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A Cost Estimation Method Considering Uncertainties Based On Monte Carlo Simulation

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Abstract
In this study, various methods for examining the internal and external risks dealing with cost estimation are reviewd. After selecting the most appropriate approach, the influencing factors are collected using the questionnaire-based method. Then, its consistency is measured with Cronbach's alpha coefficient. The prioritization of risks is conducted through the decision-making trial and evaluation laboratory (DEMATEL) method, wherein the effectiveness and probability of each case are evaluated. Next, the probability of occurrence and the impact weight of each risk are extracted by applying common probability distribution functions to the available data. Then, sensitivity analysis of the number of random variables in the Monte Carlo method is conducted. The probability of environmental risks occurring is highest, approximately 25% to 80%, while respondents estimate inflation and financial risks with greater certainty. Additionally, the impact weight of each risk is highest for inflation risk, 40%, and lowest for financial risk, 15%. Finally, the additional cost is calculated using the Monte Carlo method. The results indicate that the estimated cost of the entire project is 1.83 times the initial estimate due to risks. When compared to the actual costs of three projects located in Karaj city, the difference is at most 10%. At the same time, the initial estimate significantly deviates from reality. Therefore, the Monte Carlo simulation, which accounts for the uncertainty of risks, can be considered a suitable method for project cost estimation.

Keywords: Cost estimation, Monte-Carlo method, DEMATEL selection criteria, internal and external risk of the project.

Introduction

The cost estimate is a critical aspect of construction project management. It is essential to ensure that the project has sufficient funds to meet its financial obligations, including payments to contractors, suppliers, and other stakeholders. Cost estimate includes monitoring and controlling cash inflows and outflows throughout the project's life cycle. Various factors affect cost estimate management, including payment terms, project schedules, change orders, material costs, labor costs, financing options, and contingency planning. Project managers must monitor and control cash flow throughout the project life cycle to ensure that sufficient funds are available to meet financial obligations [1-5]. By using timely financing methods, it is possible to manage the liquidity of resources during the implementation of the project. Timely funding is one of the most effective success factors in completing projects on schedule. In other words, the lack of cost estimation, accurate planning, and budget provision during the project implementation is a significant factor causing delays in the obligations of contractors and project suppliers. Costs caused by project delays have effects and consequences such as increased costs related to consumables, labor resources, and license/contract renewals [6].

Previous studies indicated that risk is one of the main factors that leads to an increase in costs. According to [7], risk management can be used for better cost management and estimation. Other researchers [7, 8] have presented a method for risk quantification to enhance the risk management process. Another group of studies examined the reasons for the increase in costs compared to the estimated amount [9]. Estimating construction project costs is a crucial aspect of project management that involves monitoring and managing the inflow and outflow of funds throughout the project's life cycle. Because it determines the project's financial viability and its capacity to fulfill financial obligations [1, 6].

Another important aspect is the effective management of project cost estimation in construction projects. Effective project cost management involves monitoring and controlling all inflows and outflows of funds throughout the project's life cycle. Various strategies have been also studied to improve construction project costs [1, 7, 8].

Project management and analysis costs help contractors and employers evaluate the future financial situation in an integrated manner [5, 9]. Other studies [10, 11] identified the factors affecting costs in construction projects as follows: project schedule, change orders, material costs, labor costs, financing options, and contingency planning.

At the beginning of a project, an accurate cost estimate is typically prepared to secure the necessary funding. However, uncertainties and risks in the project can prevent the accuracy of such estimates. To address this, employers often allocate a financial reserve in addition to the estimated project costs. This reserve, known as contingency (probable or random), mitigates the adverse effects of uncertainties and risks, and prevents issues caused by increased project costs. Contingency calculation methods can generally be categorized into three main types: certain methods, probabilistic methods, and new calculation methods [12]. Various studies [13-21] have extensively examined these methods.

Construction projects are inherently complex and involve multiple risks that can impact their success, including financial, technical, environmental, legal, political, and social risks [22]. Managing project risks involves identifying potential risks and implementing strategies to mitigate them. There are several approaches to managing project cost risk, including forecasting, diversification, maintaining cash reserves, and effective credit management. Risk management strategies may include risk avoidance, risk transfer, risk reduction, or risk acceptance [22-24]. The risk management process consists of four key steps: identification, evaluation, mitigation, and monitoring [25].

From another point of view, risks can be categorized into two major parts: internal and external. Internal risks come from within the organization or project team. These risks can be controlled or mitigated by the project manager and include factors such as scope creep, resource constraints, and poor planning. External risks come from outside the organization or project team, which include economic conditions, political instability, natural disasters, etc. [26]. Therefore, due to the need for accurate estimation of the costs of a project, various methods have been studied and proposed. However, these approaches typically neglect uncertainty, comprehensive identification of risk factors, interaction mechanism between factors, and the co-occurrence of factors. Consequently, direct consideration of uncertainties and risks is essential for accurate project cost estimation. Some of the methods found for cost estimation, along with their advantages and disadvantages, are given in Table 1.

