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Managing of Subcontractor Risks in Construction Projects

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Abstract

In a typical building construction project, subcontracting accounts for around 40% of the total effort. Given this proportion, it would not be overstatement to say that serious dangers to the construction sector would arise if the issues related to substantial subcontracting are not addressed. This is because a subcontractor's project team's performance and excellence impact the project's outcome in terms of quality and timely delivery, which is crucial in determining a project's economic performance. The paper aims to merge risk management with subcontractor risks to manage these risks efficiently using artificially intelligent algorithms to maximize performance. the methodology of this paper includes a questionnaire to collect subcontractors' risks and then build a system to manage these risks and reduce the effect on the project performance by using a gravitational search algorithm to classify the risk and find the optimal solution. The results show that the most problems relating to the subcontractor are quality as the subcontractor fails to fulfill the quality of the decided project and hence increases cost and time; GSA shows a very good algorithm in selecting the optimal solution for each risk, as for quality performance monitoring and feedback risk the algorithm select the response is to avoid the risk by fitness 0.89 as conclusion the subcontractors have main effect on the project performance as they are responsible more than 30% of the tasks and any failure will lead to inadequate projects.

Keywords**:** Risks, Modeling, subcontractor, GSA

1. Introduction

It is well known that the building construction industry is a hub for merchants with a wide range of specializations, according to (Lew et al., 2018; Nguyen & Hoang, 2024). The breadth and complexity of the projects undertaken and the "one-time off project" character of the work environment set the building sector apart. Because the industry is so dynamic and requires the acquisition of cutting-edge methods and new technologies to facilitate the delivery of goods, subcontractors must now be used (El-Kholy, 2022). "A building firm or an individual that enters into a contract with the principal contractor to carry out particular tasks on a project as part of the overall agreement and may provide laborers, supplies, tools, equipment, and designs (El-Kholy, 2022). Laryea (2009) Ensures that subcontractors execute contracts to complete a contract's portions or parts. A subcontractor is a construction company that enters into an overall contract with a primary contractor to do specific tasks on a project. The subcontractor could supply personnel, supplies, machinery, tools, and plans for the project (Arditi & Chotibhongs, 2005; Eom et al., 2008). Three groups of subcontractors were created by Mbachu (2008): 1) Trade contractors: These contractors carry out certain tasks like painting or laying brick; 2) Specialist subcontractors: These subcontractors handle specialized services like plumbing, electricity, insulation, etc.; and 3) Labor-only subcontractors: These subcontractors carry out labor-only tasks like skilled labor and craftsmen (Mbachu, 2008). Subcontracting was not practiced as widely in past decades as today (Al-Sobiei et al., 2005).

Lew et al. (2018) state that the building industry is distinct due to the scope and intricacy of the projects it takes on and the "one-time off project" aspect of its working environment. The usage of subcontractors has become essential due to the sector's dynamic nature, which necessitates acquiring new technologies and cutting-edge methods to permit the delivery of goods (Lew et al., 2018). "An organization or person in the construction industry who enters into a written agreement with the principal contractor to carry out particular tasks on a project as part of the overall contract and who may also provide personnel, supplies, machinery, tools, and designs. Laryea (2009) revealed that subcontractors sign contracts to carry out a contract's components or sections (Laryea, 2009).

Comparatively speaking, the proportion of subcontracted projects has grown recently. Subcontracting can contribute between 50 and 90 percent, and it may account for up to 90 percent of the entire project value during a building process (Frein, 2012; Polat et al., 2015). Therefore, subcontracting issues are a topic of discussion among the influential people in the construction business. Subcontracting-related problems, on the other hand, subcontracting-related issues are among the construction industry's key risks frequently brought up in international discussions. The safety of on-site personnel is one of the dangers encountered that is frequently studied (Awwad et al., 2016; Liao & Chiang, 2015). The delay in the completion date (Chiang, 2009) and the failure in message delivery between parties during the construction stage (Piasny & Pasławski, 2015; Manu et al., 2009).

