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Evaluation of the Effective Functioning of Construction Enterprises in the Conditions of Occurrence of Diverse Risk Factors

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Abstract: Construction production in Russia and abroad (in Iraq) is facing various negative factors. The emergence of diverse factors in the implementation of investment and construction projects has an effect on the making of important decisions by the heads of construction enterprises, which may in the future be the cause of uncertainty and, as a result, the emergence of critical risks. The purpose of the study is to develop a methodology for identifying and assessing the influence of risk factors on the activities of construction enterprises in the implementation of investment projects. For the purposes of the study, mathematical and statistical models were used, such as the hierarchical analysis method and Monte Carlo, as well as the expert survey. The result of the study shows that the use of those models will significantly increase the success of construction enterprises by identifying various risk factors at the stage of construction and assessing their impact on these projects. The scientific and methodological approaches developed as a result of the study, methods for assessing risk factors, and appropriate compensatory measures to reduce or prevent the influence of these factors will significantly improve the organization of production activities of construction enterprises and will contribute to their successful development.

Keywords: construction enterprises; effective functioning; risk factors; hierarchical analysis; Monte Carlo

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Citation: Abramov, I.; AlZaidi, Z.A.K. Evaluation of the Effective Functioning of Construction Enterprises in the Conditions of Occurrence of Diverse Risk Factors. *Buildings* **2023**, *13*, 995. https://doi.org/10.3390/buildings13040995

Academic Editors: Liubov Shilova and Ginzburg Alexander

Received: 10 February 2023
Revised: 26 March 2023
Accepted: 5 April 2023
Published: 10 April 2023

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1. Introduction

The growing importance of efficient functioning in the construction industry has led to the emergence of an increasing number of studies related to the effective development of construction enterprises.

According to the current regulatory documents, a construction enterprise is an enterprise operating in the field of construction, which carries out survey and design work, the production of materials and structures, the construction of buildings and structures, and transport services. At the disposal of construction enterprises are certain resources (material, technical and labor), with the help of which the required products are created [1,2].

In addition, a construction enterprise is a complex structural dynamic system that can undergo changes, move from one qualitative state to another and has the following properties [2,3]:

- Manageability—the admissibility of a temporary change in the processes of functioning under the influence of managerial factors;
- Flexibility—the ability of the production system to adapt to changing environmental conditions;
- Longevity—the ability of the production system to function for a long time;
- Effectiveness—the ability to obtain an effect, to create the products that the consumer needs;

- Sustainability—a qualitative characteristic manifested in the ability of a production system to maintain the required level of performance.

In Russia, construction production is one of the most significant sectors of the economy (accounting for about 8% of GDP), the state of which reflects the level of economic development of the country. In 2018, employment in the construction sector accounted for 8.3% of the total employed population of the Russian Federation. Every year, the number of operating organizations in the construction business increases. At the beginning of 2018, there were more than 240 thousand enterprises in the construction sector [3,4].

The successful conduct of the construction activity of a construction enterprise refers to effective functioning in the changing conditions of a probabilistic competitive environment and diverse risks [5,6].

In order to maintain the envisaged sustainable operation, construction enterprises producing quality construction products must protect their activities in advance at the stage of implementation of construction production from the influence of relevant risks and uncertainties. Therefore, it is necessary to note the importance of cooperation between the parties involved in the construction process in order to understand the risks and potential problems and determine ways to solve them, which is achieved by assessing and analyzing the factors that cause these risks under conditions of uncertainty [7].

There is a need to develop appropriate scientifically based methods for measuring and quantifying the organizational and technological efficiency and capacity of enterprises, diagnosing rational parameters of the organizational structure of construction production and cooperation under conditions of risks and uncertainty to ensure effective performance in that enterprise [8,9].

There are a lot of previous studies and research that evaluated the impact of risks on the construction industry in many countries and used a number of different techniques and provided different results and conclusions [10,11].

The main problem of the study is that there are many risk factors that cannot be predicted during the implementation of construction projects as a result of multiple political, economic or environmental conditions, etc. Therefore, there must be an integrated approach for construction enterprises to identify, analyze and evaluate the impact of these factors on the project objectives (cost, duration and quality) for the purpose of finding solutions and measures to reduce or limit impact of these factors.

Enterprises involved in the implementation of construction projects in general and projects for the construction of multi-story buildings in particular need to use modern methods for analyzing factors affecting the efficiency of construction production, including multi-criteria decision-making methods, such as a hierarchical analysis model; use complex software in real-time large construction projects; and consider the importance of distribution models, simulation type and Monte Carlo simulation.

The novelty behind this study is to identify the unexpected factors that cannot be predicted in light of the unstable political, military, economic and organizational conditions in Iraq in addition to climatic changes and abnormal phenomena such as earthquakes, droughts, fires and the like that are widespread in the region. In addition, the novelty lies in finding a methodology for evaluating the impact of these factors on construction enterprises for the purpose of selecting the optimal alternative for enterprises that have integrated management programs to confront these risk factors by choosing modern methods of evaluation. In addition, the development and selection of appropriate measures to reduce the occurrence or limit these factors under these circumstances should also be considered.

In previous work and research, scientists have identified various key factors affecting the effective functioning of construction enterprises, such as government policy, additional costs, design errors, labor and technical factors, pressure from stakeholders, local environmental and social problems. Because so many factors have been determined, understanding the complex mechanisms that affect the efficient functioning of construction businesses seems even more difficult.

Factors affecting the performance of construction projects are generally divided into internal and external [12,13], as shown in Figure 1.

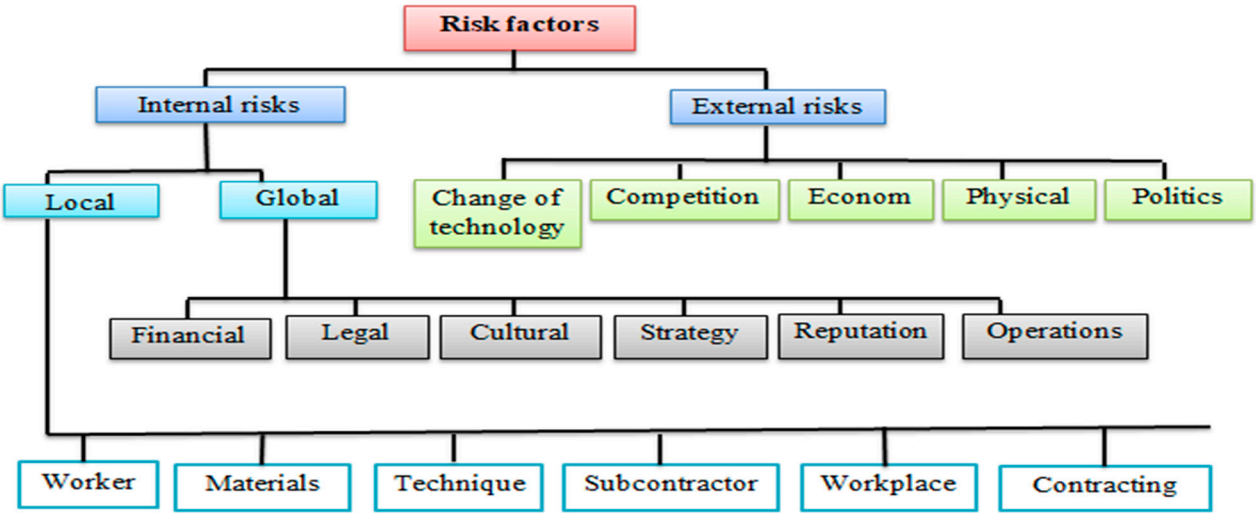


Figure 1. External and internal risk factors affecting the activities of construction enterprises.