Another technique for estimating project costs is Monte Carlo simulation, a statistical method used to model complex systems by generating random variables based on probability distributions. This method can be used to model cash flows in construction projects by simulating various scenarios that could affect the project's outcome, such as delays or cost overruns. The main objective of this study is to investigate and identify the internal and external risks affecting the project and then to rank the risks in terms of their impact on the project's success, in order to achieve an accurate cost estimation of the project. In the following, the uncertainties in the project are considered using the Monte Carlo simulation method. The impact of these risks on the project cost is evaluated, and the required reserve budget is determined. It is anticipated that the results of this study will enhance the accuracy of cost estimation by incorporating project risks into the evaluation process.

Table 1. Advantages and disadvantages of cost estimation methods presented in previous studies.

No.	Method type	Advantages	Disadvantages
1	Mathematical functions and S curve [27-32]	Most project cost estimation models use the S curve because it is the simplest method.	It does not consider uncertainty and complexity in the model, and its coefficients cannot be generalized to all projects.
2	Fuzzy Logic [33-39]	It is both simple and practical, while also capable of considering intermediate levels (probabilities).	Its reliance on the critical path method and the classical program evaluation and review technique introduces limitations, particularly the assumption of deterministic activity durations. In addition, all the risks and their mutual effects on each other are not considered.
3	Neural Networks [40-42]	Considering uncertainties relatively, the presented method demonstrates improved accuracy compared to previous methods. This enhancement is due to the modifications in fuzzy logic membership functions, optimization of genetic algorithm parameters, and the presence of unique connection layers.	Artificial intelligence cannot detect the relationship between inputs and outputs. The judgment is based on each component of the chart and does not have a specific trend, while the mutual effects of risks on each other are not considered.
4	*IRR and **C_{max} method [10, 43]	Considering project risk factors in estimating project costs (in a limited way)	The non-comprehensiveness of risk factors, as well as not considering the delay of the

			project and the increase in the amount of the budget.
5	Cost classification method with variable or fixed weighting [44-46]	Fixing the problems of the past models including considering different time delays. Additionally, adjustments to the weighting of categories during the project and its application during executive operations.	Except for the coefficient of workshop overhead and office overhead, the remaining of the categories cannot be uniform. The percentage of all categories is fixed throughout the project, and the effect of time delays on the cost is not considered.

Table 1. Countinued

No.	Method type	Advantages	Disadvantages
6	System dynamics method [3, 4]	Considering various factors involved in project cost estimation and the associated management strategies	It does not account for the effects of uncertainty on schedule delays and cost increases, the customization of parameters for specific projects, and the need for modifications to modeling equations. Furthermore, there is a lack of comprehensive cost estimation that considers the interaction of all risks.

***IRR: Internal rate of return**
****C_{max}: Maximum capital requirement**

Methods

In this study, the Monte Carlo simulation method is employed to account for uncertainties within the project, and to evaluate both internal and external risks for budget allocation purposes. The general framework of this study is illustrated in Fig. 1. Initially, project risks are identified through expert interviews and a review of previous studies. Subsequently, significant risks are prioritized and selected using the decision-making trial and evaluation laboratory (DEMATEL) method. In the following, a questionnaire method is employed to collect the probability of each risk and the weight of each effect on the project cost. The probability distribution functions for each risk are then derived using the Monte Carlo method. Finally, the final cost of the project is estimated by incorporating the identified risks.

