BIM-Supporting System by Integrating Risk Management and Value Management

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ABSTRACT

Construction projects are of great importance because of their large financial allocations in the federal budgets of countries. This study used risk management and value management as an integrative model with Building Information Modeling (BIM). Risk management techniques were used to identify risks and quantify their impact on cost, and value management was used to identify effective mitigation measures for each risk factor. This study developed software to support BIM and risk management, including measures to assess risks and their impact on the cost estimation process, to be part of the information flowing to the project parties. The total number of risks was 52 with multiple mitigation measures for each determined using brainstorming. The Fuzzy Analytical Hierarchal Process (FAHP) was used to determine the relative importance of risk and the cost range of the selected items.

Keywords-Building Information Modeling (BIM); risk management; value management; integrating model

I. INTRODUCTION

Every project has risks and one of the most important project management tasks is to ensure that these risks are minimized, if not eliminated [1]. As risks can be human-made or natural and their effects can be very devastating, there is a need to take measures to overcome them. However, the measures taken are often ineffective in various ways. Risk management plays a vital role in minimizing the consequences of unexpected events on the performance of a construction project [2]. Effective construction project planning provides an important advantage over cost, time, and customer satisfaction considerations [3]. Over the years, many tools have been introduced to help project managers overcome risks. Building Information Modeling (BIM) is an active method that enables plans to be digitized [4]. As most large construction projects have realized the importance of BIM in their operations, its use has grown in recent years [5]. Since large projects require a lot of resources and highly accurate planning, using a modeling tool provides a way to simulate the risks that can occur during the life of the project from the beginning to the end [6]. If the results are realistic, corrective measures can be used to address any challenges that may arise [7]. Risks are unforeseen situations, and understanding their effects can be beneficial to any institution. Unforeseen circumstances must be identified, understood, and evaluated to ensure that they are prevented, transported, or addressed as the institution deems appropriate [8]. Therefore, risk managers must be able to identify risk elements and measure and manage them [9].

The use of BIM is effective when the risks associated with the project are identified and defined. A project risk profile is crucial [10]. The implementation of any project will certainly face many risks that require management, some of which can be mitigated and others that are not expected [11]. BIM is a systematic approach that visualizes every part of a construction project and can use the information to make better decisions at every stage [12]. Project managers are turning to new technologies to address threats. Putting in place effective risk management plans increases the likelihood of project success, as risk is managed by avoiding or at least mitigating its effects [13]. The relationship between risk planning and mitigation implementation is often weak and ineffective. For example, many designers and contractors still work on two-dimensional (2D) platforms and use two-dimensional graphics to communicate project information and improve construction planning [14]. On the other hand, value management is a technique to analyze the functions of an element or process and determine the best value or the best relationship between value and cost. The best value is represented by a process that consistently performs the desired purpose and has the lowest life cycle cost [15]. In [16], the risk sources and factors were selected as secondary data to formulate the model, so these data are the outputs for other research, as shown in Table I. In this study, the integration of value management provides the best mitigation measure for each risk factor. The outputs for the integration model are used to support the building information model.

TABLE I. RISK SOURCES AND FACTORS

#	Sources	Code	Risk Factors
A	**Planning and Design Source**	**A1**	Unnecessary design elements
		A2	Poor flow of project information and lack of drawings
		A3	Mistakes in estimating quantities, taking-off tables, and using appropriate tools
		A4	Poor communication and coordination between project parties
		A5	Unclear requirements of the owner
		A6	False design assumptions
		A7	Inaccuracy of economic feasibility studies and poor allocation of resources
		A8	Unclear conditions, specifications, project scope, and poor site investigations
B	**Execution Source**	**B1**	Contract management and change orders
		B2	Poor occupational safety program
		B3	Design changes during execution and notification to relevant government departments
		B4	Poor project management and the effectiveness of the construction techniques used
		B5	Delayed providing and poor inventory management
		B6	Clashes in drawings and poor coordination between the concerned parties
		B7	Waste of resources and poor productivity
		B8	Poor quality of materials and work
		B9	Site access problems and unexpected ground conditions
		B10	Difficulties in negotiation and the large number of claims
		B11	Poor project management by the owner
		B12	Delayed disbursement of Payments
		B13	Contractor conflicts
		B14	Interventions of the owner and other external parties
C	**Market Source**	**C1**	Fluctuations in the supply of materials, equipment, manpower, or services
		C2	Competition risk
		C3	Fake information received from decision-makers about the market situation
		C4	Support for local raw materials with neglect of quality
		C5	Fluctuations in the demand for materials, equipment, manpower, or services
D	**Financial Source**	**D1**	Loss realized from corruption and red tape
		D2	Cost changes (transportation, maintenance, materials and equipment, land, waste management)
		D3	Owner's cash flow (financing risk)
		D4	Change in costs of tests, quality management, and insurance
		D5	Interest rate volatility and inflation rate
		D6	Change the government's financial policy
		D7	Wrong estimate of costs
		D8	Delay in completing the project
		D9	The change in the currency exchange rate
E	**Political Source**	**E1**	Internal factors such as terrorism, crime rate, sabotage, revolutions
		E2	Changes in the local labor cost
		E3	Changes in government policy
		E4	Changes to the tax law
		E5	Political risk to materials, equipment, and buildings (riot outbreak)
		E6	Political stability
		E7	Notification resulting from bilateral agreements between countries
		E8	External factors such as political and armed conflicts
F	**Legal Source**	**F1**	Breach of contracts by other parties and contractual disputes
		F2	Changes in instructions and the issuance of new laws and regulations
		F3	Changes in Projects Execution laws
G	**Environmental Source**	**G1**	Pollution, toxic emissions, and waste accumulation
		G2	Risks in environmental laws and regulations
		G3	Use of environmentally harmful alternatives
H	**Social Source**	**H1**	Disable the continuation of the project activities
		H2	Affected the country's economy and did not contribute to the employment of the labor force

II. RESEARCH METHOD

A. Qualitative Assessment

1) Risk Probability and Risk Impact Assessment

The users were asked to assess the probability of the risk occurrence and its impact on a scale from 1 (very low) to 10 (very high). The Qualitative Assessment (QA) for each risk factor was calculated by [17]:

$$QA = Risk\ Probabilty \times Risk\ Impact \quad (3)$$

QA includes an assessment of the risk impact and probability. The results of the QA of risk factors were based on the following rules:

- If QA is greater than or equal to 72, the risk is very high.
- If QA is greater than 36 and less than 72, the risk is high.
- If QA is greater than 16 and less than or equal to 36, the risk is moderate.

