Original scientific article
UDK 549.722.111:[665.71:551.781
http://dx.doi.org/10.7251/afts.2022.1427.033T
COBISS:RS-ID 137253121

STRATEGY OPTIMIZATION FOR RESPONDING TO PRIMARY, SECONDARY AND RESIDUAL RISKS CONSIDERING COST AND TIME DIMENSIONS IN PETROCHEMICAL PROJECTS

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ABSTRACT

Risk management throughout the project life cycle, from the initial phase beginning to the final phase, ended continuously and dynamically, is one of the basic requirements for the success of any project-oriented organization. To effectively identify and manage risks at all stages of the project, careful selection must be made at all levels of the organization. In some cases, implementing the response may eliminate the risk but reciprocally create additional risks for the project. Most of the available risk selection methods mainly focus on eliminating the primary risks without understanding the secondary and residual risks that may arise during the project implementation.

The occurrence of secondary risk can be a direct result of performing an activity that responds to a primary risk. This study proposes an optimization model to select risk response measures for primary and secondary risks. The difference between our proposed method and Zhao method (2018) will be that the proposed one does not lead to selecting a predetermined strategy. This method examines the two dimensions of time and costs in response to primary and secondary risks. In addition, the genetic metaheuristic algorithm has been used to solve the problem in the dimensions mentioned above.

Keywords: *Cost, Genetic algorithm, Petrochemical projects, Primary and secondary risks*

INTRODUCTION

Project risk management includes risk management planning guidance, identification, analysis, response planning, and project monitoring and control. The project risk management aims to increase the probability and effect of positive events and reduce the probability and effect of negative events in a project. Risk can exist from the moment the project starts. Running a project without an active focus on risk management can lead to serious problems that arise from unmanaged risks. Risk is considered an uncertain event that affects at least one of the project objectives in case of occurrence. This impact can be either positive or negative. We call positive and negative risks opportunity and threat, respectively [1].

When planning a project, project managers have very little information about the risks associated with each activity. As a result, time delays, additional costs, and quality reductions are potential risks. According to Wang [2], if the right response to risk is not given, the impact of risk identification and assessment will be reduced. In the threats response phase, five strategies are used, including transferring, avoidance, acceptance, reduction and improvement of decision-making level [3]. Project managers select these five strategies with different objectives according to different conditions or projects based on the level of access to resources, risks and other factors related to project objectives. In particular, risk avoidance refers to eliminating threats posed by risks.

In contrast, risk reduction aims to reduce the likelihood of the risks occurrence or impact up to an acceptable level[3]. For risk prevention, risk avoidance is always done by removing all activities related to that risk from the main plan [4]. Risk avoidance, although effective, causes a certain complexity in project management, because new activities create new risks. In contrast, risk reduction, which seems to be more practical, reduces the risk of activity by selecting and implementing a new set of measures in response to it [5]. As a result, choosing the right response to risks reduces the underlying threats in project activities.

Any response defined for project risks will lead to a change and improvement in the project risk status [6]. However, it cannot be quarantied that the response will necessarily work as planned or that the outcome of the response planning will only affect the considered risk. In some cases, implementing the response may eliminate the risk, but reciprocally create other risks for the project.

The risks of enforcing a response are called secondary risks. It is necessary to identify the secondary risks arising from the response to the main risks of the project and to evaluate the main risks in the same way. For this purpose, it should be determined what the project risk status will be after implementing the responses. In addition to the secondary risk, residual risk will be considered in this study, which is a level of risk that still exists despite creating control factors and efforts to reduce risk. Residual risks are those remaining after avoidance, transferring or adjustment reactions.

For this reason, here, we will optimize the response to the primary, secondary and residual risks of Nardis oil and gas petrochemical companies. This holding intends to import and supply the facilities related to heavy equipment, for which, they ought to plan the transportation and installation of an 800-ton tower. In addition, they must plan to carry out 19 different sets of activities so that the best possible conditions are available with the least risk available.

LITERATURE BACKGROUND

Khalilzade et al. [7] presented a new method of Failure Modes and Effects Analysis (FMEA) based on fuzzy Multi-Criteria Decision Making (MCDM) methods and multi-objective planning model for risk assessment in oil and gas planning stage. This research consisted of several stages. First, 19 major Health, Safety and Environment (HSE) risks in the OGCP were classified into six categories using the Delphi method. These factors were distinguished by reviewing project documents, checklist analysis, and consulting with experts. Then, using the fuzzy Stepwise Weight Assessment Ratio Analysis (SWARA), the experts calculated the weight of major HSE hazards. Then, Failure Modes and Effects Analysis (FMEA) and Preference Ranking Organization Method for Enrichment Evaluations (PROMETHEE) methods were used to identify the priority of the main risk factors. Finally, a multi-objective zero-one linear programming method was developed to select risk response strategies using Advanced Electronic Constraint Method (AECM).