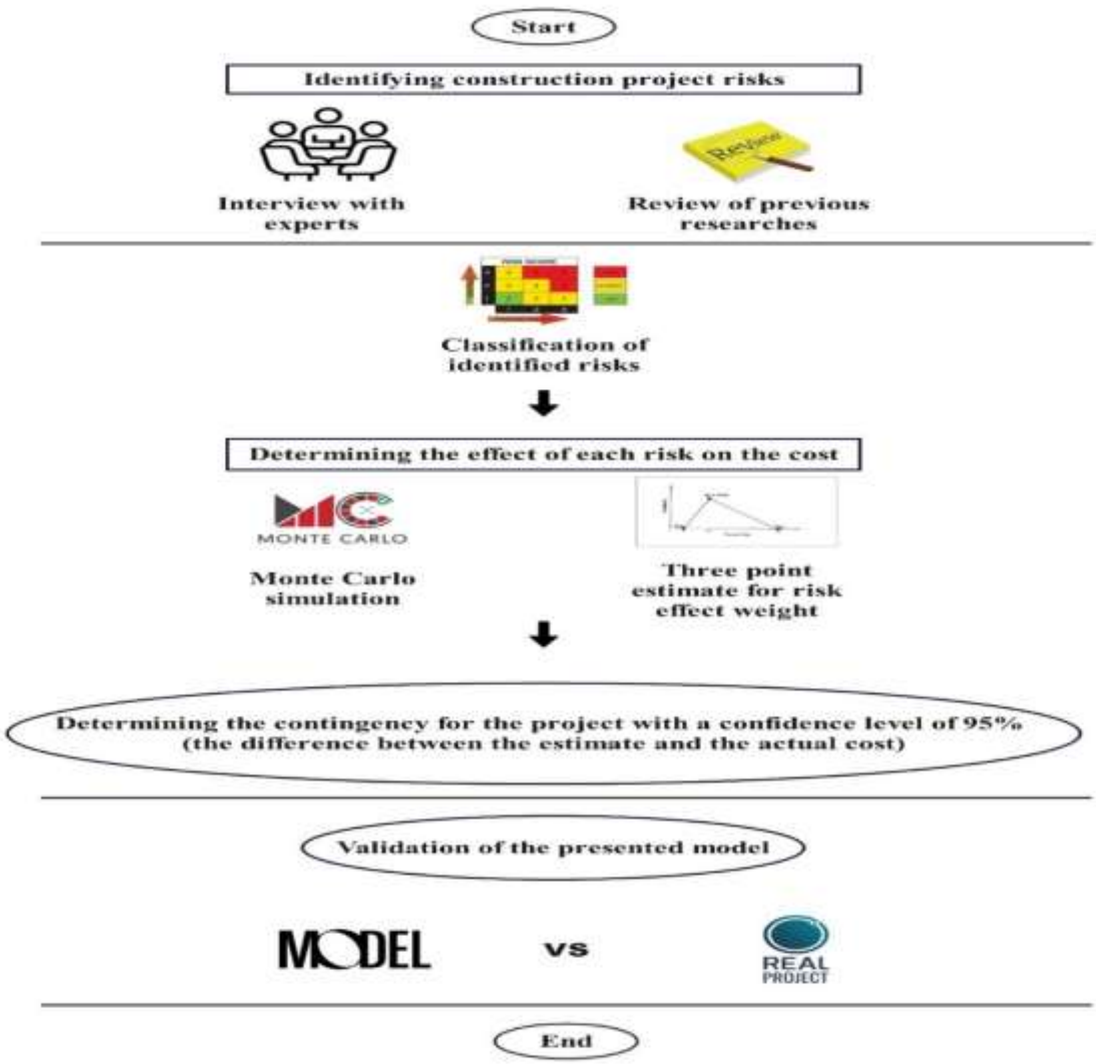


Fig. 1 General framework of this study.

Risk identification and prioritization

A checklist is prepared to identify the primary risks related to cost estimation and budget allocation. The risk identification checklist is prepared using both questionnaires and interviews. The questionnaire is distributed to a group of experts, including planning managers, project managers, consultants, academics, and workshop engineers, all of whom possess both industrial and academic experience. This expert panel identify the risks associated with the studied projects and assign a three-point cost probability (optimistic, most likely, and pessimistic) to each risk factor. To weight and prioritize the risks, the matrix method of paired comparisons and the analytical hierarchy process are employed. After identifying the risks through interviews and reviewing past studies, it is necessary to prioritize the risks using the aforementioned methods.

DEMATEL Method

In a system with internal dependence, all the criteria of the systems are mutually related; therefore, any internal relationship with one of the criteria also affects the other criteria. In this study, the DEMATEL method is employed to construct a network relation map (NRM), factors, and criteria. The steps of such

method are as follows:
Formation of the direct relation matrix
Normalization of the direct correlation matrix
Calculation of the complete correlation matrix
Development of the causal diagram
In order to identify the interrelationships among the n criteria, an n×n matrix, denoted as the direct relation matrix (**X**), is initially constructed. The experts then are requested to assess the influence of each criterion on other criteria with a number from 0 to 4, as defined by the five-level evaluation spectrum of the DEMATEL method, presented in Table 2. When incorporating the judgments of multiple experts, the simple average of their evaluations is computed, and **X** is constructed.
To normalize the direct relation matrix, the formula **N**=**X**/k is used in the following relationship. The coefficient k is determined by computing the summation of all rows and columns of **X**. The maximum resulting value is denoted by k. All the numbers of the direct relation matrix are divided by k.

$$\mathbf{X} = \begin{bmatrix} 0 & \cdots & x_{n1} \\ \vdots & \ddots & \vdots \\ x_{1n} & \cdots & 0 \end{bmatrix} \qquad (1)$$

$$k = \max\{\max \textstyle\sum_{j=1}^{n} x_{ij}, \sum_{i=1}^{n} x_{ij}\}; \mathbf{N} = \mathbf{X}/k \qquad (2)$$

The following formula is used to calculate the complete correlation matrix, **T**.

$$\mathbf{T} = \mathbf{N}(\mathbf{I} - \mathbf{N})^{-1} \qquad (3)$$

where **I** is the identity matrix and **N** is the direct relation matrix.

Table 2. The evaluation spectrum of the DEMATEL method.

Qualitative value	No effect	Very low effect	Low effect	High effect	Very high effect
Quantitative value	0	1	2	3	4

The NRM shows causal and meaningful relationships between the studied variables, based on the complete relation matrix. In this way, the calculation of threshold value enables the omission of partial relationships and facilitates the network of relationships. The NRM displays only those relationships whose corresponding values in matrix T are greater than the threshold value. The average values of the T matrix should be calculated to obtain the threshold value of the relationship. Elements within T that are smaller than the threshold are assigned a value of zero, thereby excluding their corresponding causal relationships from consideration. The DEMATEL method leads to the identification of seven risks, as presented in Table 3, which are analyzed to evaluate their impact on the project cost estimation.