- If QA is greater than 4 and smaller than or equal to 16, the risk is low.
- If QA is less than or equal to 4, the risk is very low.

2) *Relative Importance Using FAHP*

This phase determined the relative importance of the risks, built based on the risk breakdown structure (WBD) shown in Figure 1. The basic objective, "risk assessment", was placed at the top, the risk sources were placed in the middle levels, and the risk factors were placed at the lower levels. This assessment was carried out according to a scale of 1 to 9 (1 = equal importance, 9 = extreme importance). The AHP model was based on a coding system that used letters to represent sources and numbers to represent risk factors. SpiceLogic AHP software was used to obtain accuracy in the decision-making process. The main objective of using this tool was to make a pairwise comparison between all risk factors and sources and to obtain relative importance.

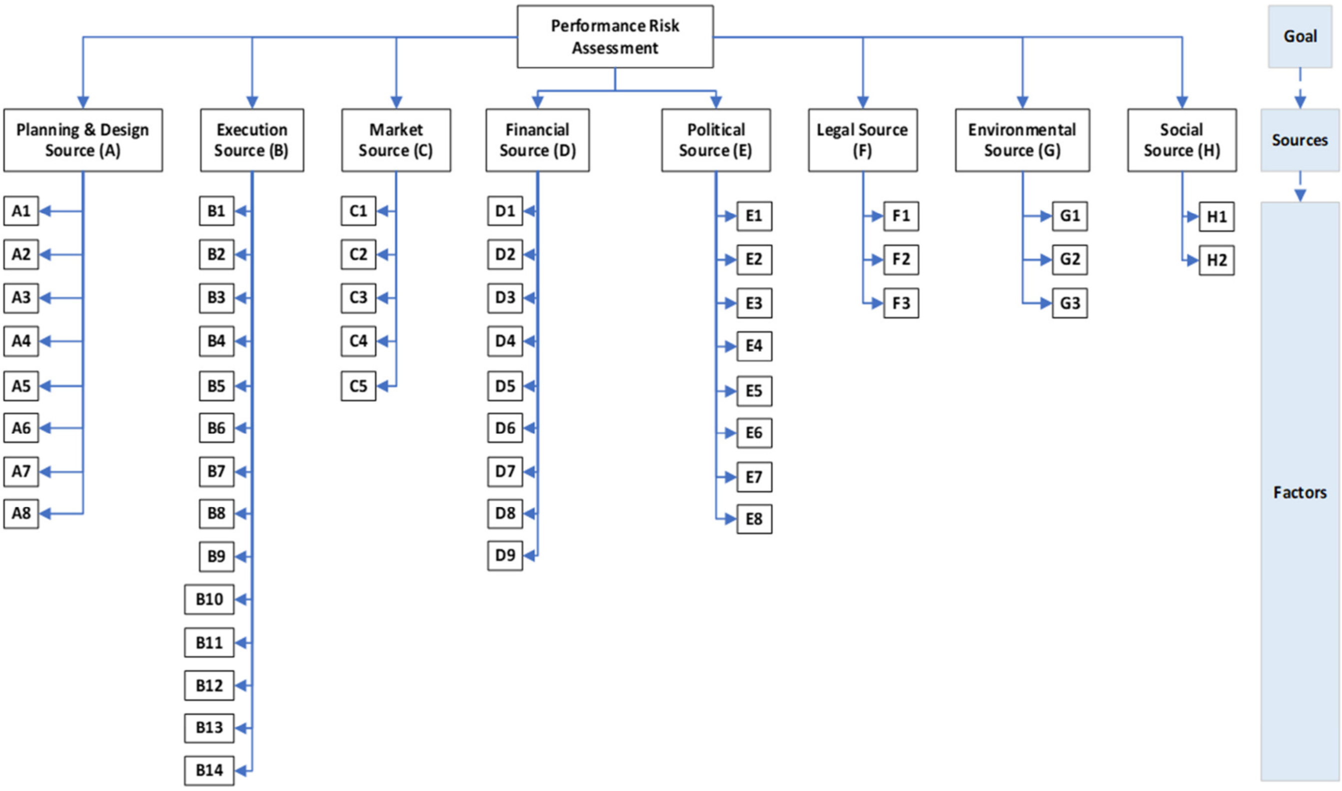

Fig. 1. AHP model for construction risk assessment.

B. *Quantitative Assessment*

The simulation was carried out using the Risk AMP add-on in Excel. The main inputs of the simulation were the activities of the project, the risks associated with each activity, and the range of the estimated costs of each activity. The trigonometric distribution was chosen because it is suitable for ideal construction activities with specific upper and lower bounds. The new costs of activities at risk obtained from the Risk AMP tool were introduced. The cost of completing the project was then calculated and repeated in this step, and the cost of each activity was extracted 1000 times by giving different costs to the events each time. The main outputs of the simulation phase were histograms showing the probability and the S-curve. The factor of cost change can be calculated by the proportion that determines the influencing factor and the affected factor or factors after multiplying the right-hand side by the coefficient of impact and interaction. The impact and interaction coefficients were taken based on the QA and the impact and probability values after conversion to a percentage. The ratio and the proportion are shown in (6) and (7).

$$\frac{C_a}{RI_a} = \frac{C_i}{RI_i} \times C_r \tag{6}$$

$$C_a = RI_a \times \frac{C_i}{RI_i} \times C_r \tag{7}$$

where C_r is the impact and interaction factor depending on QA, C_i is the cost factor for influenced risks calculated based on C_r, C_a is the cost factor for affected risks, RI_i is the RI for influenced risks, and RI_a is the RI for affected risks. The cost factor for the influence of risk factors in (6) and (7) can be calculated based on C_r, while C_i is calculated using Table II.

