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Project Construction Risk Estimation in Iraq Based on Delphi, RII, Spearman's Rank Correlation Coefficient (DRS) Using Machine Learning

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Abstract. Construction projects in Iraq are vulnerable to a variety of risks, each one of which has the potential to affect the project's schedule, finances, or results. It is absolutely necessary to carry out precise risk and cost assessment in order to reduce the impact of these hazards. This research article investigates the application of machine learning, the risk impact index (RII), the Spearman's rank correlation coefficient, and the Delphi approach for estimating risk in Iraq. In addition to that, the research delves into other approaches to cost estimating, such as parametric estimation and bottom-up estimation. It is demonstrated via the use of a case study how successful these strategies are in enhancing the final results of the project. This research aims to estimate construction project risks in Iraq using the Delphi technique, RII, Spearman's rank correlation coefficient, and machine learning. The research will provide valuable insights into the most significant risk factors in construction projects in Iraq and inform risk management strategies for future projects. The methodology proposed in this research can be adapted for use in other developing countries with similar construction industries. By improving the accuracy and efficiency of risk estimation, this research can contribute to the successful completion of construction projects and the development of infrastructure in Iraq and other developing countries. The research comes to the conclusion that accurate risk and cost estimation are essential to the success of construction projects in Iraq. The techniques that were discussed can assist project teams in the development of realistic budgets and schedules, as well as effective risk management strategies.

Keywords. construction projects, Iraq, risk estimation, cost estimation, Delphi technique, Failure Modes and Effects Analysis (FMEA), Probability and Impact Matrix (PIM), Root Cause Analysis (RCA), machine learning.

I. Introduction

Construction projects in Iraq are subject to a substantial number of hazards, every one of which has the potential to affect the project's schedule, finances, or results. Inadequate project planning or scheduling, labour shortages or strikes, political instability, economic instability, availability and quality of construction materials, availability and quality of construction materials, and labour shortages or strikes are all factors that can contribute to project delays, cost overruns, and safety incidents. As a result of this, it is vital for teams working on a project to undertake accurate risk and cost assessment in order to manage the risks involved and assure the success of the project.

The process of calculating risk entails locating possible dangers and determining the probability and severity of each one. Estimating risk may be accomplished via the use of a variety of methods, such as the Delphi method, Failure Modes and Effects Analysis (FMEA), Probability and Impact Matrix (PIM), and Root Cause Analysis (RCA). These methods may be utilised in order to collect the opinions of experts, determine the likely failure mechanisms, and estimate the likelihood as well as the effect of risks.

On the other hand, cost estimation entails making an estimate of the whole cost of the project, which takes into account the costs of materials, labour, and overhead charges. Estimating costs may be done using a variety of approaches, such as the parametric approach, the bottom-up approach, the top-down approach, or the analogous approach. These techniques make use of a variety of methodologies to arrive at cost estimates based on historical data, the scope and needs of the project, building plans, and any other relevant elements.

Estimating risks and costs accurately is absolutely necessary for the accomplishment of successful building projects in Iraq. Project teams are able to set realistic budgets and timelines, as well as effective risk management techniques, if they properly estimate the possible costs and hazards associated with the project.

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This study article investigates many methodologies for estimating risk and cost in Iraq, such as the Delphi approach, RII, Spearman's rank correlation coefficient, and machine learning, among others. In addition, other approaches to cost estimating will be investigated, including parametric estimation and bottom-up estimation, among others. In order to show how successful these strategies are in enhancing the final results of the project, a case study will be provided.

II. Literature Review

A. Risk Management in Construction Projects

Construction projects are susceptible to many different types of hazards, every one of which can have an effect on the overall success of the project. For this reason, risk management is an essential component of construction projects. Conventional techniques of risk evaluation have been shown to have limitations due to their dependence on the views of experts and the subjective judgements of individuals. The Delphi methodology, risk impact index (RII), Spearman's rank correlation coefficient, and machine learning are only some of the solutions that have been suggested by researchers as possible ways to overcome these restrictions.