It was advised that enterprises employ other variables, such as pricing, quality, delivery time, risk, prior experiences with subcontractors, and reputation, to address the issue of subcontractor selection (Lavelle et al., 2007; Hartmann et al., 2009). The two main topics not covered in the vast amount of literature on subcontracting are the subcontractors' predictions before work is awarded and the standards used to keep an eye on them while construction is underway. Thus, this study aims to address these significant difficulties in response to that. Finding potential relationships between the primary success criteria of subcontractors in the building sector, given that their engagement indicated how important these problems were to resolve. Generally speaking, a general contractor can anticipate the advantages or disadvantages of choosing a subcontractor. The resource distribution can, therefore, be pre-planned once the subcontractor's performance or shortcomings have been predicted.

This research explores key issues. To illustrate, we run nonlinear modeling and analysis, create controllers, and validate the theory results (Lew et al., 2018).

No building endeavor is risk-free. Because of the intense competition in the building industry, the situation for the workers gets worse. These dangers may impact the project's goals in the long run, as well as the budget, quality, and time. The first step in the risk management method is risk assessment, which involves determining the nature and origin of risks. The classification of risk categories and their effects on the undertaking continues. The threats that are found will be filtered and prioritized by risk analysis. After conducting a risk analysis, a risk reaction strategy is created for the job. Accordingly, a number of building projects are high risk in Malaysia because of the implementation of processes, risk identification, and monitoring and evaluation of risk responses (Professor, 2015). Projects must also follow rules like presenting, preparing, supervising, executing, and ending. The danger level is also greater during construction than in other economic sector types. Risk is frequently easily discovered in some project management procedures in the building sectors (Professor, 2015). According to the Project Management Institute (PMI), risk is an unknown circumstance that adversely affects a project goal. Adeleke et al. (2018) also showed that risk management is acknowledged.

According to (Polat et al., 2015), an increasing number of building jobs are now being subcontracted. According to studies, subcontracting can account for anywhere between 50% and 90% of the overall project value in a normal building situation (El-Mashaleh, 2009). Lew et al. (2018: 836) warned that despite the advantages of subcontracting, "Project management teams, clients, and general contractors are at risk from extensive subcontracting activities"(Lew et al., 2018). Also, the challenges these stakeholders have in overseeing such huge, diverse, and dispersed subcontractor groups account for the problem's existence. Other research has also shown additional dangers connected to subcontracting in the building sector, such as failure of the parties' message delivery during the building phase (Piasny & Pasławski, 2015), delay in the completion date (Chiang, 2009) and safety of on-site workers (Awwad et al., 2016). Using a fivepoint descriptive scale to assess possible impacts and occurrences, N.B. Chaphalkar and C.A. Shelar transformed the consequences and likelihoods into numerical measures in an equation that expressed the percentage values of effect and occurrence (Chaphalkar et al., 2011). Risk is the probability that an undesirable risk will always materialize or that a desired outcome will not materialize and cause the project to be disrupted. A project's level of uncertainty may be controlled using a collection of risk management strategies. One definition of delay is going over schedule or needing more time to finish the job (Hamzah et al., 2011). When a construction project progresses more slowly than anticipated, it is said to be experiencing a construction delay. As "the process of systematically and continuously identifying, categorizing and assessing the initial significance of risks associated with a construction project," risk identification was described by Alfredo and Pilar (del Caño et al., 2002). The paper aims to identify the effect of subcontractor risks on construction project performance.

2. Methodology

The proposed system merges subcontractors and risk management to reduce risks and contract failure and provide projects with minimum error.
The system was applied to the Ministry of Higher Education to assess its effectiveness in managing risks allocated in each step of the contracting procedure from the contract award.
The first step is to distribute a questionnaire to identify the effect of subcontractor risks on project performance. The field study was the Furthermore, all work sections done by subcontractors on projects are subject to his approval.

Table 1. Risk and its Evaluation (questionnaire)

Risks	Evaluation
Excellent work	Medium
Observation and comments	High
Effective quality planning and effective quality assurance are supported by top management.	High
Efficient management of quality	Medium
technical hazards	Medium
Poor project planning	Medium
inadequate specifications	Medium
Equipment and system malfunction	Medium
Inaccuracy in the cost estimation	Medium
Changes to the De Sign	Medium
Risks to finances	High
inadequate financial evaluation	High
Delays in payment	High
Cash flow forecast errors	High
Impractical pricing estimate	High
Risks associated with resources	High
Lack of personnel; Lack of supplies	High
Lack of plants	Medium
Risks associated with management	Medium
Poor planning on the contractor's part	Medium
Unqualified subcontractors	High
inadequate performance control and quality	High
Ineffective communication abilities	High
Relationship hazards	High
Ineffective project team communication, insufficient dedication, and inadequate planning and coordination	High
Top management supports effective quality planning and quality assurance.	High

3. Proposed system

The proposed system consists of many stages, starting from the project definition to the problem-solving. The first stage gives a general introduction about the type that considers the project name, beneficiary, funding agency, and other information related to the project. Figure (1) shows the flowchart of the proposed system.