The following categories of risk factors were observed in several scientific and field studies as well as in previous literature in Russia and Iraq for the period from 2015 to 2022. In this study, an attempt was made to identify and group risk factors during the construction phase, as shown in Table 1.

Table 1. Categories of risk factors in construction enterprises.

Categories	Russia	Iraq
Economical	The growth of inflation, changes in exchange rates, an increase in the level of taxation, an increase in prices for materials and products, insolvency of customers, and others [14,15].	Substitution of public interests by representations of power by private interests (corruption), bankruptcy of contractors of enterprises, changes in exchange rates, inflation and price fluctuations, delay or non-payment of financial contributions to enterprises [16,17].
Political and legal	Instability, changes in legal regulations, late receipt of project expertise, refusal of a construction permit, unstable political situation, major changes in the terms of the contract, inadequate technical supervision, bureaucratic costs, non-compliance with regulations of the government of the Russian Federation [13–18].	Changes in the political situation, delay in the arrival of materials and equipment due to military events, injuries to workers as a result of military events, the sudden presence of terrorist groups in the workplace, and damage to some parts of the facility and equipment as a result of military clashes [16,17,19].
Organizational	Shortage of qualified workers, errors in design and estimate documentation, change in requirements and terms of the contract by the customer, lack of material resources, failures in the supply of materials, failure to comply with safety regulations, delays in the course of construction and installation works, poor planning of production and financial activities and lack of orders to work [2,13,17,20].	Changes in the project specification and cost, poor coordination between the customer and the contractor, delay in laboratory tests, lack of human resources, late access to the construction site, incomprehensible way to reduce the damage caused by delays, unexpected events and holidays [19–21].
Technical	Lack and deterioration of machines and mechanisms, the problem of ensuring the quality of work, inefficiency and inaction of workers [14,17,20,22].	The absence of specialized mechanisms, the inefficiency and inactivity of workers, the use of faulty or obsolete machinery and equipment, old technologies, strikes and riots [13–19].
Climatic	Snowfall, storm, low temperatures and downpour [13,14].	High temperature in summer above 50 °C, heavy rain in winter, pollution, natural disasters (earthquakes, floods) [21,22].

2. Materials and Methods

As part of this study, a scheme was proposed for implementing the results of risk factors in a construction enterprise. The scheme is proposed for implementation at any construction enterprise in the Russian Federation and Iraq and other countries.

First of all, to assess the results of risk factors, the identified risks are described in detail. For implementation, it is important to consider all risks in an integrated system. Further, the management of the enterprise must evaluate each type of risk factors based on an expert assessment. This allows to determine which of the risks are the most dangerous in relation to the smooth functioning of the enterprise. The final stage of implementation is the development of methods aimed at reducing the impact of each type of risk.

The flowchart in Figure 2 illustrates the two practical steps of the study:

1. Identification and evaluation of risk factors affecting construction enterprises using a hierarchical analysis model (AHP).
2. Development and analysis of the main measures implemented by enterprises in order to limit or reduce the influence of factors using Monte Carlo simulation in the Primavera Risk Analysis PRA program.

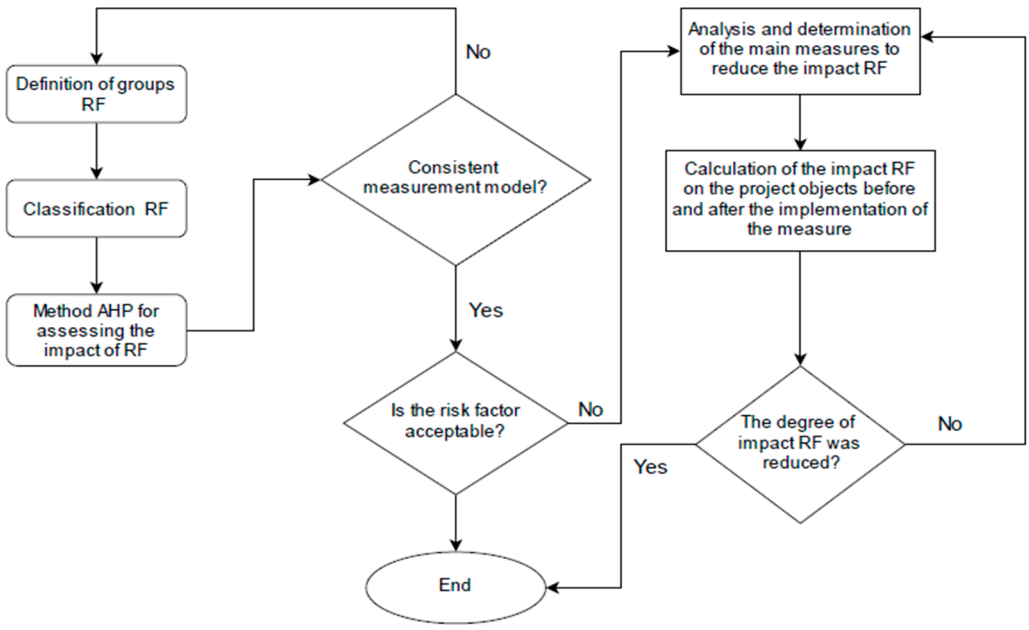


Figure 2. Algorithm of the practical stages of the study.

The process of analyzing a hierarchical model, which is considered one of the most important decision-making methods, is based on assessing the impact of risk factors on construction projects using expert assessments. In the process of questioning, experts rank the degree of influence of risks. A rational choice of factors based on an analysis of the causes and factors of a large number of risks in a group of construction projects is crucial for the results of the final assessment, in accordance with the field of study [21,23,24]. The hierarchical analysis method can be used as one of the methods of the quantitative approach in analyzing and evaluating risk factors because the reliability of expert opinions and pairwise comparison between criteria can be checked. In addition, pairwise comparisons can be made between enterprises by calculating the degree of influence of risk factors on those enterprises, and thus choosing enterprises that have an integrated program to manage these risks.

The factors were classified and provided to the experts to evaluate their influence by calculating the priority coefficient using a hierarchical model, as shown in Figure 3:

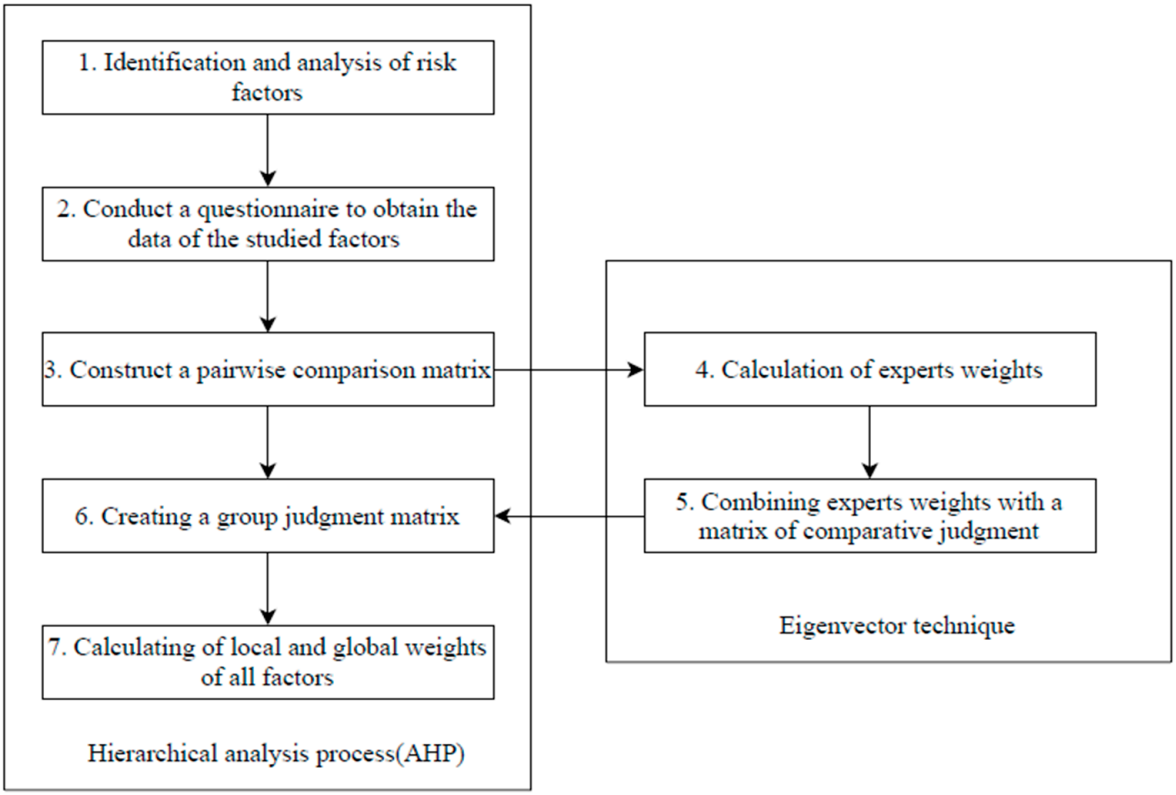


Figure 3. Algorithm of analysis of hierarchical process AHP [2,25].

The hierarchical analysis model starts by arranging groups of risk factors in a hierarchical order, then a pairwise comparison of risk factors is performed against one of the selection criteria, then priorities are extracted from these comparisons, and finally overall priorities are determined. Saaty (1980) determined the way in which this method works, and thus the degree of stability was calculated.

The process of hierarchical analysis is carried out by identifying the priority elements of the pyramid and making judgments in order to obtain a set of common priorities and checking the reliability of these judgments for making a final decision. Many outstanding works have been based on hierarchical analysis (HIA), which is applied in various fields such as planning, choosing the best alternative, resource allocation, conflict resolution, optimization, as well as numerical extensions, etc. [26].

To compare a number of groups of risk factors based on their influence, it is necessary to calculate the relative importance (priority factor) of each factor. To do this, a hierarchical analysis model is used and a survey of experts is carried out according to the following stages:

1. Building a hierarchical structure of groups of main criteria and their parameters (risk factors);
2. After completing the survey, the performance of a binary comparison within each group of factors, which can be displayed as a decision matrix [24–27].

$$M = \begin{bmatrix} 1 & x_{12} & . & . & x_{1n} \\ x_{21} & 1 & . & . & x_{2n} \\ . & . & 1 & . & . \\ . & . & . & . & . \\ x_{n1} & x_{n2} & . & . & 1 \end{bmatrix}, \quad (1)$$

where

X_{12}—the relative importance of the 1st criterion in relation to the 2nd one;

X_{21}—the relative importance of the 2nd criterion in relation to the 1st one (the reciprocal of X_{12}) [27].

The comparison results are recorded as numerical values of relative importance in relation to a given scale of absolute numbers (Table 2) [28,29].

Table 2. Relative importance weights for pairwise comparison.

Numeric Values	Expression in Verbal Variables
1	Two elements contribute equally to an object (i equals j)
3	Element i is three times more important than element j
5	Element i is five times more important than element j
7	Element i is seven times more important than element j
9	Element i is nine times more important than element j
2, 4, 6, 8	Averages used between previous weights

Since the comparison is made by multiple experts, the geometric mean is used for each comparison between two factors:

$$\mathrm{Gm} = \sqrt[n]{x_1.x_2.\ldots..x_n}, \quad (2)$$

where Gm is the geometric mean.

3. Using factor weights to prioritize after ensuring consistency.

$$\mathrm{Priority}_{\mathrm{row}} = \frac{\mathrm{Gm\ (row)}}{\sum \mathrm{Gm\ (all\ matrix\ rows)}}. \quad (3)$$

4. In order to ensure the accuracy of the conducted pairwise comparison and the absence of contradictions in the opinions of experts, the consistency ratio is checked. This is achieved by calculating the value (λ_{max}) [24–30]. The consistency ratio should not exceed 0.1.

$$\lambda\mathrm{max} = \sum \{\mathrm{Priority}_{row} \times (\mathrm{Column\ sum})\}, \quad (4)$$

$$\mathrm{Cc} = \frac{\mathrm{C_i}}{\mathrm{R_i}}, \quad (5)$$

$$C_i = \frac{\lambda_{max} - n}{n - 1}, \quad (6)$$

where Cc is the consistency ratio;

Ci is consistency index;

Ri is a random indicator, the value of which is calculated based on the number of factors (Table 3).

Table 3. Random indicators (Ri) [31,32].

n	3	4	5	6	7	8	9	10
Ri	0.58	0.9	1.12	1.24	1.32	1.41	1.45	1.49

As a rule, if the Cc is less than 0.1 and the judgments are consistent, then derivatives of the weight indicators can be used. That is, when Cc is less than 0.1, the resulting vector is considered to be within the margin of error and can therefore be accepted [2].

The priority of each criterion is calculated by pairwise comparisons between these criteria after collecting the opinions of experts participating in the survey (Table 4).

Table 4. Pairwise comparison of the main criteria.

Criteria	Organizational	Technical	Economic	Political and Military	Climatic
Organizational	X_{11}	X_{12}	X_{13}	X_{14}	X_{15}
Technical	X_{21}	X_{22}	X_{23}	X_{24}	X_{25}
Economic	X_{31}	X_{32}	X_{33}	X_{34}	X_{35}
Political and military	X_{41}	X_{42}	X_{43}	X_{44}	X_{45}
climatic	X_{51}	X_{52}	X_{53}	X_{54}	X_{55}

Using Equation (2), the value of the principal eigenvector [33] for each criterion is calculated as in the following matrix:

$$M_{Gm} = \begin{matrix} \sqrt[5]{x_{11} \times x_{12} \times \ldots\ldots\ldots \times x_{15}} \\ \sqrt[5]{x_{21} \times x_{22} \times \ldots\ldots\ldots \times x_{25}} \\ \sqrt[5]{x_{31} \times x_{32} \times \ldots\ldots\ldots \times x_{35}}. \\ \sqrt[5]{x_{41} \times x_{42} \times \ldots\ldots\ldots \times x_{45}} \\ \sqrt[5]{x_{51} \times x_{52} \times \ldots\ldots\ldots \times x_{55}} \end{matrix} \quad (7)$$