Denisova et al. [8] evaluated the implementation plans of the project in the presence of related risks. They considered and evaluated two alternative methods for planning: network modeling and integer programming. It is assumed that project risk is associated with a positive or negative event or a combination of them during project implementation. Different scenarios are created depending on the circumstances in which dangerous events occur. The amount of risk for each scenario is estimated based on the predicted values of the financial characteristics of the project.

Scenario testing is performed for each method. The described method was reviewed using an outstanding example of an infrastructure project involving part of a gas pipeline on the seabed.

In their paper, Zhang et al. [9,10] proposed a method based on case-based analysis and fuzzy optimization to provide decision support in response to project risk. The main steps of the method are: (1) formulation of alternative Risk Response Actions (RRAs) based on case-based analysis and (2) determination of the optimal set of RRA using fuzzy optimization model. Based on this method, project managers (PMs) can find alternative RRAs and determine the optimal set of RRAs. Some suggestions and managerial implications are taken from their results.

Initially, to better respond to risk in the future, it is suggested that organizations always consider a long-term perspective by being aware of the record keeping of all historic projects being managed. Second, since each RRA derived from alternative historical cases must be adapted to the existing conditions, compatibility costs must also be considered when allocating funds for RRA selection.

Piedade et al. [11] optimized crisis response time. They examined the different types of crises and their propagation at Lisbon Airport, so using an optimization model, they tried to minimize crisis response time and cost.

Wang et al. [2] used a simulation model to evaluate risk-response strategies for risk interactions to evaluate decisions. They used a genetic algorithm to solve the optimization problem.

Zhang et al. [9,10] used the integrated DIMATEL technique and network analysis to weigh the risks of derail the train at the railway station. They identified the risk response strategies using the Delphi method and ranked risk response strategies using the TOPSIS method.

Kuo et al., [12] proposed a mathematical model to adjust the cost of risk management and used the particle swarm algorithm to solve the problem. Their study examined the socio-economic situation and technical conditions under the influence of many risks due to uncertain climate. The calculations showed that the particle swarm algorithm could solve the adjustment problem without violating the model constraints. In addition to minimizing potential risk while keeping the total budget to a minimum, the proposed model can also provide appropriate risk response strategies (acceptance, reduction, transfer, or avoidance).

In a study, Koulinas et al. [13] evaluated and analyzed risk at work sites using the Greek construction sector's fuzzy network analysis process method. The results show that the proposed framework can be a useful tool for decision makers to estimate a limited emergency budget to achieve health and safety at a minimum cost.

Adeleke et al. [14] investigated the impact of external organizational factors on risk management in Nigerian construction companies using partial least squares structural equation modeling.

Soleh et al. [15] evaluated appropriate strategies such as early warning and rapid coverage and recovery in response to potential risks.

Huang & Zhao [16] believed that secondary risk in project risk management refers to the risk that arises directly from implementing a Risk Response Action (RRA). Project managers (PMs) must consider the effects of secondary risks on the RRA selection process. In this paper, they present an optimization method to solve the problem of choosing an RRA with secondary risk in mind. Their optimization model aims to minimize risk costs considering the time constraints in construction projects.

METHODS

Problem description

In this research, we will use GAMS software for data analysis. The objective function of reducing the cost of the whole project includes three types of constraints.

	=1 if the strategy *k* is allocated to the activity *i* to respond to the primary risk *l*, otherwise =0
y'_{ilk}	=1 if the strategy *k* is allocated to the activity *i* to respond to the secondary risk *l*, otherwise =0
x_i	Optimal failure rate for the activity *i*
$drisk_i$	The amount of time that the activity *i* is at risk
t_i	The amount of time for the activity *I* to be completed

Parameters

$qcost_{il}$	Predicted cost of the primary risk *l* on the activity *i*
$qtime_{il}$	Predicted time of the primary risk *l* on the activity *i*
$ecost_{ilk}$	The cost savings from allocating strategy *k* to the primary risk *l* in the activity *i*
$etime_{ilk}$	The time savings from allocating strategy *k* to the primary risk *l* in the activity *i*
$caction_{ilk}$	The cost obtained through allocating strategy *k* on the primary risk *l* in the activity *i*
$qcosts_{ilk}$	Unpredicted cost of secondary risk *l* on the activity *i* resulting from allocation of the secondary strategy *k*
$ecosts_{ilk}$	The amount of unpredicted benefit from the secondary risk *l* on the activity *i* resulting from allocation of the secondary strategy *k*
$qtimes_{ilk}$	The effect of unpredicted time cost resulting from the secondary risk *l* on the activity *i* resulting from allocation of the secondary strategy *k*
$etimes_{ilk}$	The amount of benefit of the unpredicted time effect of the secondary risk *l* on the activity *i* resulting from the allocation of the secondary strategy *k*
$cactions_{ilk}$	The amount of cost resulting from allocating the strategy *k* to the secondary risk *l* in the activity *i*
$ccrash_i$	The failure cost of the activity *I*
q_i^*	Maximum risk budget for each activity
d_i^*	Maximum acceptable delay for each activity
$dmin_i$	Minimum time required to perform the activity