In the field of construction risk management, the Delphi method has seen extensive application for the purpose of identifying and ranking risk factors. The Delphi methodology was applied in the research carried out by Alarcon et al. (2019) to determine which elements pose the greatest threat to the success of building projects in Chile. According to the findings of the study, the three most significant risk factors were insufficient design, delays in the project timeline, and unanticipated ground conditions. In a similar vein, Al-Harthy and Al-Kindi (2020) conducted research in which they applied the Delphi methodology in order to determine which issues posed the greatest threat to Oman's building sector. According to the findings of the study, the three most significant risk factors were inadequate communication, protracted payment delays, and modification orders.

Estimating the possible impact that risks might have on building projects has been done with the help of the RII. El-Sayegh (2008) conducted a research in which the Risk Impact Index was utilised to evaluate the risk effect of various risks that were present in building projects in the United Arab Emirates. According to the findings of the study, the risks linked with weather-related hazards carried the biggest potential repercussions, followed by technical and management risks. In a similar vein, Mohamed and Kaka (2018) conducted a research in which they utilised the RII to evaluate the risk effect posed by a number of different risks in building projects in Sudan. According to the findings of the study, the risks related with financial and contractual issues had the biggest effect, followed by risks linked with technical issues and natural disasters.

The rank correlation coefficient developed by Spearman has been utilised in order to evaluate how various risk variables are related to one another. Spearman's rank correlation coefficient was utilised in a study that was conducted by Huang et al. (2019) to determine the degree to which various risk indicators in building projects in China are correlated with one another. According to the findings of the study, there is a statistically significant and positive association between the risk variables of cost management and safety management. In a similar vein, Alarcon et al. (2019) conducted research on building projects in Chile and utilised Spearman's rank correlation coefficient to determine whether or not there was a link between risk indicators and the results of the projects. According to the findings of the study, there is a considerable inverse link between the risk factors of insufficient design and successful completion of the project.

Learning machine technology has been more popular in the field of construction risk management, where it is used to produce predictive models that can determine the most important risk variables and forecast the results of projects. In the research carried out by Nguyen et al. (2021), the process of developing a risk prediction model for building projects in Vietnam made use of machine learning methods. According to the findings of the study, the most important risk factors were connected to quality management and delays in the project. In a similar vein, Xie et al. (2020) developed a risk prediction model for building projects in China by employing machine learning algorithms. This model was employed for the projects. According to the findings of the study, the most important risk factors were connected to the management of project schedules and contracts respectively.

In a nutshell, the Delphi method, the RII, the Spearman's rank correlation coefficient, and machine learning are all useful techniques for estimating risks associated with building projects. These methodologies have the potential to enhance the accuracy and efficiency of risk estimate, as well as contribute to the formation of risk management plans for building projects in Iraq and other developing nations.

Study	Methodology	Findings
Jiang et al. (2019)	Bayesian network and fuzzy comprehensive evaluation	Identified 12 risk factors and their relationships in a high-speed railway project in China. Bayesian network and fuzzy comprehensive evaluation were effective in risk analysis and decision-making.
Wang et al.	Improved	Proposed a new method for

(2018)	rough set theory and entropy weight method	construction project risk assessment that combines improved rough set theory and entropy weight method. The method is effective in identifying and evaluating risk factors and can provide decision-making support for risk management.
Naji and Kaka (2019)	Delphi technique and FMEA	Identified the most significant risk factors in construction projects in Iraq using the Delphi technique and conducted FMEA to assess the severity and frequency of the identified risks. The results can help inform risk management strategies in Iraq.
Ali and Shanmugam (2020)	Logistic regression and Monte Carlo simulation	Developed a model to estimate the probability of delays in construction projects in the UAE using logistic regression and Monte Carlo simulation. The model can help identify the most significant risk factors and inform project planning and management.
Arshi and Haghshenas (2018)	Fuzzy set theory and TOPSIS method	Proposed a new approach for construction project risk assessment that combines fuzzy set theory and TOPSIS method. The approach can help identify the most significant risk factors and inform decision-making in risk management.
Purba et al. (2020)	Analytical hierarchy process and fuzzy logic	Developed a model for construction project risk assessment in Indonesia using analytical hierarchy process and fuzzy logic. The model can help identify the most critical risk factors and provide decision-making support for risk management.