Then, all the rows of the matrix are summed to calculate the sum of the geometric mean, as in the Equation:

$$\sum Gm = \sqrt[5]{x_{11} \times x_{12} \times \ldots \times x_{15}} + \sqrt[5]{x_{21} \times x_{22} \times \ldots \times x_{25}} + \sqrt[5]{x_{31} \times x_{32} \times \ldots \times x_{35}} + \sqrt[5]{x_{41} \times x_{42} \times \ldots \times x_{45}} + \sqrt[5]{x_{51} \times x_{52} \times \ldots \times x_{55}}. \quad (8)$$

The priority of each risk factor criterion can be determined by dividing the geometric mean of that criterion by the sum of the geometric mean of all rows (Equation (9)).

$$\begin{matrix} P_{c1} = \sqrt[5]{x_{11} \times x_{12} \times \ldots \times x_{15}} / \sum Gm \\ P_{c2} = \sqrt[5]{x_{21} \times x_{22} \times \ldots \times x_{25}} / \sum Gm \\ P_{c3} = \sqrt[5]{x_{31} \times x_{32} \times \ldots \times x_{35}} / \sum Gm. \\ P_{c4} = \sqrt[5]{x_{41} \times x_{42} \times \ldots \times x_{45}} / \sum Gm \\ P_{c5} = \sqrt[5]{x_{51} \times x_{52} \times \ldots \times x_{55}} / \sum Gm \end{matrix} \quad (9)$$

After identifying and assessing risk factors, construction industry specialists can make the necessary decisions and implement organizational and technological measures. These measures are designed to contain risks by reducing the likelihood of their occurrence or minimizing their impact [15–34].

To manage risks, there are a number of measures that can be implemented depending on the type of risk factor:

1. Risk avoidance. This measure implies risk elimination or complete avoidance [35]. The advantage of this strategy is that it is the most effective way to manage risk. However, risky activities can be very profitable; then, the disadvantage of this measure is that all the benefits of risk are also lost. Therefore, this strategy is best used as a last resort when other strategies have failed to reduce risk.
2. Reduction (mitigation) of risks. This approach consists of applying measures that reduce the likelihood of a negative outcome or minimize the consequences of a risk if it does occur. This is probably the most common strategy and it is suitable for a wide range of different risks. This allows to continue the activity while making it less dangerous [13–35].
3. Risk transfer. This strategy implies the transfer of risk from one party to another with payment in return. There are two options for implementing this strategy: pay an insurance company to manage the risk (insurance) or pay some other company to manage the risky activity (outsourcing).

4. Risk acceptance. When the cost of risk reduction is higher than the likely losses, or when the risky activity brings a large profit, it is better to accept the risk.

According to the stages of the risk matrix and Monte Carlo modeling [36,37], the main purpose of the method is to assess the impact of risk factors on construction enterprises and on the construction duration before and after the implementation of the main criteria that were adopted as compensatory measures for reducing or limiting the influence of these factors (Figure 4).

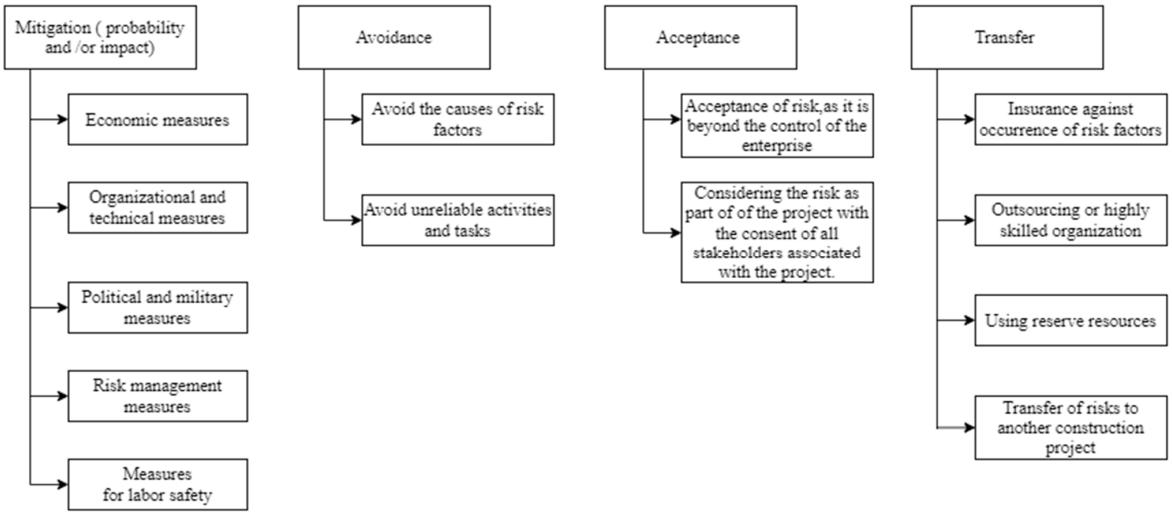


Figure 4. Compensatory measures to reduce or limit the impact of risk factors.

Based on studies, site visits, interviews with construction organizations, as well as the study of economic and geopolitical situation in Iraq, measures were identified and highlighted to reduce or limit risk factors [38], which are presented in Table 5.

The simulation is performed using the Monte Carlo method. During the simulation process, the project model is computed many times (iterated), with input values (e.g., cost estimate or activity duration) being randomly selected for each iteration from the probability distributions of these variables. A histogram (for example, total cost or project completion date) is calculated based on iterations [39–41]. Risk analysis (Oracle primavera) is used for Monte Carlo modeling and simulation.

The Risk Register provides tools to help make better risk mitigation decisions. A risk score is used to assign an overall rating to a risk based on the likelihood of the project and impact thresholds.

The following factors influence the determination of the risk assessment:

- Project risk assessment matrix;
- Scores entered in the highlighted Risk Assessment Matrix (probability and impact chart grid);
- Selected approaches to the Risk Assessment Matrix (highest impact, average impact, average individual impact);
- Probability of the risk occurring.

Each risk impact (on duration, cost, quality, etc.) is recorded [42–44]. The risk score matrix contains probability thresholds, the graph contains cost impact thresholds and any other user-defined impact thresholds, all of which are used in calculating the risk score. Risk Score is an item on the Edit menu that allows the user to customize risk and impact scores. The Risk Matrix, found under the View menu, displays a graphical representation of risk data, both before and after mitigation, to help determine the effectiveness of the mitigation measures planned for each risk. Primavera risk analysis can capture start and finish dates for each work in a project that has a high probability (e.g., 80%) during risk analysis, and then it uses a Gantt chart to allocate those dates to each task [45,46].

Table 5. Criteria for reducing or limiting the impact of risk factors on the work of construction enterprises.

