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"Risk Assessment in Construction: A Comprehensive Analysis of Cost Implications Using Monte Carlo Simulations in Iraqi Service Projects"

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Abstract:

With the global surge in population and advancements in the construction sector, there is an imperative call for effective risk management within construction projects. Many of these risks surface during the implementation phase, including those associated with design, planning, management, financing, contractual changes, and unforeseen conflicts. These risks, if not managed properly, can jeopardize the project's objectives, leading to delays, budget overruns, and compromised quality. This study endeavors to pinpoint, assess, and analyze risk-related factors influencing the cost of service projects. Utilizing IBM SPSS v26, Microsoft Excel, and XLRISK for Monte Carlo simulations, this research determined risk probabilities spanning from optimistic to pessimistic scenarios. Primary data was amassed through comprehensive surveys, questionnaires, and interviews, focusing on crucial risk factors and their corresponding relative importance index (RII). Monte Carlo Simulation (MCS) was employed for risk analysis, supporting up to 10,000 iterations for diverse project scenarios. Service projects from Iraq were analyzed, establishing the cost implications in the presence of risks and deducing the project costs across varying confidence levels.

Keywords: Risk assessment, construction cost, project management, Monte Carlo simulation, relative importance index, Iraqi service projects.

1. INTRODUCTION

Construction projects in general and service projects in particular in our country suffer from a continuous increase in the risks they face during the implementation phase due to the increase in population and the country's need to remove traffic jams and congestion, so there is a need to manage these risks and try to treat them to maintain the expected cost of the project for the purpose of completing the project within the standards required namely cost, time and quality with risk control. The nature of risks must be understood, analyzed and solutions found if they materialize during implementation. The objective of project risk management is to take advantage of or improve on positive impacts (opportunities) while avoiding or managing negative risks (threats). This is because poorly managed threats can lead to major issues such as delays or cost overruns (1). Project management requires careful consideration of risks. It uses a systematic strategy that enables these organizations to deal with unexpected events in order to prevent, reduce and control risks. Therefore, risk management entails identifying the influencing elements that may have a negative impact on the project objectives (2).

Project managers can schedule their priorities and allocate resources more effectively with the help of risk management, which makes decision-making more reliable and helps the project succeed and achieve its goals (3). Risk management helps transfer risks to the other party so that they can be managed and accepted (4). Identifying, evaluating, analyzing and responding to project risks are essential steps in establishing a systematic risk management system. (5), quantitative methods such as sensitivity analysis, Monte Carlo simulation, analysis, etc. to estimate and describe risks numerically.

Qualitative methods are used to prioritize risks associated with project objectives based on an assessment of their likelihood and impact (6). The aim of the research was to find risks that arise during the implementation phase of construction projects, in addition to ways to prevent them from occurring in the first place and reduce losses in time and expenses. This research covers operations and explains how to deal with the most important factors affecting cost risk and apply them to real projects. By using the Excel XL Risk program to create a Monte Carlo simulation and sensitivity analysis using the Tornado chart, which shows the effect of the axes in sequence on the cost of the project. Through these results, we can know the degree of completion of the project at different levels of confidence (50%, 80%, 95%).

2. MATERIALS AND METHODS

The research method used can be summarized as follows: Thirty-five risk factors were identified and categorized into six main themes that cause construction risks based on personal interviews, literature review and field survey as shown in the table1. Then the questionnaire was distributed to the Ministry of Construction and Population and its affiliated formations, and as a result the collected data were analyzed using the statistical analysis software package (SPSS). The Relative Importance Index (RII) was found for each axis of the questionnaire as in

table 2, and it was used in Excel XL Risk software to create a Monte Carlo simulation to find out the degree of project completion with different levels of confidence (50%, 80%, 95%). Sensitivity analysis also using the Tornado chart to find out the degree of influence of the axes in sequence on the total cost of the project. Thus, the results showed the degree of completion of the project with a level of confidence and the most important axes affecting the cost of construction projects.