Therefore, after introducing the variables and parameters of the model, it is necessary to examine the objective functions and constraints, which are as follows:

$$minz_1 = \sum_i \sum_l qcost_{il} + \sum_i \sum_l \sum_k caction_{ilk} * y_{ilk} - \sum_i \sum_l \sum_k ecost_{ilk} * y_{ilk}$$

As it is clear from the above equation, the predicted cost of risk on each activity is added to the cost of risk response and then deducted from cost savings of the risk response. This equation optimizes the primary risk cost of the project. However, the important point is the amount of residual risk cost, which is included in the below equation as follows:

$$residual\,risk = \sum_i \sum_l qcost_{il} - \sum_i \sum_l \sum_k ecost_{ilk} * y_{ilk}$$

The next equation to be explained points to the secondary risk. The secondary risk arises from the strategy's response to the primary risks, which may give rise to the secondary risk. For this reason, the second objective function seeks to minimize the cost of responding to secondary risk whose equation is as follows:

$$minz_2 = \sum_i \sum_l \sum_k qcosts_{ilk}\, y_{ilk} \quad {}_{il} + \sum_i \sum_l \sum_k cactions_{ilk} * y_{ilk} - \sum_i \sum_l \sum_k ecosts_{ilk} * y'_{ilk}$$

As seen from the above equation, the unpredicted cost of secondary risk incurred on each activity is added to the cost of secondary risk response and then deducted from the cost savings caused by risk response. This equation optimizes the cost of the project's secondary risk. However, the important point is the amount of residual risk, which is included in the below equation as follows:

$$residual\,risk = \sum_i \sum_l \sum_k qcosts_{ilk} * y_{ilk} \quad {}_{il} - \sum_i \sum_l \sum_k ecosts_{ilk} * y'_{ilk}$$

Now it is necessary to describe the cost of failure of activities as follows:

$$minz_3 = \sum_i ccrash_i * x_i$$

Now, the cost of activity failure has been determined, namely, all the objectives of the model have been described and the main objective is to minimize the cost of primary and secondary risks and the cost of failure of activities. In this step, the constraints of the model must be explained, the first of which that will form the problem node network, is as follows:

$$t_j \geq t_i + d_i + drisk_i - x_i \qquad \forall(i,j)$$

$$t_i \leq tdue \qquad \forall(i)$$

The above constraint will calculate the time it takes to complete an activity. The next constraint to be described is the one that determines the maximum amount of delay that an activity can have, which is calculated through the following equation:

$$drisk_i \leq d_i^* \qquad \forall(i)$$

$$drisk_i = \sum_l qtime_{il} - \sum_l \sum_k etime_{ilk} * y_{ilk} + \sum_i \sum_l \sum_k qtimes_{ilk} * y_{ilk} - \sum_i \sum_l \sum_k etimes_{ilk} * y'_{ilk} \qquad \forall(l,k)$$

The above constraint calculates the residual time caused by the project's primary and secondary. However, the above constraints will be satisfied with the following three conditions

$$drisk_i \geq 0 \qquad \forall(i)$$
$$x_i \geq 0 \qquad \forall(i)$$
$$x_i \leq d_i - dmin_i \qquad \forall(i)$$

Now that the network formation and time constraints of the problem have been described, we will consider the constraints on risk costs as follows:

$$\sum_l qcost_{il} - \sum_l \sum_k ecost_{ilk} * y_{ilk} + \sum_i \sum_l \sum_k qcosts_{ilk} * y_{ilk} - \sum_i \sum_l \sum_k ecosts_{ilk} * y'_{ilk} \leq q_i^* \qquad \forall(l,k)$$

The above constraint will examine the allocated budget so that the total residual cost of the primary and secondary risk does not exceed the budget amount. Compared to Zhao [16], our fundamental innovation is not leading to choosing a predetermined strategy. These are the following two constraints examining the two dimensions time and cost in response to primary and secondary risks as follows:

$$ecost_{ilk} + etime_{ilk} * ccrash_i \geq caction_{ilk} * y_{ilk} \qquad \forall(i,l,k)$$

$$ecosts_{ilk} + etimes_{ilk} * ccrash_i \geq cactions_{ilk} * y'_{ilk} \qquad \forall(i,l,k)$$

These two constraints will work so that if the benefit of responding to the primary and secondary strategy is greater than the cost of responding to the activity, then that strategy will be selected. If that response does not benefit, that strategy will not be selected.