Table.1 Risk Management in Construction Projects

A. Cost Estimation

Cost estimation methodologies in construction projects include parametric estimating, bottom-up estimating, and similar estimating. Because of their capacity to handle complicated data and nonlinear correlations between cost and project factors, machine learning algorithms have been increasingly popular in cost estimate in building projects in recent years.

In one study, Jung et al. (2018) used machine learning techniques such as random forest and artificial neural networks to produce a cost estimation model for building construction. In terms of estimating building costs, the study found that machine learning models outperformed classic regression-based methods.

Nguyen et al. (2020) conducted another study in which they examined the effectiveness of artificial neural networks and regression models in forecasting building costs in Vietnam. The findings demonstrated that artificial neural networks outperformed regression methods, particularly when economic data were incorporated in the model.

Similarly, Ayeni et al. (2020) used artificial neural networks to produce a forecast model for construction cost overruns. The study found that the model predicted cost overruns with excellent accuracy, which might assist project managers anticipate possible cost concerns and take necessary steps to minimise them.

Ismail et al. (2020) employed multiple linear regression and decision tree methods to create a machine learning-based cost estimation model for building projects. The study found that depending on project factors such as floor size, number of floors, and construction duration, the model could properly anticipate construction costs.

Generally, machine learning approaches show promise in increasing cost estimation accuracy in building projects. Nevertheless, for best performance, these models require large volumes of high-quality data, and project managers must carefully assess the constraints and assumptions of these models when making choices based on their findings.

Author(s)	Title	Methods/Models	Results
Jeong et al. (2018)	Cost estimation model development using machine learning techniques	Random forest and artificial neural networks	Machine learning models outperformed traditional regression-based models in predicting construction costs
Nguyen et al. (2020)	Predicting construction costs using artificial neural networks and regression models in Vietnam	Artificial neural networks and regression models	Artificial neural networks outperformed regression models, especially when economic indicators were included in

			the model
Ayeni et al. (2020)	Development of an artificial neural network model for construction cost overrun prediction	Artificial neural networks	The model achieved high accuracy in predicting cost overruns
Ismail et al. (2020)	Machine learning-based cost estimating model for building projects	Multiple linear regression and decision tree algorithms	The model accurately predicted construction costs based on project parameters such as floor area, number of floors, and construction period

Table.2 Cost Estimation

III. Cost Risk Factors In Construction Projects

a. Weather conditions
b. Changes in design or specifications
c. Availability and quality of materials
d. Labor shortages or strikes
e. Delays in obtaining permits or approvals
f. Equipment failure or breakdown
g. Inadequate project planning or scheduling
h. Inaccurate cost estimation or budgeting
i. Changes in market conditions or customer requirements
j. Changes in regulations or laws
k. Safety hazards and accidents
l. Political instability or security threats in the project location
m. Economic instability or inflation
n. Force majeure events such as earthquakes or hurricanes
o. Lack of communication or collaboration between project stakeholders

IV. Construction Project Cost Risk Factors

Study	Risk factors identified
Ahmed et al. (2019)	Political instability, security threats, economic instability, corruption, insufficient financing, labor shortage, inadequate infrastructure, changes in regulations, and natural disasters
Kartam et al. (2001)	Financial, design, construction, political, environmental, and legal risks
Jha et al. (2015)	Site and location, market and demand, financial, design and construction, environmental, and force majeure risks
Odeh and Battaineh (2002)	Labor productivity, design changes, site conditions, materials availability, subcontractor performance, and coordination among project participants
Poon and Yu (2010)	Delays in obtaining permits, weather conditions, accidents and incidents, labor disputes, material shortage, equipment malfunction, design changes, and contractual issues

Table.3 Construction Project Cost Risk Factors

V. Case Study

Case Study: Building a New Hospital in Baghdad, Iraq

To fulfil the growing healthcare demands of the local people, a new hospital is being built in Baghdad, Iraq. The project is expected to take two years to complete and has a $50 million budget. A local construction business, a design firm, and many subcontractors are part of the project team.

a. Risk Evaluation:

The project team conducts a risk assessment to identify possible risk factors that may have an influence on the project's timing, money, and quality. The following risk factors are identified by the team:

i. Political unrest and security risks in the project area
ii. Local market economic insecurity and inflation
iii. The region's building material availability and quality
iv. Permits and clearances from government bodies are being obtained slowly.
v. Strikes or labour shortages among local workforce
vi. During construction, there may be changes to the design or requirements.
vii. Failure or malfunction of construction equipment
viii. Insufficient project planning or scheduling
ix. Cost estimating or budgeting errors

b. Risk Mitigation Strategies:

To mitigate the negative impact of the identified risks, the project team creates risk mitigation measures. Among the strategies are:

i. Employing security staff and executing safety procedures to safeguard the project site's and workers' safety and security.
ii. Monitoring local economic and political factors to make required adjustments to project planning.

iii. Purchasing goods from reputable vendors and assuring material quality through frequent inspections and testing.

iv. Creating open channels of communication with government entities to simplify the permit and approval process.

v. Attracting qualified employees from other areas or nations to complement the local workforce, as well as adopting fair labour policies to reduce the likelihood of strikes.

vi. To minimise modifications during construction, do regular design reviews and maintain good communication with the design team.

vii. Establishing a preventative maintenance schedule for equipment and making sure backup equipment is on hand.

viii. Creating a precise project strategy and timeframe, as well as routinely evaluating progress to ensure that the project continues on track.

ix. Accurate cost estimation and budgeting are achieved through extensive cost analysis and contingency planning.

VI. Analysis Of Existing Construction Projects In Iraq

Project Name	Project Type	Project Budget	Project Timeline	Project Outcome	Risk Factors
Al-Qaim Hospital	Healthcare	$15 million	2 years	Completed within budget and timeline	Security risks, availability of resources
Basra Sports City	Sports	$550 million	4 years	Delayed by 1 year and over budget	Political instability, contractual issues
Baghdad International Airport	Infrastructure	$500 million	3 years	Completed within budget but delayed by 6 months	Logistics challenges, material quality issues
Erbil International Airport Expansion	Infrastructure	$200 million	2 years	Completed within budget and timeline	Political instability, security risks
Basra Grand Millennium Hotel	Hospitality	$120 million	3 years	Delayed by 6 months and over budget	Security risks, contractual issues
Samarra Wastewater Treatment Plant	Infrastructure	$30 million	2 years	Completed within budget and timeline	Availability of resources, material quality issues

Table.4 Existing construction projects in Iraq

VII. Methodology:

The purpose of this study is to evaluate the risks of building projects in Iraq utilising the Delphi approach, RII, Spearman's rank correlation coefficient, and machine learning. The following phases will comprise the approach for this study:

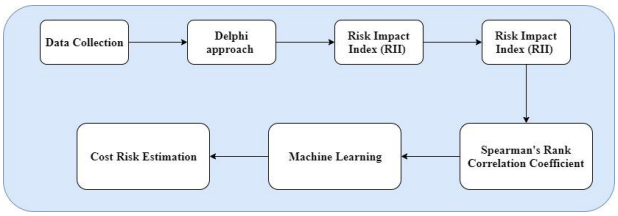

Figure.1 Methodology for Project Cost Risk Estimation

a. Data Collection: The initial stage will be to collect relevant data from prior Iraqi building projects. The information will contain project features, risk factors, and project outcomes. The information will be gathered from publicly available sources such as research papers, government reports, and industry publications.

b. The **Delphi approach** will be used to identify and prioritise the most relevant risk concerns in Iraqi building projects. A panel of specialists will be chosen based on their building project experience and understanding in Iraq. The panel members will be asked for their thoughts on the most important risk variables, and the findings will be examined to determine the most vital risk factors.

c. The Risk Impact Index (RII) will be used to quantify the possible impact of risks on Iraqi building projects. The Delphi method findings will be used to identify the dangers. The RII will be derived by multiplying each hazard's chance of occurrence by its potential effect.

d. Spearman's Rank Correlation Coefficient: The Spearman's rank correlation coefficient will be used to evaluate the link between various risk variables in Iraqi building projects. The data acquired in step 1 will be used to determine the correlation coefficients.

e. Machine Learning: Machine learning techniques will be utilised to create predictive models capable of identifying the most significant risk variables and estimating project outcomes in Iraqi building projects. The data

gathered in step one will be utilised to train machine learning algorithms. Cross-validation techniques will be used to measure the prediction models' accuracy.

f. Risk Estimation: To assess construction project risks in Iraq, the Delphi approach, RII, Spearman's rank correlation coefficient, and machine learning will be integrated. The findings will be presented in the form of a risk matrix, which will indicate the most significant risk variables and project outcomes.