Table1.Identify the most important construction Risks

Category	**NO.**	Risks
Planning and design	1.1	Inaccurate schedule
	1.2	The degree of complexity of the designs
	1.3	Incorrect execution planning
	1.4	Not following the workflow with the schedule constantly and addressing things as they go
	1.5	Between the employer and the contractor, there is a lack of cooperation and communication
	1.6	No match between the table of quantities and the charts
	1.7	Increase the time period for one of the activities within the project
	1.8	The delayed delivery of changed designs at the construction site due to a lack of relevant information.
Resource Management	2.1	Delay in ordering materials
	2.2	Poor storage of raw materials
	2.3	Unavailability of skilled workers
	2.4	Lack of control over materials within the site
	2.5	Arrival of some goods and equipment from the country of origin after schedule
	2.6	Requesting materials that do not meet the requirements of the project.
	2.7	During transportation, keep supplies away from the job site and any waste that will arise.
	2.8	Equipment and machinery lack regular maintenance
financing	3.1	Inflation and fluctuations in prices and currencies
	3.2	Delay in making payments for advances under the contract
	3.3	The change order amounts are higher than the reserve amount
	3.4	Failure to agree on the project cash flow schedule
r a c	4.1	Assignment of bids to an incompetent contractor (not taking into

		consideration the referral controls)
	4.2	Errors or missing items in contracting contracts
	4.3	One of the parties' failure to adhere to the agreement's provisions
	4.4	Not selecting a contract type that is suitable for the project's needs
	4.5	Weak experience of the subcontractor and technical staff
Change orders, disputes and claims	5.1	Implementing projects that do not meet the requirements, which results in rejection and rework
	5.2	the formation of legal conflicts between the project stakeholders during the execution phase
	5.3	Not documenting change orders at the specified time and when changing
	5.4	Too many additional works (created paragraphs) and modifications during implementation
	5.5	The difference in the periods granted to change orders

External risks	6.1	The existence of obstructions on the property (such as underground water, water pipelines, and electrical equipment...)
	6.2	The deterioration of the security situation
	6.3	Accidents occur due to lack of safety precautions
	6.4	Bad and harsh weather conditions
	6.5	Difficulty accessing the site (distant from the places of supplying basic services, raw materials, labor and machinery...)

Table 2. Relative importance index for each axis and percentages

Item	optimistic	pessimistic	RII	%
A1	98%	104%	0.85	0.170238334
A2	98%	104%	0.846	0.169437212
A3	96%	109%	0.814	0.16302824
A4	98%	107%	0.816	0.1634288
A5	98%	106%	0.824	0.165031043
A6	96%	106%	0.843	0.168836371
Total			4.993	

This letter was used to denote each axis of the questionnaire.

A1: It is the focus of design and planning.

A2: It is the focus of resource management.

A3: It is the focus of financing.

A4: The focus of contracts.

A5: It is the focus of disputes.

A6: It is the focus of external risks.

In this table, it shows the percentages that were used in the modeling process, where the final total cost of each project was relied on, and three cost possibilities were used, which are (Optimistic, Most Likely, Pessimistic) focus of the questionnaire.

After that, the relative importance index (RII) was used for each axis of the questionnaire, and the weight of each factor was found in relation to the total number of the relative importance index (RII).

3. Run a Risk analysis

Monte Carlo simulation (MCS) technology is used in risk analysis, which covers 10,000 iterations, and multiple scenarios to estimate the final cost of the project, taking into account the existence of the risk factor. A maximum of 10,000 repetitions (several times) was adopted to generate project scenarios Hence, activities will move between max and min 10,000 times to reflect accurate results.

4. Modeling for a case study

Using costs for different types of service projects in Iraq, the MCS model was used to consider the most important risk factors that came from the quatitative risk analysis step. During the implementation of part of these projects, many problems and risks were encountered that caused cost overruns. This means that projects cannot be completed on time and on budget as planned. Based on the total cost of the project as a case study, risk analysis is done using Excel XL RISK software to prove the study theory and get a good analysis. The results of the analysis are useful reports that include a risk chart (s-curve) for the entire project and for each person's actions, showing the level of confidence for the cost of completing the project. The risk expert will be able to look at the risk drivers with these reports before developing a risk plan. Also, to find the right reports that show how risks affect project costs and how general uncertainty affects the activity as a whole.