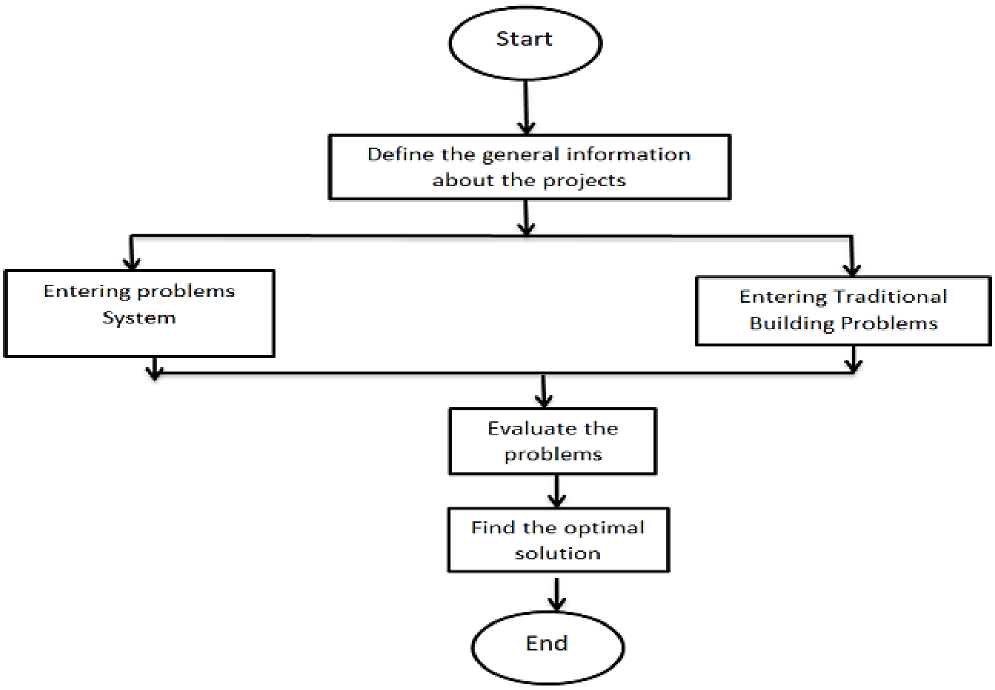

Fig 1. Proposed System

First, the system has a user interface for entering the user name and password, as in Figure (2).

Fig 2. Welcoming User Interface

Figure (3) shows the window containing the identification and analysis process of the risks. The window includes the risk name, impact, and probability of the risks based on a Likert scale from 1 to 5 for both probability and impact. If the risk has a high assessment, it will be entered into the Table to find its optimal response; otherwise, it will not be entered and ignored