In the case of projects where there is more than one cost factor and more than one influencing factor, (8) can be used to find the compound cost factor C_T [18]:

$$C_T = (C_{a_i})^{(1-0.2(n-1))} \tag{8}$$

where i is the number of cost factors, and n is the number of conditioning variables. The total cost factor can be calculated using [13, 18]:

$$\mathrm{CF}_T = 1 + C_T \tag{9}$$

Then, the new cost of the activity in the effect of the risk factors was calculated based on:

$$Cost\ result\ in\ risk\ factors = \\ Cost\ Factor \times Cost\ from\ Montecarlo\ Simulation \tag{10}$$

TABLE II. COST FACTOR FOR INFLUENCE RISKS

Cr	C_i
0.5-1	0.1
0.4-0.49	0.08
0.2-0.39	0.05
less than 0.2	0.01

III. BRAINSTORMING SESSIONS

The brainstorming sessions aimed to determine the active mitigation measures. This process included the following steps:

A. Step 1: Creating the Environment

This step determined the group brainstorming session. According to interviews, the sample was selected based on two criteria. First, the respondents willing to participate in sessions, and second, their experience in the Iraqi construction industry. The results of the interviews showed that 11 engineers were ready to participate and 7 had more than 15 years of experience. Experience and skills are critical points in selecting the sample that makes a sensitive decision. Table III shows details of the brainstorming session.

TABLE III. BRAINSTORMING SAMPLE SPECIFICATIONS

No.	**Position/Current Institution**	**Experience (Years)**	**Background**
1	Head of risk management department/ UNDP Iraq.	28	Project management
2	Program manager/ NRC Iraq.	21	Civil engineering
3	Project manager/Alkhattab Company for General Contracting, Ltd.	20	Project management
4	Assist. prof. Dr./ University of Mosul.	16	Civil engineering
5	Engineering department manager/ Anbar Province.	27	Civil engineering
6	Engineering department manager/ Thefaf AlRafidain for General Contracting, Ltd.	29	Project management
7	Risk department manager/ NRC Iraq.	26	Civil engineering

B. Step 2: Identifying the Problem

This step aimed to identify the mitigation measures for each risk factor. The plan was developed using an online whiteboard for visual collaboration [19].

C. Step 3: Generating and Sharing Ideas

This step included generating many ideas on mitigation measures. The participants presented the ideas and improved each one if needed. Figure 2 shows the output of the brainstorming session for risk factor A1 and Figure 3 shows the mitigation measures for risk factor B3. In case the suggestions of the participants need to improve, the participants need to try improving the ideas to get them in good quality.

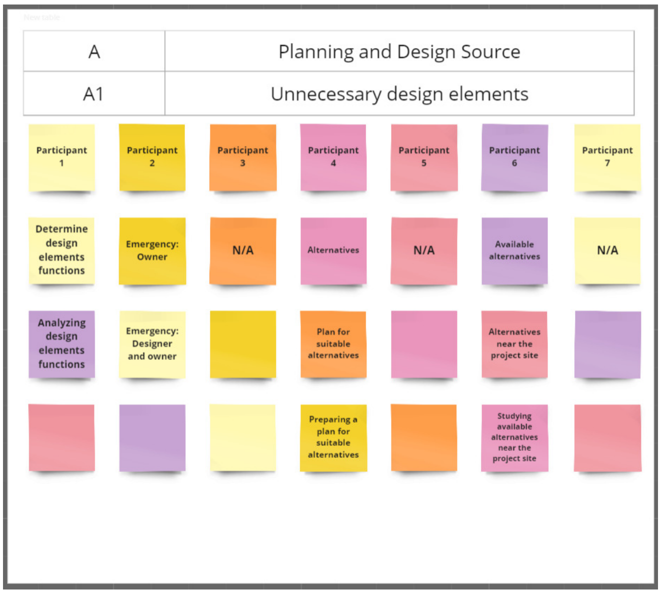

Fig. 2. Generation of ideas for mitigation measures for factor A1.

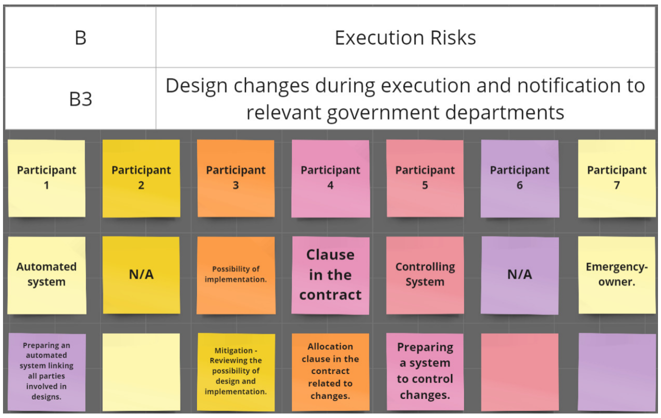

Fig. 3. Generated ideas for mitigation measures for factor B3.

IV. SOFTWARE INTERFACE FOR THE BIM-SUPPORTING SYSTEM

Figure 4 shows the main interface of the program, which demonstrates the definition of the software. The second interface included general information about the project. The software supports the project parties in the documentation process. Figure 5 shows the information required to input. The documentation function is important in the long-term consideration of building the database concerned with the monitoring and evaluation process. Therefore, the software has great value in the construction environment and improves performance in the construction sector. The project data interface included user, responsibility, project name, province, and date.