5. Case study and Discussion

Establishing a health center located in the Iraqi capital / Baghdad. The project aims to serve citizens and provide them with health services. The health center consists of two and a half floors with a total area of 750 square meters. The estimated cost of the project is (1,119,539,200 Iraqi dinars) as shown in the table3, based on the relative importance index for each axis. Scenario risk analysis can be represented by the most important reports related to the final cost for the purpose of completing the project. The reports consist of an S-curve graph and a distribution analyzer graph. In the data collection process for the Monte Carlo simulation, prices were taken into account as a percentage of the total cost. The x-axis represents the cost of completing the project and the y-axis represents the probability of completing the project. Since the risk analyst has performed 10,000 iterations of the simulation. Figure 1 shows the frequency chart for

which the specific cost for this project is 1,119,539,200 IQD. This is the cost that can make this project confident (with a confidence level of 50%). In addition, the cost of making this project confident (at a confidence level of 80%) is 1,144,800,000 IQD, which means that 25,260,800 IQD must be added to the original cost of the project and (at a confidence level of 95%) The cost is 1,166,611,445.45 IQD, which means it must be added to the original cost of the project.

Table3. Three possibilities of cost and expected cost

The main axes	optimistic	Most likely	pessimistic	Random value
A1	154869589.3	186,589,866.67	218310144	201152874.83
A2	154869589.3	186,589,866.67	218310144	192864599.61
A3	156735488	186,589,866.67	216444245.3	180796502.62
A4	156735488	186,589,866.67	216444245.3	192184545.85
A5	155802538.7	186,589,866.67	217377194.7	181313511.90
A6	154869589.3	186,589,866.67	218310144	174948401.21
		1,119,539,200.00		**1,110,884,235.09**