Table 3. Identified risks.

No.	Risks	No.	Risks
1	Design change (change of design specifications after phase 2 design)	5	**Contractual risks**
2	Change in the project schedule	6	**Lack of materials**
3	Inflation	7	**Financing risk**
4	Environmental risks		

In this study, after identifying the risks, two questionnaires were prepared. The first questionnaire focuses on the probability of occurrence of each risk, with the assigned values determined based on the classification of articles related to risk management in investment [13, 14], as described in Table 4.The second questionnaire evaluates the impact of each risk on construction costs (Table 5) and is defined using three points: optimistic, most likely, and pessimistic intervals.

Table 4. The first questionnaire sample: The probability **of** occurrence of each risk based on the category of articles related to risk management in investment.

Category	Qualitative definition	Range	Maximum probability
A	Scarce	It occurs under exceptional circumstances (events with a return period of 100 years).	1%
B	Unlikely	It happens in limited and unpredictable cases (events with a return period of several decades)	20%
C	Likely	Its occurrence in the project is not out of mind (events with a return period of several months to several years)	45%
D	Very likely	It usually takes place in the project (events with a return period of several weeks to several months)	80%
E	Almost certain	An event that is expected to happen in the next few days or weeks	95%

Table 5. The **second** questionnaire sample.

Risk	The range of risk impact on construction costs (percentage)		
	Optimistic	Most likely	Pessimistic
Design change (change of design specifications after phase 2 design)			
Change in the project schedule			
Inflation			
Environmental risks			
Contractual risks			
Lack of materials			
Financing risk			

Fig. 2 illustrates the proposed algorithm for Monte Carlo modeling used to predict the additional cost of a project. As outlined in the figure, risks that cannot be quantified are excluded from the scope of this study. Otherwise, in case of the risk's repeatability, by calculating the probability of its occurrence as well as the effect weight of each risk, it is possible to estimate the additional cost of the project using a Monte Carlo simulation with high repetition.

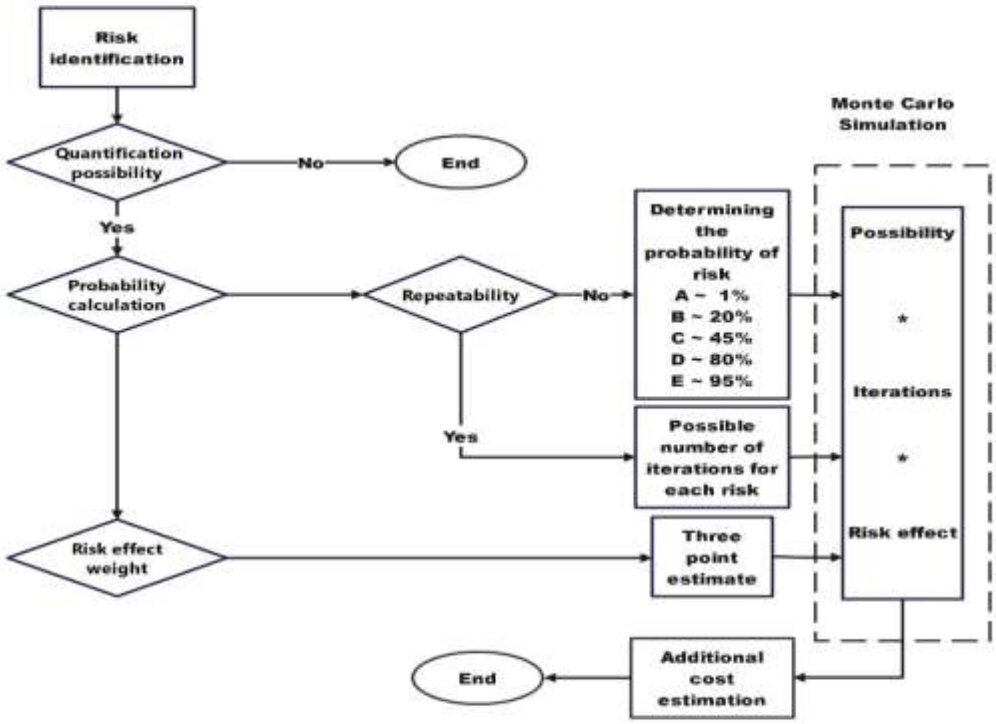


Fig. 2 Proposed model to estimate the construction cost using the Monte Carlo method.

Validity and reliability of data collection method

Considering that the identified risks are extracted from credible and peer-reviewed articles, the validity of the content is well-established. Furthermore, since the respondents are selected from among industry experts, their insights carry the necessary credibility. To assess the reliability of the questionnaires used in this study, Cronbach's alpha coefficient is employed. Cronbach's alpha is a widely recognized method for measuring the reliability of a questionnaire. It is derived from the average covariance (correlation) among the questions (subjects or items) within a questionnaire (test). Cronbach's alpha coefficient is applicable to all scales where the level of measurement of the indicators is rank, distance, or relative. In this study, Cronbach's alpha values for the first and second questionnaires are 0.93 and 0.82, respectively. These values are acceptable as previous studies [15], thereby confirming the reliability of the questionnaires.