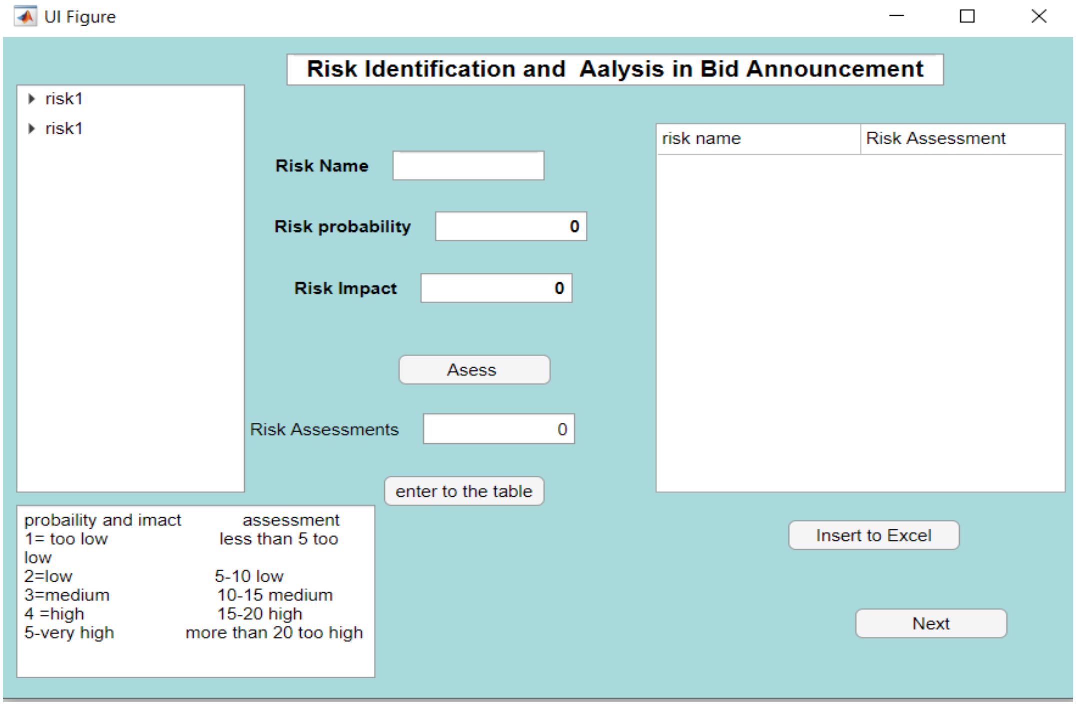

Fig3. Risk Identification and Analysis

After each risk is identified and analyzed, it will move to the next step, which is finding the optimal response, each department has a list of previous risks with their treatments, and treatment sometimes differs for the same risk, therefore if the same risks are repeated with some suggested response, the selection of the reaction is done on random based, therefore an optimization model was developed using genetic algorithm and gravitational search algorithm based on the properties of risk in respect to its cost, time and its effectiveness. Figure (4) shows the window that was designed for the risk response selection.