Criteria (Measures)	Subcriteria
Economic measures	1. Monitoring of the economic situation (government policy, inflation, tax rate); 2. Controlling exchange rate fluctuations to avoid high prices for materials, equipment and labor; 3. Exclusion of situations related to corruption and bribery. Unacceptability of illegal cooperation schemes; 4. Formation of a reserve in the enterprise budget in case of price increases.
Organizational and technical measures	1. Determination of channels of communication and information transfer between the customer and the contractor for the smooth coordination of actions; 2. Establishment of deadlines for the completion of work and sanctions for their violation; 3. Provision of qualified labor force; 4. The use of modern mechanisms and technologies suitable for the construction of multi-story buildings and the reconstruction of buildings; 5. A ban on the use of construction equipment by workers without appropriate qualifications and experience; 6. Determination of the possibility of deviation from the deadlines for the delivery of the project as a result of unforeseen circumstances (without significant damage to the quality of construction products); 7. Additional investments in equipment, materials, personnel and logistics schemes. Review of suppliers of equipment and materials.
Political and military measures	1. Maximum monitoring of the situation in the construction region, development of schemes and methods for emergency evacuation of employees in the event of a military attack, explanation of personal security measures; 2. Development of routes for the delivery of workers and equipment to the construction site lying outside the closed roads and the location of checkpoints; 3. Creation of a protective fence around the construction site and organization of round-the-clock security of the construction site by the enterprise; 4. Prevention of protests and political demonstrations near the construction site, as they cause malfunctions.
Risk management measures	1. Forecasting the occurrence of risk factors for the purpose of further risk management; 2. Diagnostics of risk sources (RF diagnostics); 3. Monitoring the project, its indicators, monitoring the development of risks and identifying relevant action scenarios for the enterprise during the occurrence of each of the possible risks; 4. Drawing up periodic reports on the risk factor, the likelihood of occurrence of risks, updating the information database for each investment and construction project; 5. Providing the management team at the enterprise with the necessary training: technical knowledge about the construction methods and technologies used in the projects.
Measures for labor safety	1. Proper planning, taking into account weather factors, to ensure the most suitable conditions for work; 2. Assessing the conditions in which site crews operate to ensure maximum performance. 3. Construction enterprises must ensure that adequate personal protective equipment is available for workers at all times. 4. Workers receive the necessary training in workplace safety and the need to use protective equipment.

According to the form of the questionnaire provided in Table 6, the experts participating in the survey assess the probability of risk factors, as well as their impact on investment and construction projects.

Table 6. Survey of experts to assess the impact of risk factors and their probability.

Rating	Probability Degree	Impact Degree
Very low	≤10%	≤5%
Low	>10–30%	5–10%
Average	>30–50%	>10–20%
High	>50–70%	>20–40%
Very high	>70%	>40%

Determining the probability of each risk is the first step in the risk analysis stage [10,47,48]; the second stage is that each identified risk is assigned an estimated impact degree that can affect the final project scope [11–49] (Table 7).

Table 7. Classification of risks based on the impact on project activities.

	Project Objectives	Very Low (0–10)	Low (>10–30)	Average (>30–50)	High (>50–70)	Very High (>70)
Risk	Cost	The cost increase is not significant	Cost increase <10%	Cost increase 10–20%	Cost increase >20–40%	Cost increase >40%
	Duration	Increasing the duration is not significant	Increase in duration <5%	Increase in duration 5–10%	Increase in duration 10–20%	Increase in duration >20%
	Quality	Qualitative degradation is hardly noticeable	Insignificant impact on the quality of activities	Moderate impact on the quality of activities	High impact on the quality of activities	Very obvious impact on the quality of activities

Using the PRA software (P6 professional 16.1), the simulation is repeated hundreds or thousands of times, so the simulation result is very close to the expected degree of influence [40–52] (Table 8).

Table 8. Probability and risk impact matrix in the PRA program [53,54].

Probability \ Impact	≤5%	5–10%	>10–20%	>20–40%	>40%
≤10%	5	9	18	36	72
>10–30%	4	7	14	28	56
>30–50%	3	5	10	20	40
>50–70%	2	3	6	12	24
>70%	1	1	2	4	8

The area colored in green indicates that the degree of importance of the risk (Probability × Impact) is very low, the area in yellow is of low importance, the area in dark green is of medium importance, the area in red is of high importance, and the area in dark red is of very high importance.

3. Results

In accordance with the stages of the hierarchical analysis described above, calculations were made of the relative importance (priority) of construction enterprises in Iraq in terms of the impact of risk factors on them. A pairwise comparison was made between the main factors, and after ensuring consistency, the relative importance (priority) was determined (Table 9).

Table 9. Results of expert opinion analysis.

Risk Factors	Organizational	Technical	Economic	Political and Military	Climatic	Geometric Mean	Priorities
Organizational	1	2	1/2	1/2	3	1.084472	18.46
Technical	1/2	1	1/3	1/3	2	0.644394	10.96
Economic	2	3	1	2	4	2.168944	36.92
Political and military	2	3	1/2	1	3	1.551846	26.42
Climatic	1/3	1/2	1/4	1/3	1	0.425142	7.24
Total	5.83	9.50	2.58	4.17	13.00		

Using the obtained results and Equation (4), the value (λ_{max}) was calculated to obtain the consistency coefficient.

$$C_i = \frac{5.114 - 5}{5 - 1} = 0.0285.$$

According to Table 3, Ri = 1.12 (n = 5, number of groups of factors studied).

$$Cc = \frac{0.0285}{1.12} = 0.025 < 0.1(\text{there is consistency}).$$

Figure 5 shows the priorities (relative priority) of the main groups of factors. According to experts, the relative priority of economic risk factors is in the first place; in second place are organizational risk factors, then the technical factors, followed by political and climatic factors.

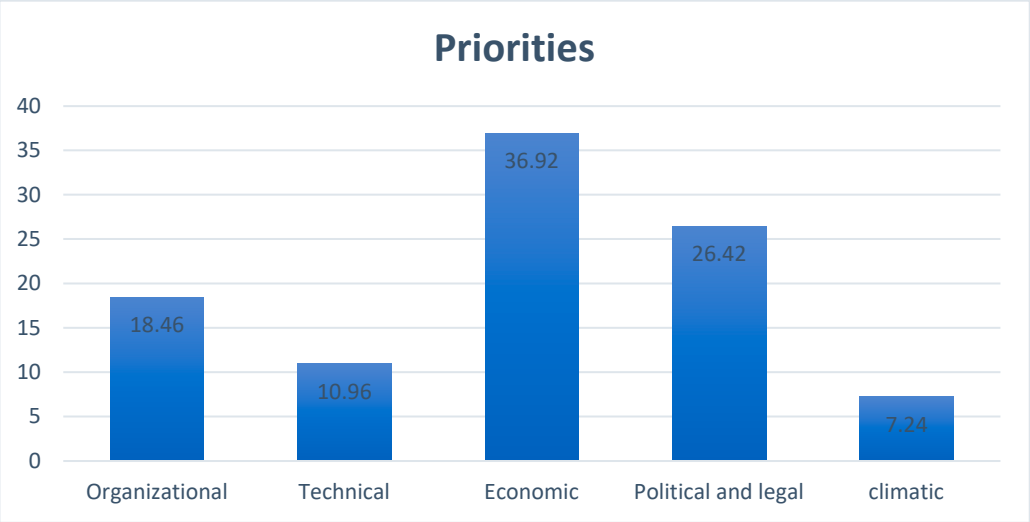


Figure 5. Priorities (relative importance) of the main groups of factors.

A risk analysis of the project schedule was carried out at Alamako LLC, which is implementing the Iraq Gate residential complex project (Iraq Gate) in the center of Baghdad, Al-Mutanna Street. The primavera risk analysis tool depicted was used to develop the project schedule risk model. The project schedule risk analysis begins by applying uncertainty to schedule activity durations, and a triangular distribution is used with minimum, maximum, and most likely values.

After applying uncertainty to the planned activities, a risk register is created to identify risk events and link them to the activities of the enterprise in order to complete the Monte Carlo analysis and, finally, to build a plan of the affected risks. The risks in the Register were created based on the probability and impact risk data collected in Building 5 (Iraq Gate). The risk register generated by the primavera risk analysis is shown in Figure 6.