Result and discussion

simulation

This technique finds many applications in evaluating discrete stochastic processes as well as complex reliability issues with a limit condition function and several maximum possible points. The Monte Carlo method estimates failure probability through three fundamental steps:

Random number generation using the cumulative probability distribution function of random variables between zero and one.

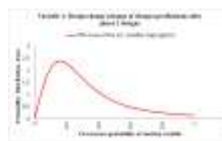
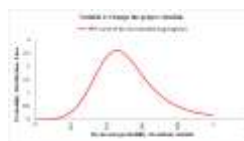
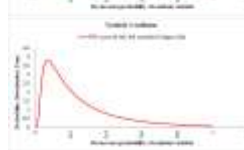
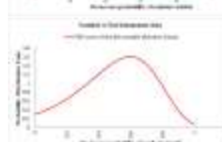
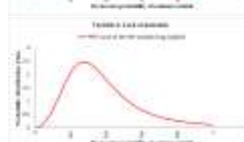
Estimation of each random variable using the statistical characteristics of the generated random variables from the previous step.

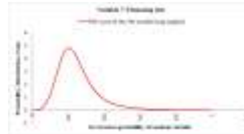
Estimation of the limit condition function based on the data generated in step 2 and estimation of failure probability.
The Monte Carlo method involves generating random samples for each variable $\mathbf{X}_i$ and evaluating the limit state function, $g(\mathbf{X}_i)$. A sample X_i is considered to be in the failure region if $g(\mathbf{X}_i) > 0$ and in the health region if $g(\mathbf{X}_i) \leq 0$. The Monte Carlo simulation, employed to evaluate the limit state function with randomly generated variables, requires a large number of iterations. During each iteration, the vector $\mathbf{X}_i$ is randomly sampled to generate multiple points within the failure domain.

Data mining method and Monte Carlo implementation

According to Table 3 and the selection of seven random variables affecting the calculation of additional costs due to risk assessment, the random variables in this study are fitted according to the samples. In Table 6, 30 random samples are collected from the first questionnaire to determine the probability of occurrence for each risk.
Additionally, the range of risk influence on the construction period costs, expressed as a percentage, is provided as a three-point estimate. These data are collected in the second questionnaire, with the same sample size of 30 as in the first questionnaire. In this way, the data are fitted according to the triangular probability distribution function.

Table 6. Probability distribution functions.

Risk	Distribution function type	Graph model	Parameters
Design change (change of design specifications after phase 2 design)	Log-logistic		β α
Change in the project schedule	Log-logistic		β α
Inflation	Fatigue Life		β α
Environmental risks	Extreme Value		a b
Contractual risks	Normal		μ σ
Lack of materials	Log-logistic		β α

Financing risk	Log-logistic		β α

Probability distribution function (PDF)

If x is a continuous random variable, its PDF is represented by a non-negative function f(x), such that for two numbers a and b (a<b), the probability that x has a value in the interval [a, b] is given by the integral f(x) from a to b:

$$P(a < x < b) = \int_a^b f(x)dx \qquad (4)$$

The total area under the PDF curve is equal to 1, which represents the total probability. By examining the behavior of selected variables in previous studies, the behavior of variables "Design change, Change in the project schedule, Lack of materials and Financing risk", "Inflation", "Environmental risks" and "Contractual risks" are considered as Log-Logistic, Fatigue Life, Extreme value and Normal probability distribution respectively. Each of these functions has its own unique parameters, which are shown in Table 6.

After collecting the data, using the probability distribution function, a probability distribution function is fitted for each variable according to the data, and the characteristics of each are extracted according to Table 6. The results can be seen in Table 7. The distribution functions can be seen in Fig. 3. As it is clear from Fig. 3, all the data related to questionnaires 1 and 2 for all seven risks are fitted so that their probability distribution function is according to Table 6. The values of the parameters related to each risk are also extracted and stored in order to carry out a Monte Carlo simulation with different numbers of repetitions using these characteristics.

Table 7. Characteristics extracted from fitting the data with the corresponding probability distribution.

Risk	The probability distribution name	Characteristic
Design change	Log-Logistic	μ= -1.2961, σ= 0.4966
Change in the project schedule	Log-Logistic	μ= -0.6970, σ= 0.2011
Inflation	Fatigue Life	β= 0.1849, γ= 0.9457
Environmental risks	Extreme value	μ= 0.5976, σ= 0.2290
Contractual risks	Normal	μ= 0.4183, σ= 0.2045
Lack of materials	Log-Logistic	μ= -1.0653, σ= 0.3274
Financing risk	Log-Logistic	μ= -1.4702, σ= 0.238