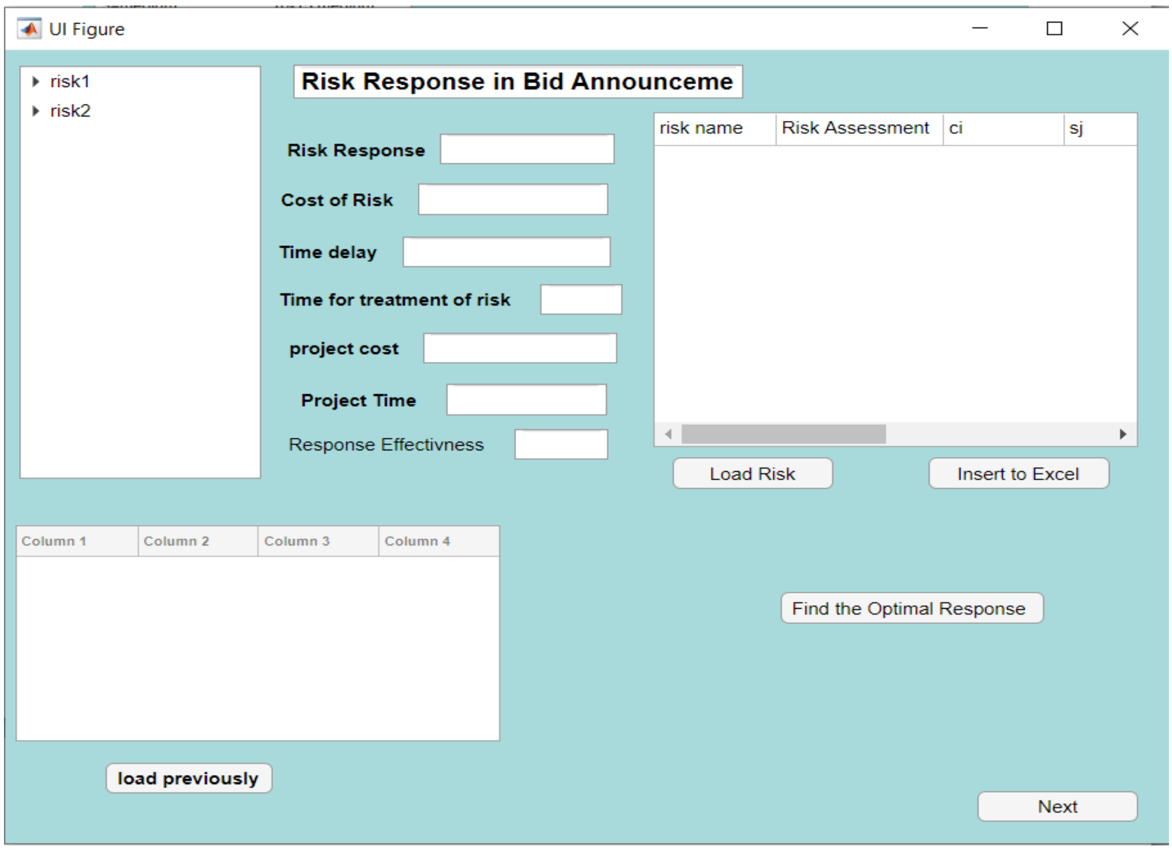

Fig 4. Risk Response

In Figure (4), the process of the risk response selection depends on many factors shown in the figure, with each one having a certain effect on the project. The response will be entered with its cost, which means how much this treatment will take from the whole budget of the project; then two inputs regarding time will be entered; the first one concerns the time of the treatment, and the second one represents the delay due to the risk, the effectiveness of the response will also be entered based on the opinion expert and finally both time and cost of the project will be entered. The model was developed by Naj and Ali (2017). The model will be applied to the contracting procedure to select the optimal response in a construction project. Before applying the case study, a brief description of the two algorithms will be explained.

Gravitational Search Algorithm

Rashedi et al. created GSA in 2009 to resolve optimization issues. The mass interactions and the gravitational law influence the algorithm of the population type with heuristics. The algorithm comprises several searcher bots that react to one another through gravity (Rashedi et al., 2011). The masses symbolize the agents' performance and are viewed as objects. Gravity is the force that causes all agents to transfer globally to one another and the goal. In actuality, the masses surrender to the laws of motion in Equation (2) and gravity as demonstrated in Equation (1).

$$F = G\frac{m_1 m_2}{r^2} \quad (1)$$

and $a = \frac{F}{M}$ (2)

as in equation (1), F signifies the gravitational force magnitude, G is the constant of gravitational, first and second objects m_1 and m_2 mass, and r is the two objects distance. Equation (2), Newton's second law, demonstrates that when a force, F, is used to object, it speeds up, based on the force and its mass, m. The algorithm that has been used is explained in the algorithm in the Table (2)

Table 2. GSA Algorithm (Author)

Algorithm GSA
Input: A data set of the entire projects Output: maximize the best response

Begin
Step (1): Input the GSA parameters
Step (2): define the file name
Step (3): define the range of the data
Step (4): calculate the mass, velocity, and acceleration
Step (5): define the mathematical model
xij(i,j) = X(i,j);
ci = X(2,i);
sij = X(3,i)*tmax;
Cmij(i,j) = ci(j)*max(xij(i,j));
Smij(i,j) = sj(j) - (sij(j)*xij(i,j))
Tmax: % T Period of execution Time(days)
ci: % spending Cost
sj : % Delay time
sij: % Treating time
bmax: % B Budget
eij = fdata: % rating factor
X=Pop;
Step (6): define an upper and lower limit for Xij
Xij from 0-1
Step (7): calculate the objective function according to
Max Zz= eij(j)* X(i,j);
Step (8): update the mass, velocity, and acceleration
Step (8): optimize the projects
END

The risk matrix that has been used in Table (3)

Table 3 Risk Matrix

Risk Matrix		Severity				
		Insignificant	Minor	Moderate	Major	Severe+K10:P21
Likelihood	Almost Certain	Medium	High	Very High	Very High	Very High
	Likely	Medium	High	High	Very High	Very High
	Possible	Low	Medium	High	High	Very High
	Unlikely	Low	Low	Medium	Medium	High
	Rare	Low	Low	Low	Low	Medium

These models were used for both algorithms and then the questionnaire forms were collected and entered into the system to identify the risk assessment to find its response.