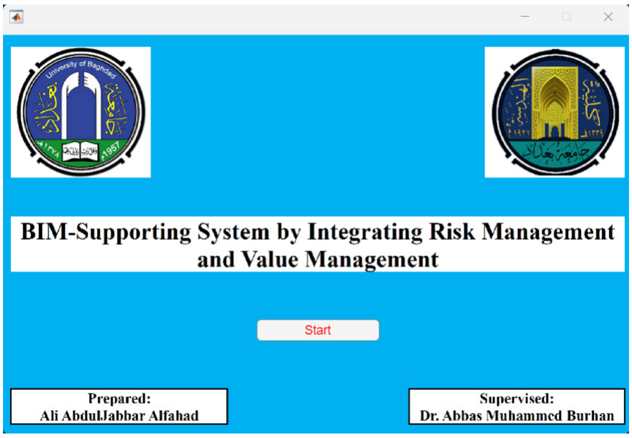

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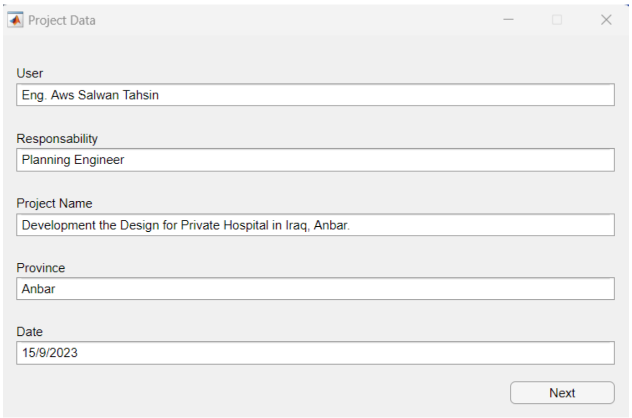
Fig. 4. The main interface.



Project Data

User
Eng. Aws Salwan Tahsin

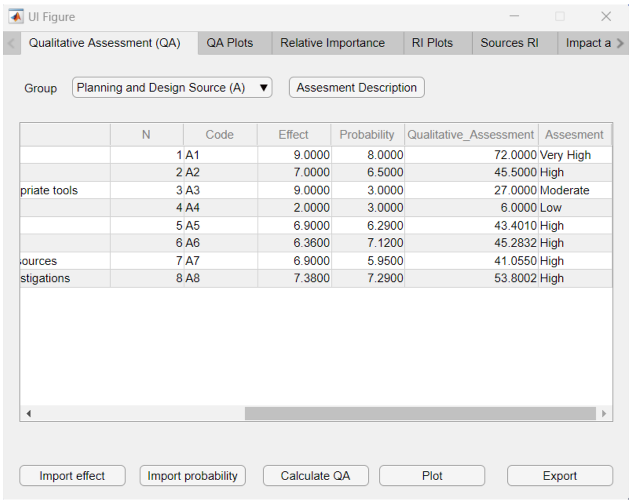
Responsability
Planning Engineer

Project Name
Development the Design for Private Hospital in Iraq, Anbar.

Province
Anbar

Date
15/9/2023

Fig. 5. Project information.



UI Figure

Group Planning and Design Source (A)

	N	Code	Effect	Probability	Qualitative_Assessment	Assesment
	1	A1	9.0000	8.0000	72.0000	Very High
	2	A2	7.0000	6.5000	45.5000	High
priate tools	3	A3	9.0000	3.0000	27.0000	Moderate
	4	A4	2.0000	3.0000	6.0000	Low
	5	A5	6.9000	6.2900	43.4010	High
	6	A6	6.3600	7.1200	45.2832	High
ources	7	A7	6.9000	5.9500	41.0550	High
stigations	8	A8	7.3800	7.2900	53.8002	High

Fig. 6. Qualitative assessment calculations.

The third interface included the QA calculation. Many options in this interface include the import probability and the effect of experts' opinions. The user can adjust the probability and impact values depending on the nature of the project and the surrounding environment. The calculation for all sources was imported into the program, and the user was able to modify all values. The plots for each source were built into the program according to the values selected by the user. Figure 6 shows a qualitative assessment interface that provides the ability to modify the impact and probability for each. There is a required action in the assessment description to monitor risk factors. Figure 7 shows the plots for each source, which were built into the software, to identify the sensitivity analysis.

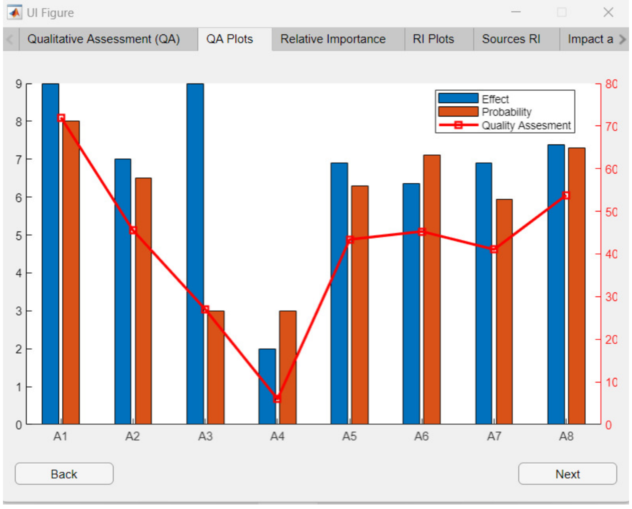
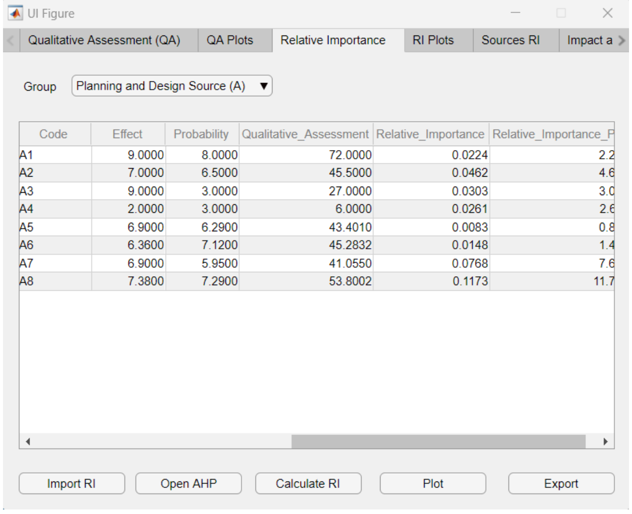


Fig. 7. Plot for planning and designing source.