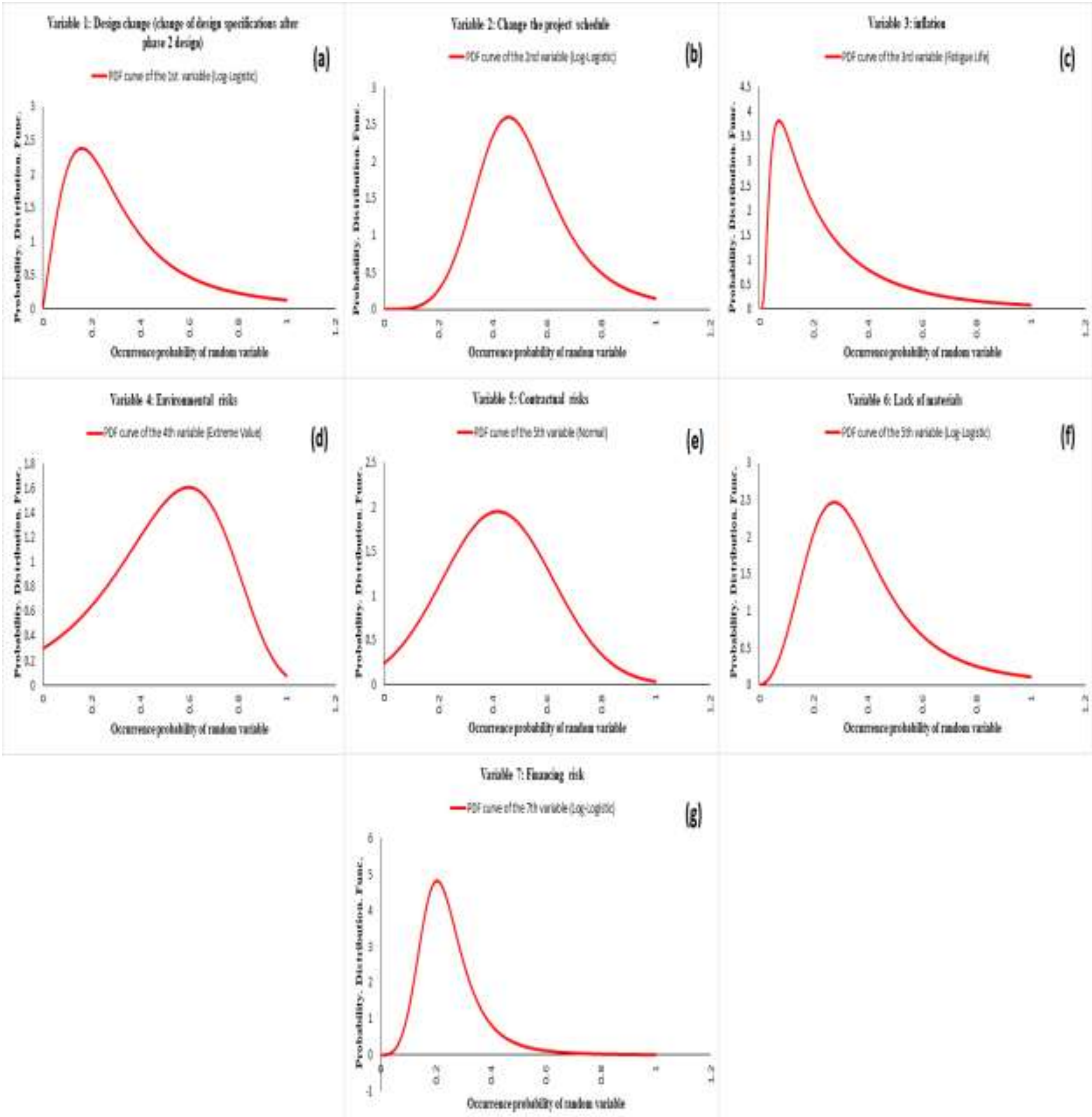


Fig. 3 Chart of PDFs extracted from data for each risk; a) Design change, b) Change in the project schedule, c) Inflation, d) Environmental risks, e) Contractual risks, f) Lack of materials, and g) Financing risk.

From Fig. 3, it is clear that the respondents considered the range between 10%and 30% as the most likely state for the first risk. Also, the ranges of 35% to 65%, 5% to 25%, 25% to 80%, 35% to 60%, 10% to 45%, and 10% to 30% are considered by the respondents for the probability of the second to seventh risk. By examining graphs such as Figs. 3-c and 3-g, it can be seen that the sharper the graph is extracted, it means that the probability of risk occurrence is stated with greater certainty by the respondents. On the contrary, the longer and wider the graph is, it shows the difference in respondents' opinions on the possibility of that risk occurring. In this part, it is clear that inflation and financial risk are estimated more accurately than other risks. Therefore, due to the uncertainty that has arisen by using Monte Carlo simulation and with a lot of repetition in the selection of random variables, an attempt will be made to verify the results of the additional cost estimation.