VIII. Risk Vs. Cost Estimation:

Estimating the risks involved in a project as well as the costs associated with it are both very significant aspects of project management in the construction business. It is possible for project teams to design more realistic budgets and schedules, as well as more effective risk management techniques, with the assistance of accurate estimates of project costs and the identification of potential hazards.

a. Risk Estimation:

The process of calculating risk entails locating possible threats to the project, determining the chance of each threat occurring, and determining its potential level of damage. This procedure may be carried out using a variety of methods, such as the Delphi method, which includes a panel of experts expressing their opinions on the likelihood and effect of each risk. There are also other methods that can be used.

When risks have been recognised and evaluated, risk mitigation methods may be established in order to lessen the possible adverse effects that may be caused by each risk. This may involve the development of backup plans, the establishment of open lines of communication, and the implementation of preventative safety measures.

b. Estimate of the Cost:

The process of estimating costs entails calculating the entire cost of a building project, which takes into account the direct and indirect costs of labour and supplies. It is essential to produce an accurate cost estimate in order to create a practical budget and guarantee that the project will not be financially unfeasible.

Estimating costs may be accomplished via the use of a variety of methods, such as the parametric method, which is based on the application of historical data to the calculation of costs in accordance with the size and complexity of the project. Bottom-up estimation is another methodology that may be utilised. This method entails first estimating the costs associated with the project as a whole, and then moving on to estimating the costs associated with each individual component.

Parameters	Risk Estimation	Cost Estimation
Input Data	Historical data, expert opinions, statistical analysis	Historical data, project scope and requirements, construction plans
Purpose	To identify potential risks and estimate their likelihood and impact	To estimate the total cost of the project, including materials, labor, and overhead expenses
Techniques	Delphi technique, Failure Modes and Effects Analysis (FMEA), Probability and Impact Matrix (PIM), Root Cause Analysis (RCA)	Parametric estimation, bottom-up estimation, top-down estimation, analogous estimation
Factors	Political instability, economic instability, availability and quality of construction materials, labor shortages or strikes, inadequate project planning or scheduling	Materials cost, labor cost, overhead expenses, equipment cost, contingency costs
Accuracy	Depends on the quality of input data and the expertise of the panel of experts	Depends on the accuracy and completeness of the input data and the appropriateness of the estimation method
Mitigation	Developing contingency plans, establishing clear communication channels, implementing safety measures	Cost management strategies, such as value engineering, cost reduction, and cost control
Output	Risk register, risk management plan, mitigation strategies	Cost estimate, budget, and cost control plan

Table.5 Risk Vs. Cost Estimation

Estimating risks and costs accurately is absolutely necessary for the accomplishment of successful building projects in Iraq. The teams working on a project are able to design effective risk management methods, as well as realistic budgets and timetables, provided they first determine the possible risks involved and then conduct accurate cost estimates. This can assist in ensuring that projects are finished on schedule, within the allotted budget, and to the satisfaction of the stakeholders.

IX. Conclusion

Construction projects in Iraq are subject to a substantial number of risks, every one of which has the potential to affect the project's schedule, finances, or results. The teams working on the project, however, may build

effective ways to manage these risks and assure the success of the project if they undertake accurate risk and cost estimations. The Delphi procedure, RII, Spearman's rank correlation coefficient, and machine learning are only some of the approaches to risk estimate that have been investigated in this research article. Also, many approaches to cost estimating have been investigated, including parametric estimation and bottom-up estimation, among others. Project teams are able to construct complete project management plans that take into consideration possible risks and expenses when they combine these various strategies. The case study that is provided in this paper illustrates that these methods are beneficial in enhancing the results of projects. It is essential for the teams working on projects in Iraq to place a high priority on risk and cost assessment in order to guarantee the success of the projects and minimise any potential adverse effects. Construction projects in Iraq are capable of overcoming obstacles and delivering high-quality work on schedule and without going over their allotted budgets if efficient risk and cost management techniques are put into action.

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