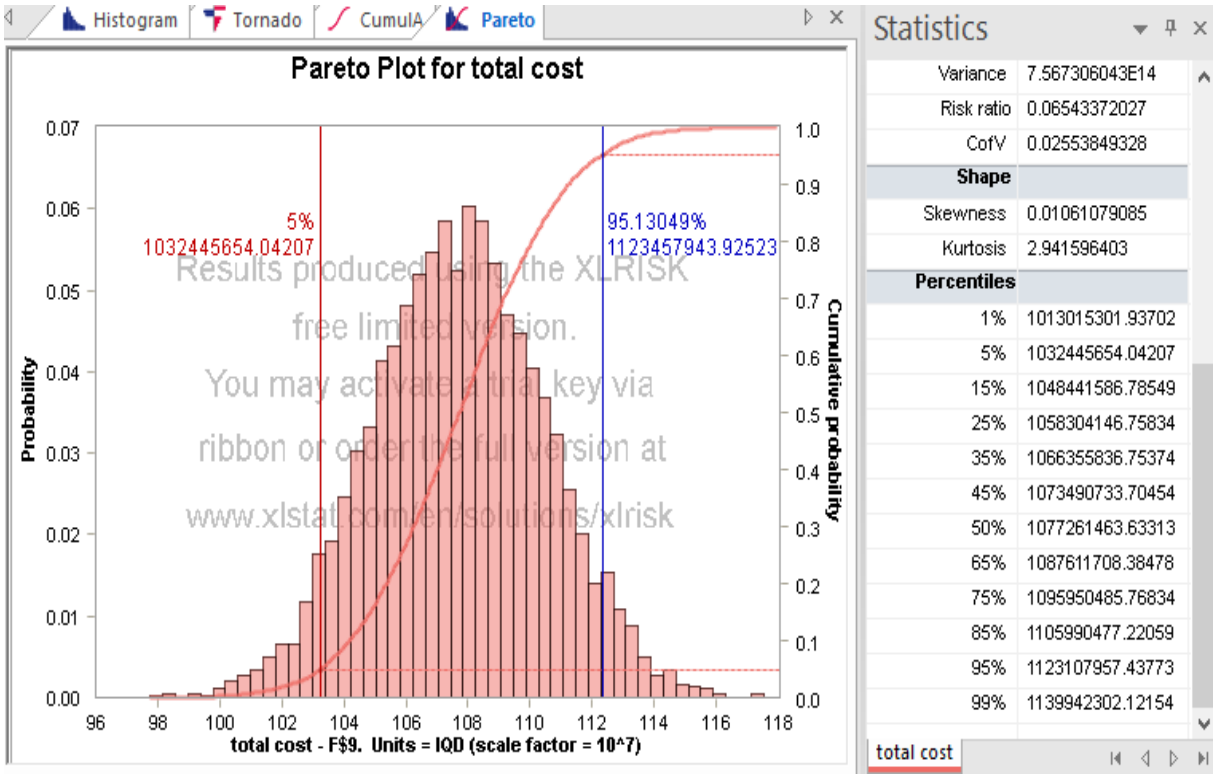

Figure1 Cost for the entire project

Sensitivity analysis using the Tornado Cost Sensitivity chart to study the health center construction project as shown in Figure 2, where it displays a list of activities classified in descending order according to the degree of their impact (degree of correlation) on the cost of the project. Where the most important factor was the first axis (design and planning) and the sixth axis (other sources of risk), followed by the third axis (financing), the fifth axis (change orders, disputes and claims), the second axis (resource management), and finally the fourth axis (contracting). The least impact on cost relative to the rest of the other axis.

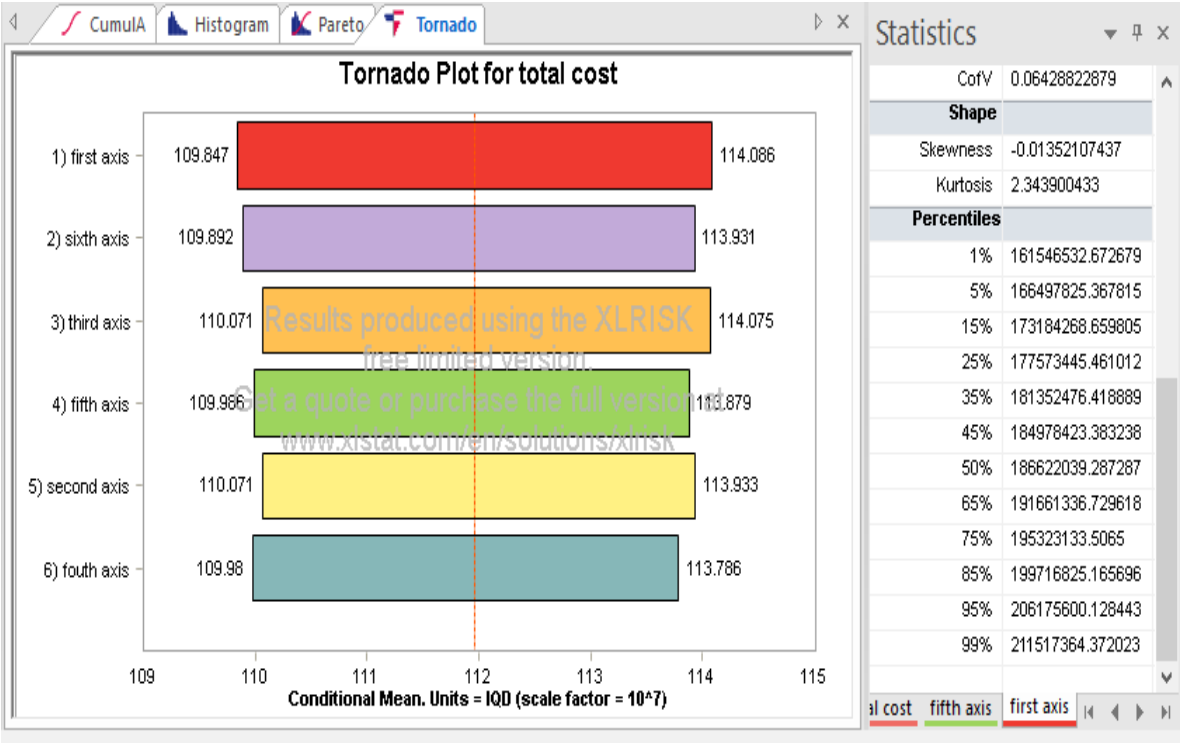

Figure 2 Sensitivity analysis using a Tornado chart

6. Conclusion:

Many scholars emphasized the importance of understanding the risks that may arise during the construction of projects and devised several methodologies with the aim of managing, monitoring and reducing these risks. There are still many risks present in the various initiatives, despite the diverse strategies these researchers have put in place. In this research, the quantitative risk analysis was dealt with using MCS technique with Excel XLRisk software for risk and sensitivity analysis. The outputs of the risk analysis revealed that there is a different risk impact on construction projects, as the results showed the probability of completing the project with different levels of confidence.

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