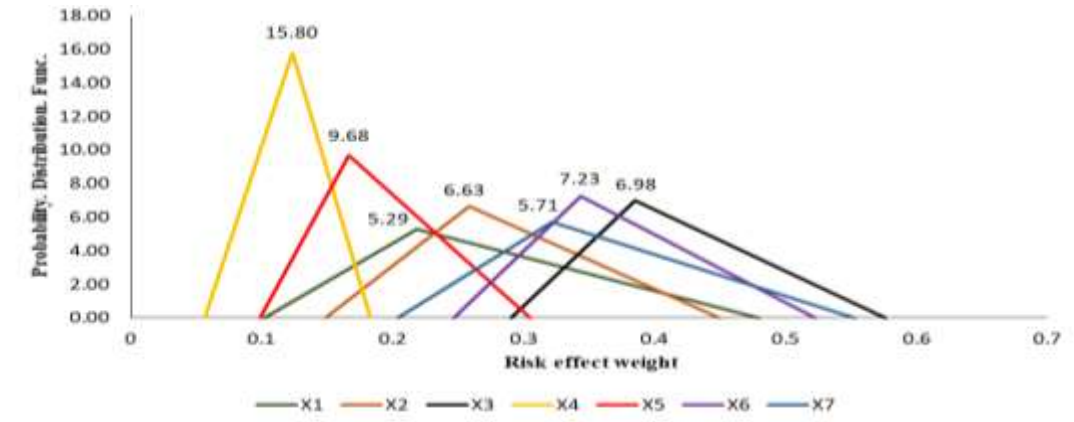


Fig. 4 Triangular probability distribution function diagrams for the effect weight of project risks.

A triangular distribution function is fitted for the effect weight of each risk, which can be seen in Fig. 4. As can be seen, the effect weight of the 3rd risk (inflation risk) is the highest and the most likely value is about 40%, which is considered by the respondents. Also, the lowest effect weight is related to the 4th risk (environmental risk) and its most probable value is about 15%. In order to compare the weights of other risks, high to low values are related to risks 3, 6, 7, 2, 1, 5, and 4, respectively.

Generating random numbers with Monte Carlo

In order to generate random numbers, it is necessary to select them based on the obtained probability distribution in such a way that the value of correlation or non-correlation of the variables is considered. The correlation matrix serves as an analytical tool for this purpose, which shows the correlation coefficients between variables in the range of -1 to 1. If two variables exhibit a high positive correlation, it indicates that they tend to vary in the same direction. Conversely, a high negative correlation signifies that the variables move in opposite directions. A correlation coefficient of zero implies the absence of a linear relationship between the variables. In the first step, random numbers are generated using the standard probability distribution function for each variable. Then, by using the concept of correlation and Cholesky decomposition, the random numbers are multiplied by the Cholesky coefficient, **U**, to produce random numbers with a standard and correlated probability distribution. The Cholesky coefficient is calculated as follows:

$$R = \mathbf{U}\mathbf{U}^{\mathbf{T}} \quad (5)$$

which, R, is the correlation matrix of data extracted by the Pearson method.

Finally, the cumulative distribution function (CFD) for each variable, Φ(x), is calculated. Using Eq. (6), random numbers with the desired probability distribution and correlation, based on specifications extracted from the sample data, can then be generated.

$$\begin{aligned} x &= \mathrm{CFD}^{-1}\big(\Phi(x)\big) \\ \Phi(x) &= \mathrm{CFD}(\mathrm{F}(\mathbf{X})\mathbf{U}) \end{aligned} \quad (6)$$

Using the following equation, the additional cost incurred due to all risks is obtained. This amount is considered as a reserve or contingency budget forecast.

$$\mathrm{ECC} = \mathrm{n}\mathbf{X}\mathbf{W} \quad (7)$$

where ECC, n, **X**, and **W** are the extra cost coefficient, the number of occurrences of each random variable,

the probability of each random variable, and the weight effect of each random variable, respectively.
The output will be reliable when the sensitivity of the final result to the number of chosen random numbers is verified. Table 8 shows the sensitivity of the extra cost output value to the number of random variables. Additionally, Fig. 5 illustrates that as the number of random variables increases, the accuracy of the result improves and remains constant after a certain value. Table 8 shows that 100,000 random numbers are sufficient to achieve the final result.

Table 8. Sensitivity analysis of the number of random variables in the Monte Carlo method.

Number of random variables selected	0	5	10	50	100	1000	10000	100000	200000
ECC	0	0.5806	0.7982	0.8221	0.8108	0.8219	0.8275	0.8360	0.8350

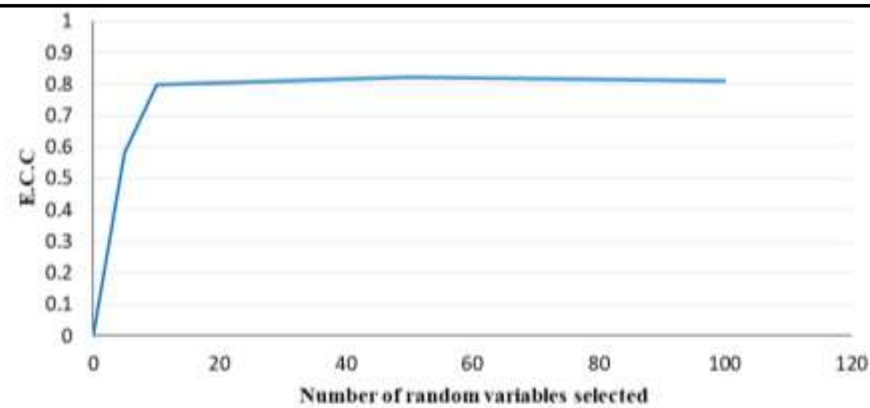


Fig. 5 Sensitivity analysis for the number of selected random variables.