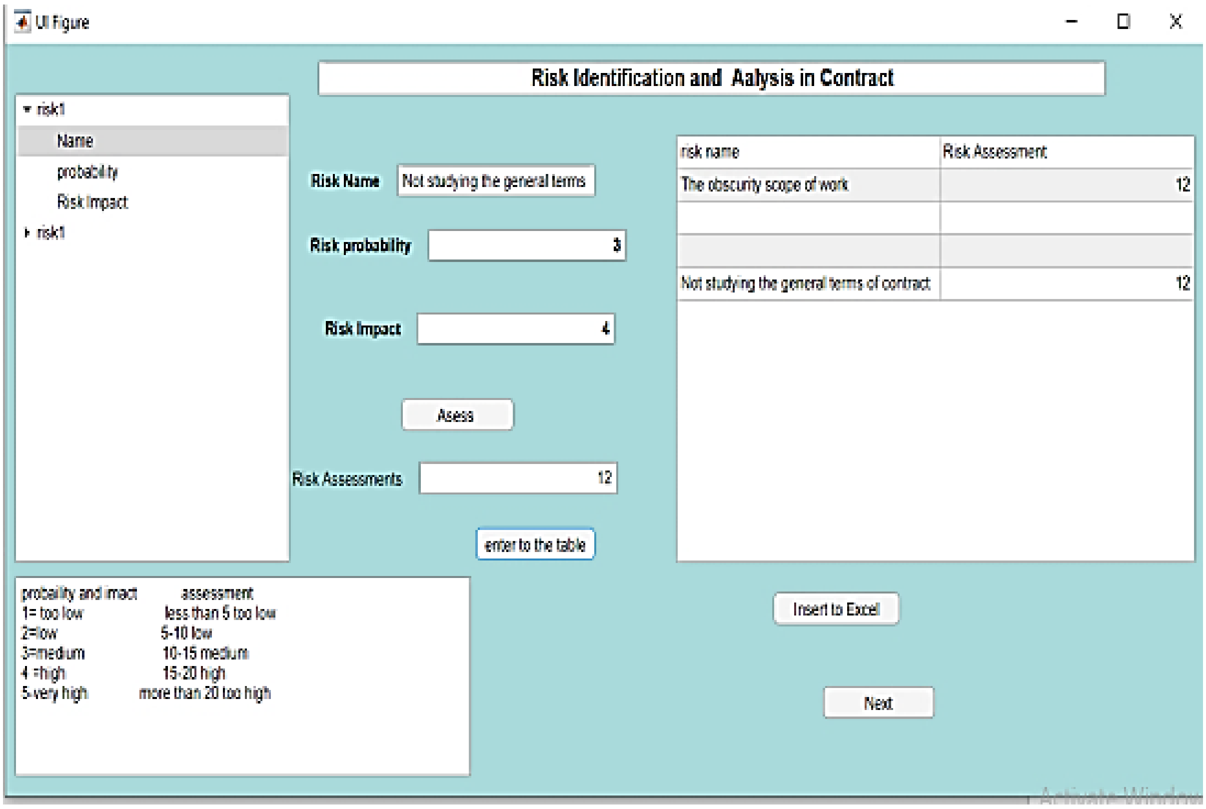

Fig 5. Risk Analysis in the Case Study

This process continues for the five projects till all the information is completed.