The proposed software was linked to AHP to build the matrix for all factors and sources. Consistency is the most important measure of the results from pair comparison in FAHP. Pair comparison is a method of calculating the weights for each item to compare two factors [20]. FAHP consistency is determined by the CI value from the paired comparison table. If its value for a case exceeds 0.1, it is inconsistent, and a paired comparison should be performed again [21]. Consistency is shown in the bottom interface in the red box. The consistency ratio for all pairwise comparisons was less than 0.1. The relative importance interface includes many options. The import RI button concerns the input of relative importance from an Excel sheet. The open AHP button is for modifying the pairwise comparison using the AHP software. The calculate RI button inputs the RI that is extracted from any AHP software. The relative importance of each source and plot can be extracted as shown in Figures 8 and 9. In addition, the relative importance of all sources was calculated using the AHP software.

The relative weighted assessment was calculated to determine the effect of the change cases on the risk factor components, as shown in Figure 10. Evaluations of each one were inserted into the database with the possibility of modification. The software tests the ability of mitigation measures to mitigate risk factors. If the mitigation factor is less than 20%, the new mitigation measures can be added to the program using the add button. The export button provides a mitigation measure report, as shown in Figure 11. In some cases, all mitigation measures are not active for special environments. For this case, the software provides a tool to calculate QA.



Group: Planning and Design Source (A)

Code	Effect	Probability	Qualitative_Assessment	Relative_Importance	Relative_Importance_P
A1	9.0000	8.0000	72.0000	0.0224	2.2
A2	7.0000	6.5000	45.5000	0.0462	4.6
A3	9.0000	3.0000	27.0000	0.0303	3.0
A4	2.0000	3.0000	6.0000	0.0261	2.6
A5	6.9000	6.2900	43.4010	0.0083	0.8
A6	6.3600	7.1200	45.2832	0.0148	1.4
A7	6.9000	5.9500	41.0550	0.0768	7.6
A8	7.3800	7.2900	53.8002	0.1173	11.7

Fig. 8. Simulation of RI for planning and design source.

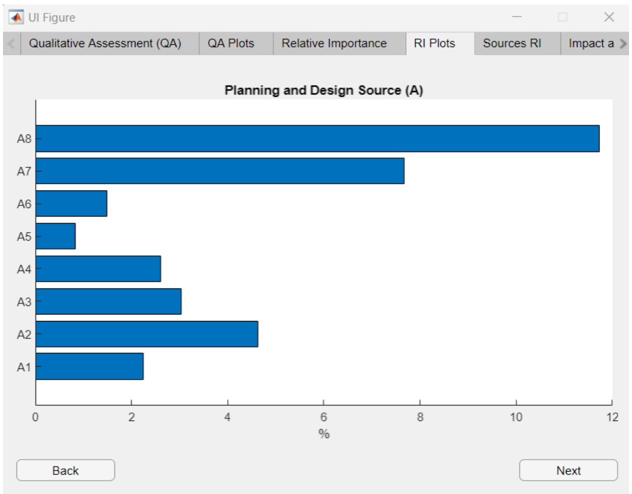
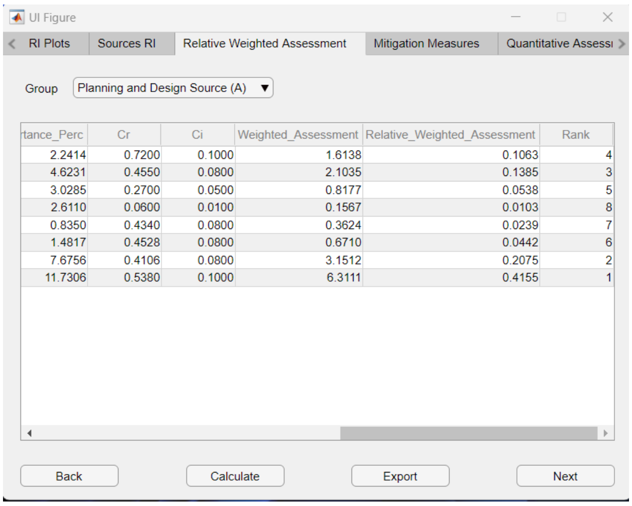


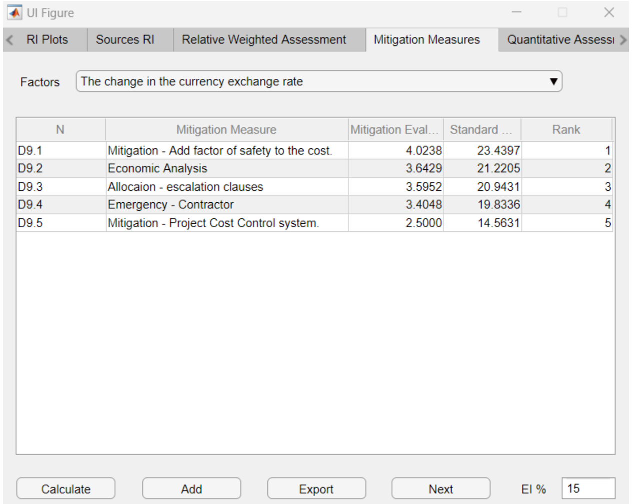
Fig. 9. Plots of RI for planning and design source.