As shown in Table 8 and Fig. 5, the average value obtained from the Monte Carlo method for estimating the extra cost caused by the internal and external risks of the project, which is caused by the probability of occurrence, the number of occurrences and the weight of the effect of the seven prioritized risks, is approximately 0.83. This value is calculated assuming that the number of occurrences of each risk is 1. This means that if, during the construction phase of a project, the mentioned risks occur even once, the estimated cost at the beginning of the project has an error of about 83%. Therefore, this will significantly affect the completion time, liquidity, project management, and overall profit or loss.

Comparison with a case study

For comparison purpose, several mega-urban construction projects in Karaj city, Iran, are examined. Information regarding the estimation of the project costs as well as the cost changes and the required reserve budget due to internal and external risks is collected. Table 9 shows that the amount of contingency estimation, taking into account the uncertainty of risks, with only a 10% from the actual and final cost of the projects, can respond well to the forecast of costs. In contrast, cost estimates and projections for these projects, when internal and external risks are not considered, showed a significant deviation from reality during project implementation. Thus, it is evident that using this modeling approach can improve cost prediction and support better decision-making in project management.

Table 9. Comparing between actual cost spent, project cost estimation, and estimated cost in this study.

Project	Initial cost estimate (billions of Rials)	Actual cost spent (billions of Rials)	Project cost estimation (billions of Rials)	Estimated cost in this study (billions of Rials)
1	121	233	172	221
2	62	105	85	113
3	254	443	380	464

Investigating the effect of inflation on the total added cost

As a parametric study, the effect of inflation as a key parameter on the estimation of construction project costs in Iran is investigated. According to the Monte Carlo simulation results shown in Fig. 6, variations in the amount of inflation (weight of risk effect) to any extent, result in changes in the ECC by approximately 41%. Therefore, an increase or decrease in inflation does not necessarily lead to a proportional increase or decrease in project costs.

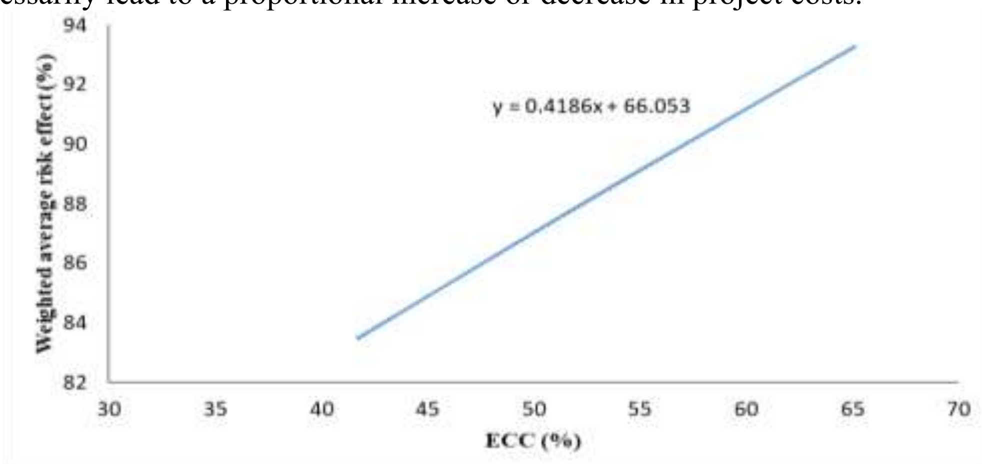


Fig. 6 The effect of inflation on ECC.

Conclusion

The purpose of current study is to develop a suitable, comprehensive, and simple method for predicting project costs while considering the effects of risks and all influencing factors. Additionally, it aims to identify the root causes and connections of the increase in time and cost of project activities. In this way, the Monte Carlo method determines the average effect of seven prioritized risks. The impact of these seven risks on the objective function includes the number of occurrences, the probability of occurrence during construction, and the amount of their impact on the project cost.

The most important results obtained are as follows:

The results of Monte Carlo simulation after sensitivity analysis revealed that, assuming each risk occurs once during the project, the construction cost increases by approximately 83%. This demonstrates that incorporating the impact of internal and external risks during construction leads to more accurate cost estimations. This, in turn, influences project management, completion time, scheduling, material procurement, and cash flow.

A parametric study investigates the effect of inflation, a key parameter, on construction project cost estimation in Iran. Monte Carlo simulation output revealed that changes in the inflation rate (weight of risk effect) to any extent, lead to changes with a factor of about 40%. Therefore, the decrease or increase in inflation does not necessarily decrease or increase the project costs by exactly the same amount. For future studies, the individual impact of each risk on the value of ECC could be investigated.

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