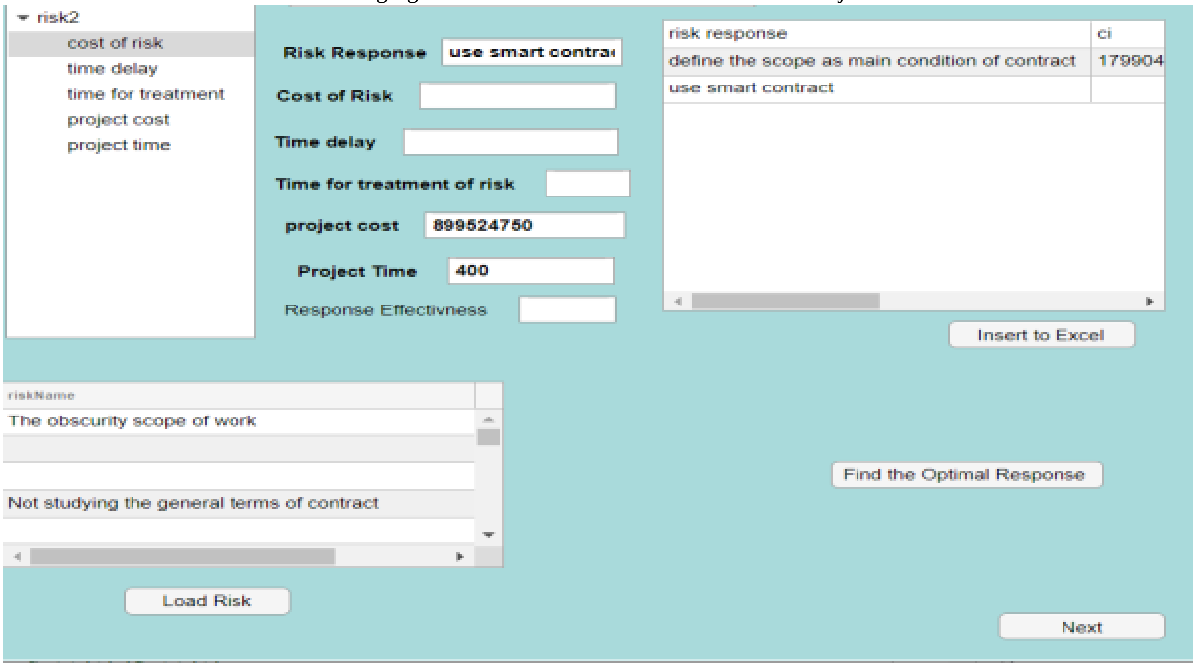

Fig 6. Risk Response in the Case Study

Figure (5) shows the response for each risk. Three responses were selected for each risk, and the effective response is shown in Table (3).

Table 4. Risks with its Response (questionnaire)

Risk	Risks response	Effectiveness
Quality performance Monitoring and feedback Top management support	Accept (do nothing)	0.6
	Transfer (transfer risk to contractor)	0.7
	Avoid (using smart contract)	0.9
Effective quality planning Effective quality assurance Effective quality control	Accept (do nothing)	0.5
	Transfer (transfer risk to contractor)	0.8
	Avoid (using smart contract)	0.95
Technical risks Inadequate project formulation Poor specification	Accept (do nothing)	0.65
	Mitigate	0.75
	Avoid (use sufficient criteria to choose the contractor)	0.93
System and equipment failure Quality performance Monitoring and feedback	Accept (do nothing)	0.55
	Transfer (transfer risk to contractor)	0.66
	Avoid (using smart contract)	0.85
Top management support Effective quality planning Effective quality assurance	Accept (do nothing)	0.69
	Transfer (transfer risk to contractor)	0.77
	Avoid (using BIM software)	0.89
Effective quality control Technical risks Inadequate project formulation	Accept (do nothing)	0.45
	Transfer (transfer risk to contractor)	0.8
	Avoid (using BIM software)	0.9
Poor specification Quality performance	Accept (do nothing)	0.68
	Transfer (transfer risk to contractor)	0.49
	Avoid (using smart contract)	0.8
Monitoring and feedback Top management support Effective quality planning	Accept (do nothing)	0.65
	Transfer (transfer risk to contractor)	0.66
	Avoid (using BIM software)	0.9
Effective quality assurance Effective quality control Technical risks	Accept (do nothing)	0.55
	Transfer (transfer risk to contractor)	0.69
	Avoid (using smart contract)	0.89
Inadequate project formulation Poor specification	Accept (do nothing)	0.77
	Transfer (transfer risk to contractor)	0.8

	Avoid (using smart contract)	0.87
Quality performance Monitoring and feedback Top management support	Accept (do nothing)	0.77
	Transfer (transfer risk to contractor)	0.77
	Avoid (using smart contract)	0.87
Effective quality planning	Accept (do nothing)	0.67
	Transfer (transfer risk to contractor)	0.8
	Avoid (using smart contract)	0.9

Table (3) shows the most frequent risks that occur in most projects in the Ministry of Higher Education. The response was collected from what was implemented, adding to it the one suggested by the researcher and offered to the expert with their profit and gain; each response is given an effectiveness range from (0-1) to know its effectiveness depends on the period and type of the project.

