Low equipment efficiency / productivity	74.51	7	Lack of ability and experience	71.96
8	Poor contractor prequalification's	73.86	8	Unavailability of skilled labors	69.61
9	Unclear project scope	73.33	9	Skilled labor high wage scales	69.41
10	Design changes during construction	73.33	10	Design error	68.82
11	Inflation	71.37	11	Unclear project scope	67.65
12	Suspension of work by owner	70.78	12	Rises of taxes rate	67.25
13	Skilled labor high wage scales	70.00	13	Late material delivery	67.17
14	Rareness imported spare parts	69.80	14	Low equipment efficiency / productivity	66.67
15	Labor strikes	69.61	15	Labor strikes	66.67
16	Poor quality and rework	69.41	16	Many construction phases	65.10
17	Design error	69.02	17	Suspension of work by owner	64.90
18	Potential of riots & disturbances	66.08	18	Geotechnical problems during construction due to improper soil investigation	62.72
19	Rises of taxes rate	65.49	19	Import / Export restrictions	62.55
20	Owner reputations	65.10	20	Breakdown of equipment	60.98

After comparing the results of the two methods (RII) and (FGDMA) there is a little difference between results due to the role of global weight (the weight of each respondent) in ranking risk by (FGDMA) method which would make difference in ranking risk factors.
According to the (FGDMA) the most effective risk factor on both time and cost is (Inflation), but with (RII) method the most effective risk factor on both time and cost is (Owner financial stability).

5 Recommendation

- Risk management of mega construction projects in Egypt using fuzzy logic.
- Analysis of risk factors for highway construction projects in Egypt.
- Identification and assessment of risk factors affecting infra structure construction projects in Egypt.

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