Risk Register

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Qualitative Quantitative

Risk			Pre-Mitigation (Data Date = 11/...			Mitigation		Post-mitigation		
ID	T/O	Title	Probability	Schedule	Score	Response	Title	Probability	Schedule	Score
R1	T	Delay or non-payment of financial contributions for the enterprise.	H	VH	56	Reduce		L	M	12
R2	T	Delayed arrival of material and equipment due to military checkpoints and traffic jam.	H	H	56	Avoid		M	M	20
R3	T	Inefficiency and inaction of workers.	H	H	56	Reduce		H	M	28
R4	T	Substitution of public interests by representations of power by private interests (corruption)	M	M	20	Avoid		L	H	24
R5	T	Strike and riots.	H	H	56	Transfer		M	H	40
R6	T	High temperature in the summer to more than 50 ° C	H	H	56	Avoid		M	H	40
R7	T	Exchange rate changes	M	M	20	Accept		M	M	20
R8	T	Downtime associated with unplanned events (holidays).	H	H	56	Avoid		VL	L	4
R9	T	Lack of mechanisms and technical means.	M	M	20	Transfer		L	L	12
R10	T	Changes in legislation and legal norms in the field of construction activities.	H	M	28	Avoid		L	M	12
R11	T	Correction of the project execution (introduction of changes to the project specification, its cost, etc.	H	H	56	Accept		H	H	56
R12	T	Injuries to workers due to non-compliance with safety regulations or as a result of hostilities.	H	H	56	Avoid		H	M	28
R13	T	Poor coordination between project participants.	M	H	40	Reduce		VL	L	4
R14	T	Low qualification of staff.	M	M	20	Reduce		L	L	12

Figure 6. Risk registers for the project schedule.

After 1000 iterations with PRA, a sensitivity analysis was performed using a tornado plot. This allowed to establish which risks have the greatest potential impact on the project. Figure 7 shows that parameter R_1 (delay or non-payment of financial contributions for the enterprise) has the greatest potential impact on the overall duration of the project.

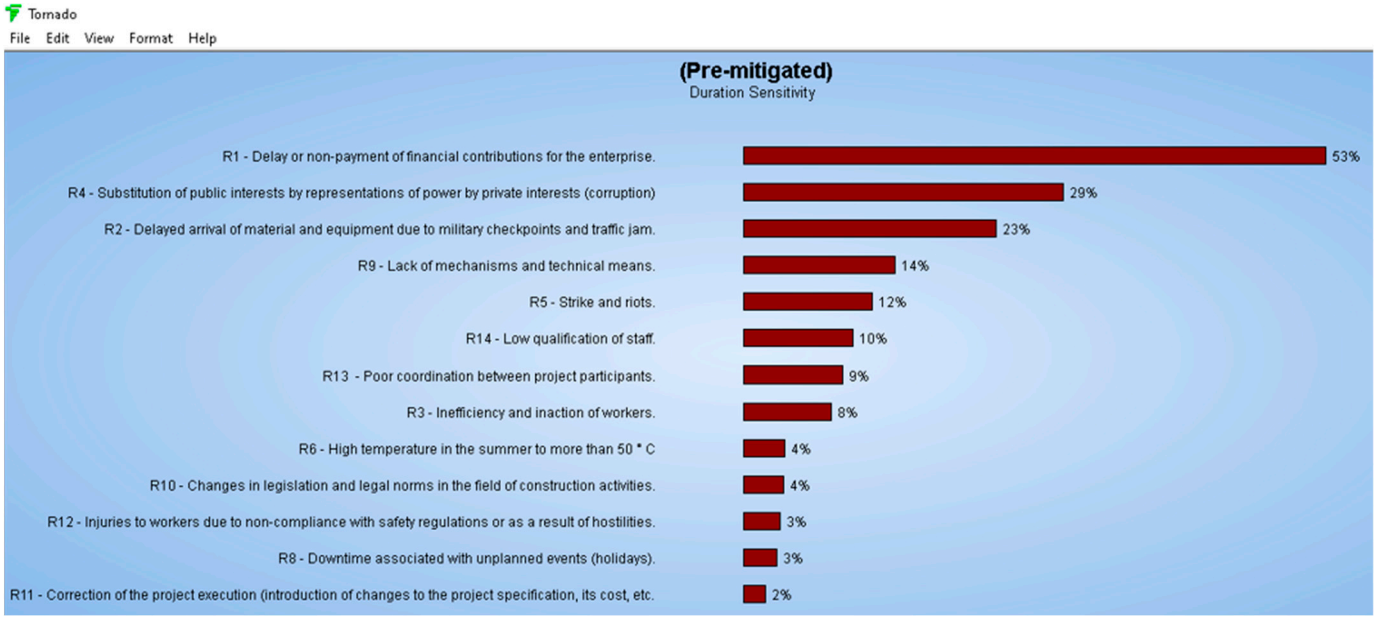


Figure 7. Tornado sensitivity plot.

Then, based on 1000 iterations, a Monte Carlo simulation of the initial project schedule was performed, and probable work schedules were compiled before and after the introduction of compensatory measures to reduce or prevent risk factors.

Figure 8 shows a histogram of the cumulative distribution of all types of work on the project in accordance with the original work schedule. With a probability of 50%, all project work can be completed on 9 August 2021 (576 days). With a probability of 80%, the project can be completed on 20 September 2021 (588 days).

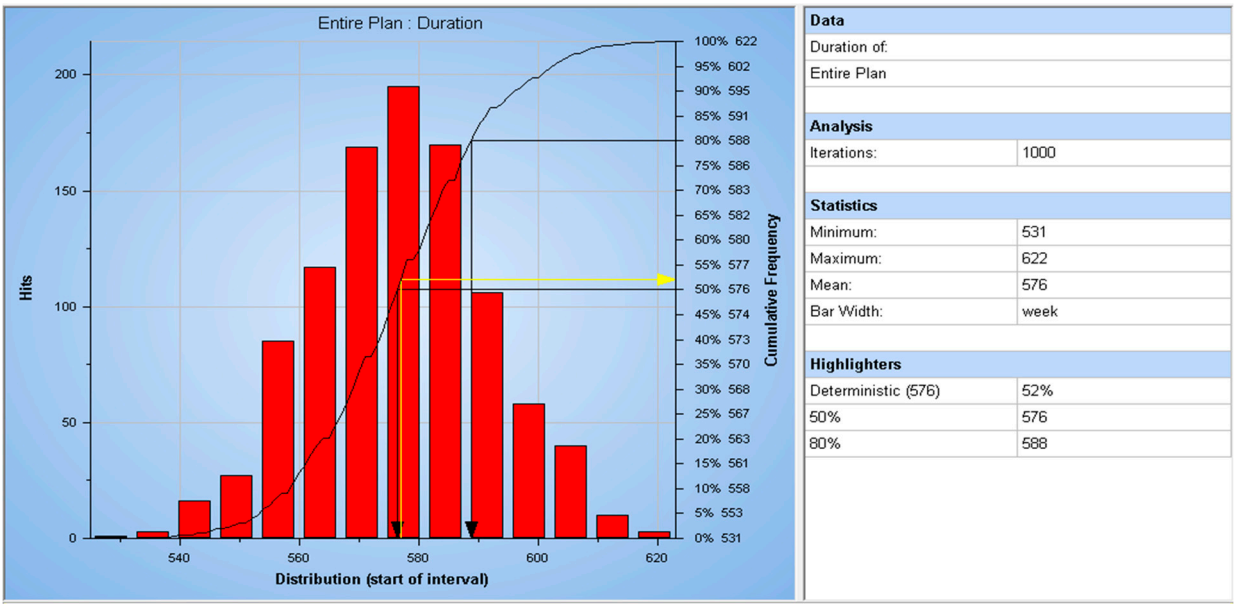


Figure 8. Histogram of the duration of the original project plan.