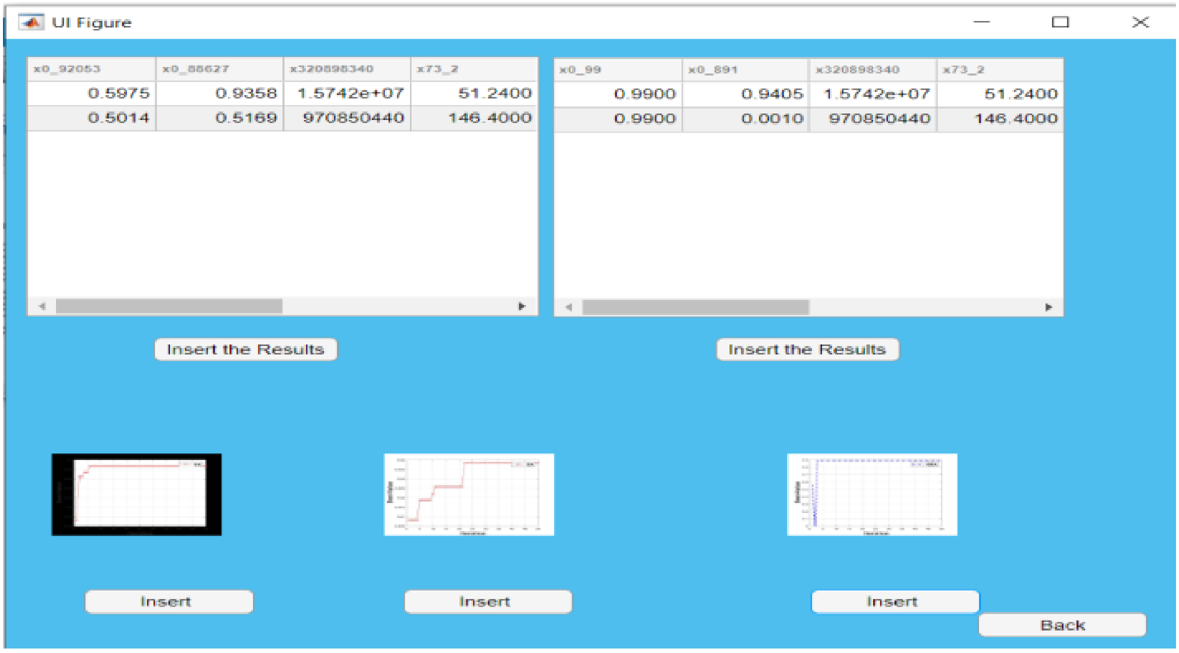

Figure 7: Optimal Response in the Case Study

Figure (7) shows an example of the optimal response for the risk in project one and the application of GSA.

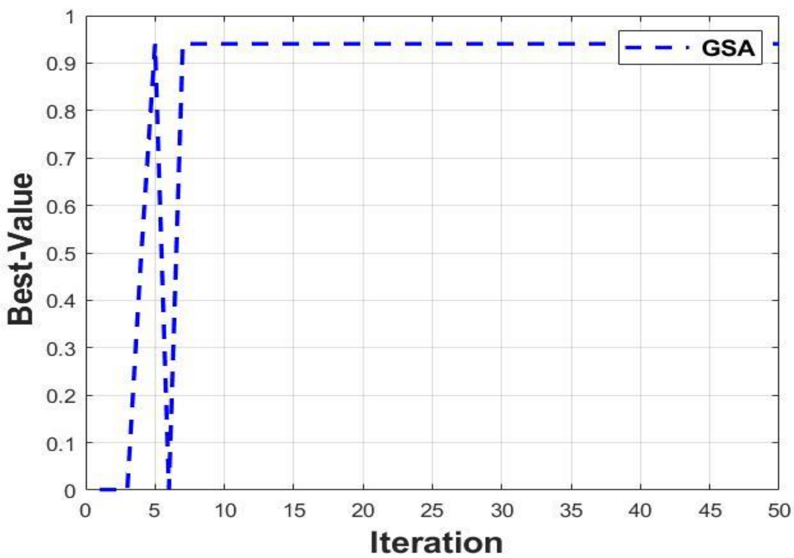

Fig 8. Optimal Response for Risk 1 using GSA (Author)

4. CONCLUSIONS

This study investigated how subcontractor risk management affects building construction

projects' quality performance. Five goals were established based on the suggested assumptions in order to accomplish this goal. The following five goals were to be ascertained:
(1) the influence of subcontracting's financial risk on the quality of building construction;
(2) the influence of subcontracting's resource risk on the quality of building construction;
(3) the influence of subcontracting's technical risk on the quality of building construction;
(4) the influence of subcontracting's managerial risk on the quality of building construction; and
(5) the influence of subcontracting's relationship risk on the quality of building construction. After a thorough literature study, a questionnaire survey was carried out. The proposed system for merging risk management with contracts is considered an efficient method to manage the risks in the contracting procedure.
GSA is considered an effective tool for selecting the best response for the risks.

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