Group: Planning and Design Source (A)

tance_Perc	Cr	Ci	Weighted_Assessment	Relative_Weighted_Assessment	Rank
2.2414	0.7200	0.1000	1.6138	0.1063	4
4.6231	0.4550	0.0800	2.1035	0.1385	3
3.0285	0.2700	0.0500	0.8177	0.0538	5
2.6110	0.0600	0.0100	0.1567	0.0103	8
0.8350	0.4340	0.0800	0.3624	0.0239	7
1.4817	0.4528	0.0800	0.6710	0.0442	6
7.6756	0.4106	0.0800	3.1512	0.2075	2
11.7306	0.5380	0.1000	6.3111	0.4155	1

Fig. 10. Relative weighted assessment.

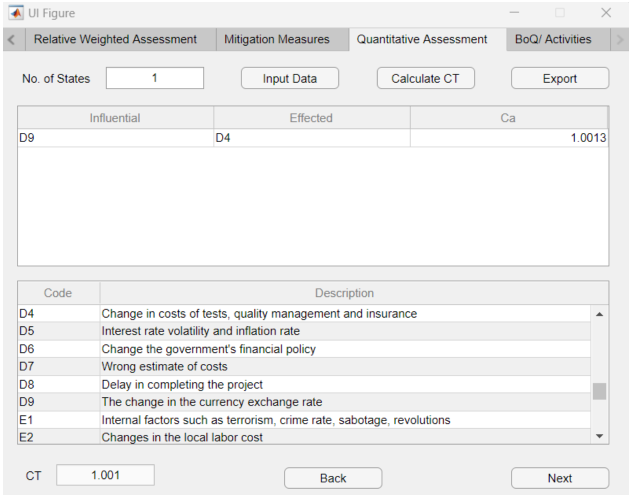


Factors: The change in the currency exchange rate

N	Mitigation Measure	Mitigation Eval...	Standard ...	Rank
D9.1	Mitigation - Add factor of safety to the cost.	4.0238	23.4397	1
D9.2	Economic Analysis	3.6429	21.2205	2
D9.3	Allocaion - escalation clauses	3.5952	20.9431	3
D9.4	Emergency - Contractor	3.4048	19.8336	4
D9.5	Mitigation - Project Cost Control system.	2.5000	14.5631	5

EI % 15

Fig. 11. Mitigation measures.



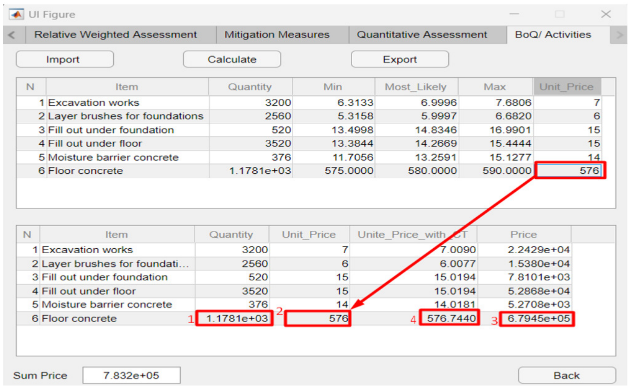
No. of States 1

Influential	Effected	Ca
D9	D4	1.0013

Code	Description
D4	Change in costs of tests, quality management and insurance
D5	Interest rate volatility and inflation rate
D6	Change the government's financial policy
D7	Wrong estimate of costs
D8	Delay in completing the project
D9	The change in the currency exchange rate
E1	Internal factors such as terrorism, crime rate, sabotage, revolutions
E2	Changes in the local labor cost

CT 1.001

Fig. 12. Quantitative assessment for the proposed case.



N	Item	Quantity	Min	Most_Likely	Max	Unit_Price
1	Excavation works	3200	6.3133	6.9996	7.6806	7
2	Layer brushes for foundations	2560	5.3158	5.9997	6.6820	6
3	Fill out under foundation	520	13.4998	14.8346	16.9901	15
4	Fill out under floor	3520	13.3844	14.2669	15.4444	15
5	Moisture barrier concrete	376	11.7056	13.2591	15.1277	14
6	Floor concrete	1.1781e+03	575.0000	580.0000	590.0000	576

N	Item	Quantity	Unit_Price	Unite_Price_with_CT	Price
1	Excavation works	3200	7	7.0090	2.2429e+04
2	Layer brushes for foundati...	2560	6	6.0077	1.5380e+04
3	Fill out under foundation	520	15	15.0194	7.8101e+03
4	Fill out under floor	3520	15	15.0194	5.2868e+04
5	Moisture barrier concrete	376	14	14.0181	5.2708e+03
6	Floor concrete	1.1781e+03	576	576.7440	6.7945e+05

Sum Price 7.832e+05

Fig. 13. BOQ/Activities.

On the other hand, the software provides a quantitative assessment of any risk factor. The quantitative interface was designed to determine the cost factor according to (7), measuring the impact of risk factors on the cost of construction, as shown in Figure 12. In BOQ/Activities, the bill of quantities can be entered, which consists of a range of unit prices that is constituted from the AMP risk tool, and the user selects a single value and adds the risk impact quantitatively to the unit price. Figure 13 shows the six items of the bill of quantities as a sample to test the software.

V. DATA INPUT TO THE BIM MODEL

The case study was the "Development of the Design for a private hospital in Iraq, Anbar". The BIM model was developed and the proposed software was used as integrated with the BIM to validate the structural model shown in Figure 14.