Figure 9 shows a histogram of the cumulative distribution of all work on the project after applying the risk effect and before the implementation of measures to reduce or limit the impact these risks. With a probability of 50%, all work on the project can be completed on 4 March 2022 (783 days). With a probability of 80%, all work on the project can be completed on 25 April 2022 (805 days).

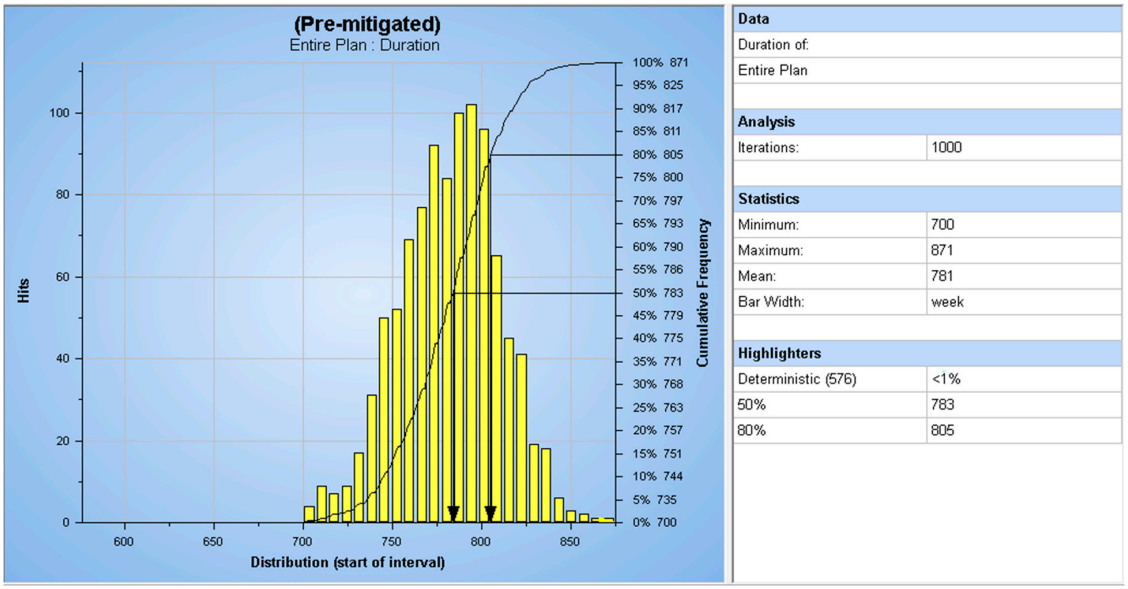


Figure 9. Histogram of the duration of the project before the implementation of measures to reduce or limit the impact of risks.

Figure 10 shows a histogram of the cumulative distribution of all types of work on the project after the implementation of measures to reduce or limit the impact of risks. With a probability of 50%, all work on the project can be completed on 25 October 2021 (674 days). With a probability of 80%, all work on the project can be completed on 8 November 2021 (698 days).

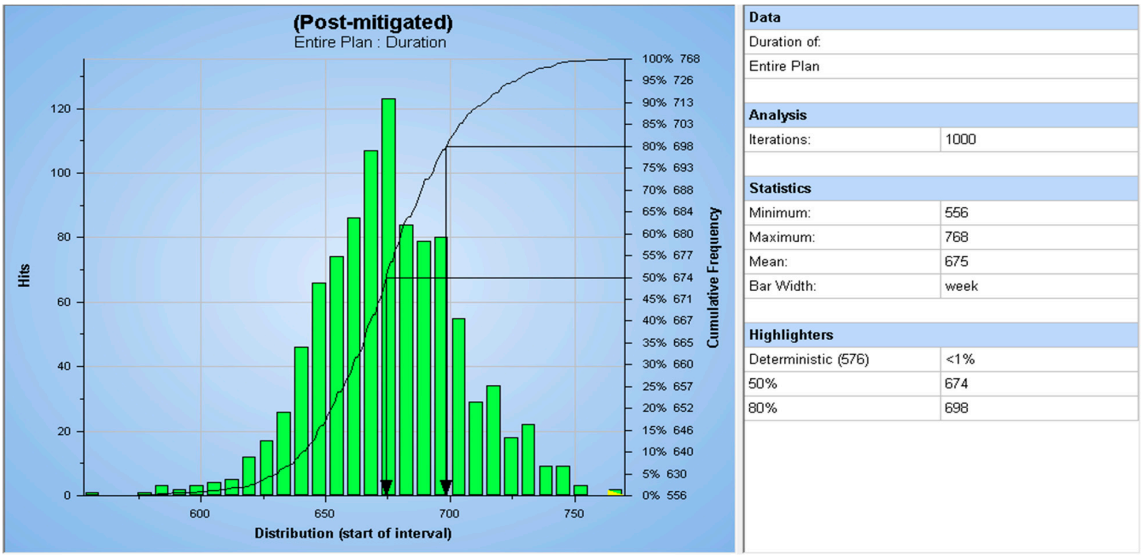


Figure 10. Histogram of the duration of work on the project after the implementation of measures to reduce or limit the impact of risks.

Figure 11 shows a comparison of the graphs of the project's initial likely duration, duration before and after mitigation.

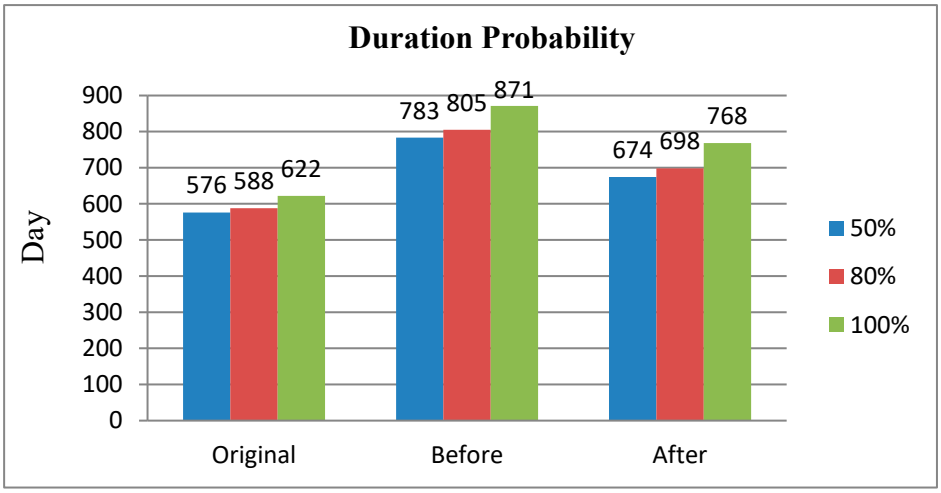


Figure 11. Comparison of project duration schedules.

Figure 12 shows the relationship between the probability distribution of the original project plan and its duration, the duration of the project during exposure to risks, and after the application of mitigation procedures for these risks.

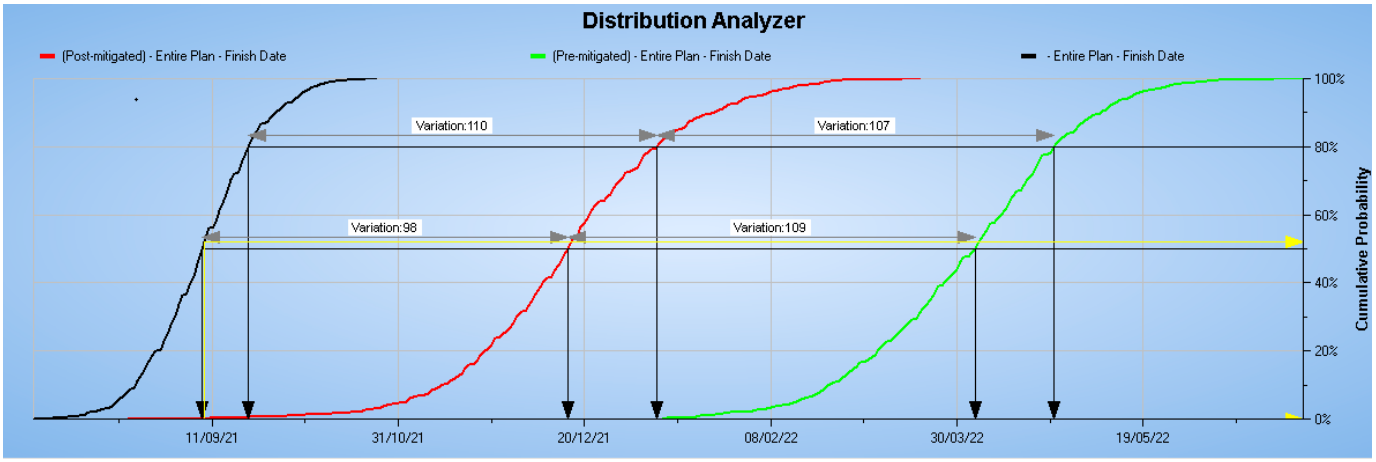


Figure 12. Variations in project duration under the influence of risks and after the implementation of compensatory measures.

It has been established that after the introduction of compensatory measures to mitigate the impact of risks, the duration of the project will be reduced by 109 days with a probability of 50% and by 107 days with a probability of 80%.

4. Discussion

This study is in line with previous studies [38,43] by risk evaluation technique. In the studies [10,49,52,54], Monte Carlo modeling has been used to evaluate the cost and duration of construction projects in the event of the emergence of types of risks and uncertainties. In this study, the risk factors were analyzed, determining the relative importance of each group of these factors by assessing the impact of these factors on the construction enterprises during the construction phase using hierarchical analysis. The necessary compensatory measures were developed to reduce the impact of these risks, and measure the effectiveness of these measures in reducing the duration of the project using Monte Carlo modeling.

In addition, modeling in the PRA program has justified itself in assessing the effectiveness of the functioning of construction enterprises in Iraq and other countries. The applied methodology makes it possible to fully assess the impact of risk factors on the duration of

an investment and construction project and develop the necessary compensatory measures to mitigate this impact.

In the process of applying the developed methodology, a large number of factors that have a negative impact on the implementation of investment and construction projects are identified; the opinions of highly qualified specialists are taken into account; a comprehensive assessment of negative factors is carried out and their impact on the activities of construction projects is checked. Thus, the proposed method is reliable, flexible, does not require high costs, time and effort.

The main aspect that differentiated the study from other studies was that the risk factors were not just evaluated using different methodologies, but rather the necessary measures to reduce or limit the impact of these factors were developed and evaluated and applied on a practical example for the purpose of evaluating the effectiveness of these measures that should be developed and managed by construction enterprises.

5. Conclusions

This study identified a number of risk factors that actually occurred, data obtained from examining a number of completed construction projects, from theoretical studies, and interviewing a number of construction industry experts to determine the extent of the impact of these factors on each of the projects' objectives and safety.

The study of the main risk factors affecting the activities of construction enterprises led to the conclusion that at the moment, the actual problem is the lack of an integrated approach to the analysis and classification of these factors in unstable industrial, economic and political conditions.

In this study, on the basis of the theoretical, statistical and mathematical studies carried out, the scientific problem of assessing and managing risk factors at the stage of implementation of an investment–construction project is solved.

It has been established that the method of hierarchical analysis can be used as one of the methods of a quantitative approach in the analysis and decision-making in construction organizations by collecting the opinions of experts (decision-makers) and combining them into a decision matrix in order to obtain the required alternatives.

According to experts, during the construction of high-rise buildings in Iraq, economic (financial) risk factors are most likely to occur, followed by political and military risk factors, organizational, and technical and environmental factors.

A methodology for assessing the impact of risk factors on the activities of construction enterprises is proposed, which is suitable for use at any construction enterprise, regardless of its location—in Russia, Iraq or other countries. Compensatory measures have been developed to reduce or prevent the influence of various risk factors.

The Alamko Construction enterprise, which is carrying out the construction of the Iraq Gate residential complex in the center of Baghdad, has coped well with the occurrence of risks, their impact and a comprehensive program for managing them. The organization also took into account economic and geopolitical factors beyond its control, in accordance with the data of the expert survey.

The results showed that with a probability of 80%, the initial duration of the project is 588 days. After the occurrence of risks and their differentiated impact, the duration of the project increases significantly—up to 805 days. Implementation of compensatory measures to reduce and (or) limit the impact of these risks can reduce the duration of the project to 698 days, i.e., by about 107 days.

Based on the results of a study on the assessment of the impact of risk factors on the activities of construction enterprises in Iraq, the following recommendations have been developed:

- For the construction sector and urban infrastructure, it is necessary to choose areas located far from military bases;
- All employees must be familiar with the rules of safety and behavior in case of emergencies at work;

- Warning signs should be installed in specially designated places and constant monitoring of the construction site and the surrounding area to prevent undesirable situations;
- It is necessary to control price fluctuations in the construction market and changes in the exchange rate;
- It is necessary to establish a ban on protests and demonstrations of all forms near construction sites.

One of the most important limitations of the study is not receiving all the opinions of the respondents during the questionnaire or not providing the respondents with full explanation of the importance to the questionnaire; however, appropriate methods were chosen that would measure the reliability and stability of the respondents' opinions.

Using the approved method, the basics of risk management in the implementation of investment can be evaluated, including construction projects, construction production and equipment management, the impact of compensatory measures on the cost and quality of the project and on the quality of sustainable construction as a whole, which will be studied in future research.

Author Contributions: Conceptualization, I.A.; methodology, I.A. and Z.A.K.A.; software, Z.A.K.A.; data analysis, Z.A.K.A.; investigation, I.A. and Z.A.K.A.; data curation, I.A. and Z.A.K.A.; writing—original draft preparation, Z.A.K.A.; writing—review and editing, I.A. and Z.A.K.A.; final conclusions, I.A. and Z.A.K.A. All authors have read and agreed to the published version of the manuscript.

Funding: This research received no external funding.

Institutional Review Board Statement: Not applicable.

Informed Consent Statement: Not applicable.

Data Availability Statement: Not applicable.

Conflicts of Interest: The authors declare no conflict of interest.

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