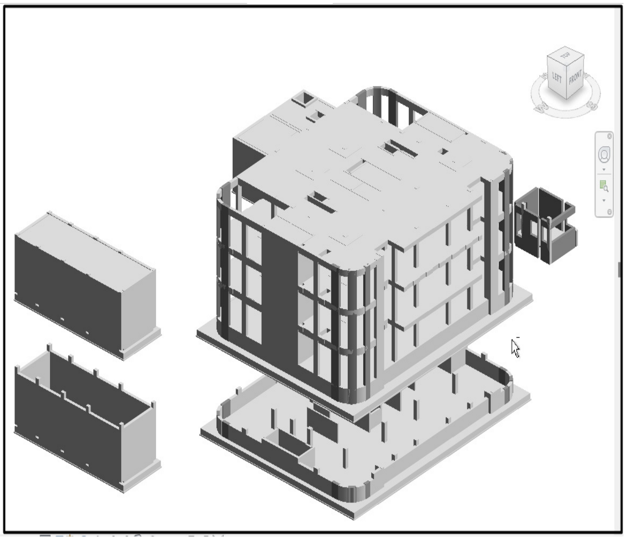


Fig. 14. Structural model for a hospital building in Iraq.

In common cases, mitigation measures may be active for most factors. In cases where the environment of the project is special and the factor(s) is (are) not mitigated, there is a possibility to quantify its (their) impact. In these cases, we propose a way to input the risk factors into Revit as a parameter in the quantity take-off process. The main objective of this phase is to monitor and evaluate risk factors in the progress of the project and to observe the increase in the cost at the root. Figure 15 shows the case study project, highlighting the first floor. In the quantity take-off process, the floor concrete is calculated to determine the quantities and the unit price. The unit price was calculated using the model in the proposed software. Figure 15 highlights the slab for the first-floor concrete. The quantity take-off process integrates the risk factor into the building information modeling. The risk factor that was not mitigated at an acceptable level for a user was converted to all project development and would be part of the information flow.

The total quantity was obtained from Revit and the unit price (576 $/m^3) was selected in the BIM support system according to the range 575-590 $/m^3, based on the simulation process. The unit price with the risk impact was 576.744 $, after using the model in the proposed software. This value was entered into Revit to calculate the total cost for each item and the total cost for all items. The value shown in Figure 13 in the red box and coded 1, 2, 3, and 4 was indicated at some points. Box 1 indicated the quantity that came from the quantity take-off in Revit. Box 2 indicates the selected value according to the simulation ranges. Box 4 indicates the unit price after multiplying by the cost factor. Box 3 indicates the total price for the first floor. Figure 16 shows the quantity take-off performed using Revit. Researchers were supposed to add the risk exposure column as a parameter to be an important part of the information flow at all stages of the project to contribute to mitigating the risks.

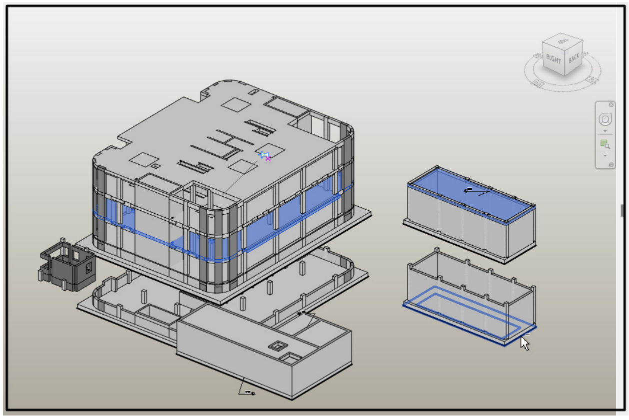
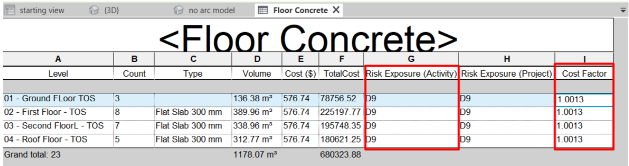


Fig. 15. Concrete floor for case study.



<Floor Concrete>

A	B	C	D	E	F	G	H	I
Level	Count	Type	Volume	Cost ($)	TotalCost	Risk Exposure (Activity)	Risk Exposure (Project)	Cost Factor
01 - Ground FLoor TOS	3		136.38 m³	576.74	78756.52	D9	D9	1.0013
02 - First Floor - TOS	8	Flat Slab 300 mm	389.96 m³	576.74	225197.77	D9	D9	1.0013
03 - Second FloorL - TOS	7	Flat Slab 300 mm	338.96 m³	576.74	195748.35	D9	D9	1.0013
04 - Roof Floor - TOS	5	Flat Slab 300 mm	312.77 m³	576.74	180621.25	D9	D9	1.0013
Grand total: 23			1178.07 m³		680323.88			

Fig. 16. Take-off quantity for floor concrete.

VI. CONCLUSION

Risk management in construction projects plays a critical role in their success. This study investigated risk management and integrated it with value management to select effective mitigation measures. This study showed that most risk factors can be mitigated using measures proposed by the system, and if the project has the specified consideration, it can quantify the impact of the risk factor on cost. According to the results of the case study in Iraq, the current situation of the local currency is rapidly changing due to the unstable economy. The proposed software calculates the impact of this risk factor on the cost and input to the quantity take-off. The unit price of concrete in Iraq was 576 $/m^3, and after calculating the risk impact was 576.744 $/m^3. The column of risk impact factors showed the root of the change rate in unit price. This point requires building special standards to determine the procedures and risk factors code with training for all parties that are concerned with BIM. Finally, the user can add unlimited situations for risks that cannot be mitigated to determine the impact on cost. Risks in construction projects still constitute a major obstacle. The proposed system can manage risks and link them to building information modeling to be part of the information that is transferred between the project parties.

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REFERENCES

[1] Y. Zou, A. Kiviniemi, and S. W. Jones, "A review of risk management through BIM and BIM-related technologies," *Safety Science*, vol. 97, pp. 88–98, Aug. 2017, https://doi.org/10.1016/j.ssci.2015.12.027.

[2] M. D. Nguyen, P. Q. Tran, and H. B. Nguyen, "An Application of Analytic Network Process (ANP) to Assess Critical Risks of Bridge Projects in the Mekong Delta Region," *Engineering, Technology & Applied Science Research*, vol. 13, no. 3, pp. 10622–10629, Jun. 2023, https://doi.org/10.48084/etasr.5802.

[3] K. Abuhasel, "Sustainable Green City Development Project Analysis using the Critical Path Method (CPM) and the Crashing Project Method on Time and Cost Optimization," *Engineering, Technology & Applied Science Research*, vol. 13, no. 3, pp. 10973–10977, Jun. 2023, https://doi.org/10.48084/etasr.5980.

[4] L. Zhang, M. J. Skibniewski, X. Wu, Y. Chen, and Q. Deng, "A probabilistic approach for safety risk analysis in metro construction," *Safety Science*, vol. 63, pp. 8–17, Mar. 2014, https://doi.org/10.1016/j.ssci.2013.10.016.

[5] A. Tomek and P. Matějka, "The Impact of BIM on Risk Management as an Argument for its Implementation in a Construction Company," *Procedia Engineering*, vol. 85, pp. 501–509, Jan. 2014, https://doi.org/10.1016/j.proeng.2014.10.577.

[6] M. M. Dishar and M. R. Altaie, "Use Risk Score Method to Identify the Qualitative Risk Analysis Criteria in Tendering Phase in Construction Projects," *Journal of Engineering*, vol. 28, no. 7, pp. 31–42, Jul. 2022, https://doi.org/10.31026/j.eng.2022.07.03.

[7] A. S. Filippetto, R. Lima, and J. L. V. Barbosa, "A risk prediction model for software project management based on similarity analysis of context histories," *Information and Software Technology*, vol. 131, Mar. 2021, Art. no. 106497, https://doi.org/10.1016/j.infsof.2020.106497.

[8] S. F. R. AL-Aga and A. M. Burhan, "Risk Assessment in BOT Contracts using AHP Technique," *Journal of Engineering*, vol. 29, no. 1, pp. 61–75, Jan. 2023, https://doi.org/10.31026/j.eng.2023.01.04.

[9] P. Brous, M. Janssen, and P. Herder, "The dual effects of the Internet of Things (IoT): A systematic review of the benefits and risks of IoT adoption by organizations," *International Journal of Information Management*, vol. 51, Apr. 2020, Art. no. 101952, https://doi.org/10.1016/j.ijinfomgt.2019.05.008.

[10] A. A. Saffar, K. Raheem, and A. A. Ghaleb, "Improving the Performance of Construction Project Information and Communication Management Using Web-Based Project Management Systems (WPMSs)," *Journal of Engineering*, vol. 20, no. 10, pp. 79–82, 2014.

[11] Y. Zou, A. Kiviniemi, S. W. Jones, and J. Walsh, "Risk Information Management for Bridges by Integrating Risk Breakdown Structure into 3D/4D BIM," *KSCE Journal of Civil Engineering*, vol. 23, no. 2, pp. 467–480, Feb. 2019, https://doi.org/10.1007/s12205-018-1924-3.

[12] O. H. Abdullah and W. A. Hatem, "Alternative Construction using BIM in Old Educational Buildings," *Engineering, Technology & Applied Science Research*, vol. 13, no. 2, pp. 10316–10321, Apr. 2023, https://doi.org/10.48084/etasr.5390.

[13] S. H. Han and J. E. Diekmann, "Making a risk-based bid decision for overseas construction projects," *Construction Management and Economics*, vol. 19, no. 8, pp. 765–776, Dec. 2001, https://doi.org/10.1080/01446190110072860.

[14] N. Van Thuyet, S. O. Ogunlana, and P. K. Dey, "Risk management in oil and gas construction projects in Vietnam," *International Journal of Energy Sector Management*, vol. 1, no. 2, pp. 175–194, Jan. 2007, https://doi.org/10.1108/17506220710761582.

[15] E. Kissi, E. B. Boateng, T. Adjei-Kumi, and E. Badu, "Principal component analysis of challenges facing the implementation of value engineering in public projects in developing countries," *International Journal of Construction Management*, vol. 17, no. 2, pp. 142–150, Apr. 2017, https://doi.org/10.1080/15623599.2016.1233088.

[16] A. A. Alfahad and A. M. Burhan, "A Hybrid Method for Identifying Risks Affecting Performance in Construction Sector in Iraq," in *International Research Conference on Engineering and Applied Sciences 2023 (IRCEAS2023)*, Baghdad, Iraq, Oct. 2023.

[17] S. Byström and A. Pierre, "Risk Management in the bidding context A Schedule Risk Analysis Approach," MSc Thesis, Linkoping University, 2003.

[18] J. E. Diekmann and W. D. Featherman, "Assessing Cost Uncertainty: Lessons from Environmental Restoration Projects," *Journal of Construction Engineering and Management*, vol. 124, no. 6, pp. 445–451, Nov. 1998, https://doi.org/10.1061/(ASCE)0733-9364(1998)124:6(445).

[19] "Miro | The Visual Workspace for Innovation." https://miro.com/.

[20] S. F. R. AL-Aga and A. M. Burhan, "Risk Assessment in BOT Contracts using AHP Technique," *Journal of Engineering*, vol. 29, no. 1, pp. 61–75, Jan. 2023, https://doi.org/10.31026/j.eng.2023.01.04.

[21] R. W. Saaty, "The analytic hierarchy process—what it is and how it is used," *Mathematical Modelling*, vol. 9, no. 3, pp. 161–176, Jan. 1987, https://doi.org/10.1016/0270-0255(87)90473-8.