Now, after this constraint, we have to examine the relationship between the two primary and secondary strategy variables, as follows:

$$y_{ilk} \geq y'_{ilk} \qquad \forall(i,l,k)$$

The above constraint indicates the dependence of the secondary risk on the primary one, which the secondary risk will not receive any value until the primary risk is effective.

Problem solving method

Because the research problem is from the category of NP-hard problems, meta-heuristic algorithms are used to solve numerical samples with medium and large dimensions, Figure 1.

In this study, according to the review of the research literature, genetic algorithm is used because it has a higher level of application compared to other algorithms in problem solving, which has a very high level of efficiency in solving various problems [17].

The result of the genetic algorithm in this study:

Here, the variables zero and one have a similar structural problem. Similarly, we will first design a chromosome related to the allocation of the strategy *k* to respond the primary risk *l* on activity *i*, which will be done in two steps, as follows, Table 1.

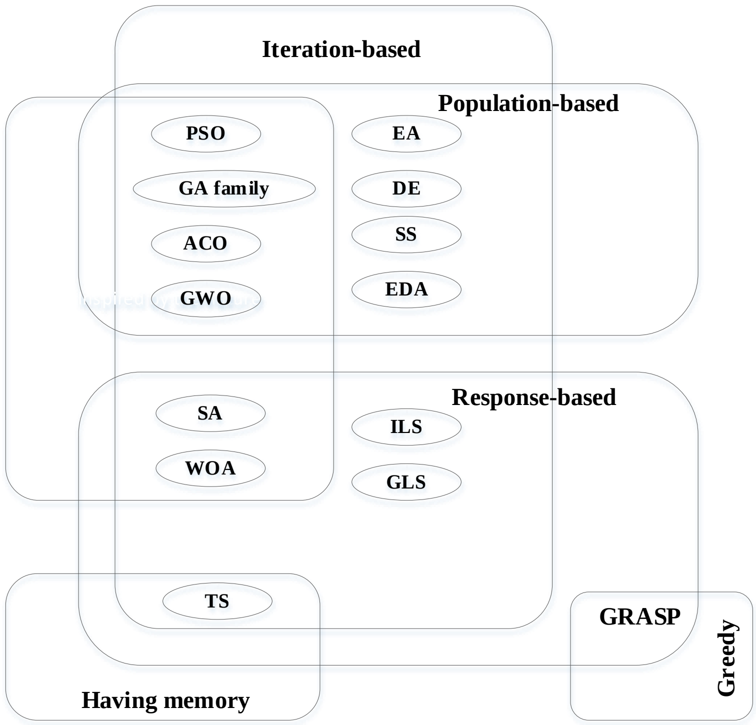

Figure 1. Classification of meta-heuristic algorithms based on design structure and the implementation way

Table 1. Allocating the primary risk to activities

Activity No.	D1	D2	D3	D4	D5
Risk No.	R1	R1	R1	R1	R1
Allocation	0	1	0	1	0

As it can be seen from Table 2, chromosome works in such a way that if it takes a value of one in each allocation, that primary risk will occur and now we have to assign the strategy to the resulting risks, as follows:

Table 2. Allocating strategy to risk

Activity No.	D1	D2				D3	D4				D5
Risk No.	R1	R1				R1	R1				R1
Strategy No.	0	K1	K2	K3	K4	0	K1	K2	K3	K4	0
	0		1	1		0		1	1		0

As observed, the secondary risk variable has the same function. Still, the failure rate variable of activity *I* will be a continuous chromosome from integers up to the allowable delay of activity. In this study, cross-over will be used as the main operator and mutation will be used as the second operator. The cross-over operator used is of two-point cut-off type. The mutation operator is also activated by selecting several chromosomes and changing their values.

After this step, the replacement operator is applied. The purpose of the replacement is to select the right parents in each generation to attend to the next generation. Here, the random sampling strategy without substitution is used for the replacement operation [18]. The following pseudo-code presents the genetic algorithm's structure used in the present study.

Input**: fitness function, max iteration, Population size, Crossover rate, Mutation rate* ***Output**: the elitist* *Initialize a population randomly* *Calculate the fitness of population and find elite* $t = 0$ ***While** $t \leq T$ **do *Perform crossover using two-point crossover operator* *Perform Mutation* *Carry out the replacement strategy and evaluate* *Calculate the fitness and return elite* $t = t + 1$ ***End*** *Final solution ← elite* ***End*** ***Return** Final Solutions*
Pseudo-code: Genetic algorithm

The numerical example description

A company active in importing and supplying facilities related to heavy equipment intends to plan transportation and installation of an 800-ton tower. To do this, they have to plan to carry out 19 different sets of activities so that the best possible conditions are available with the least possible risk. These activities are described in Table 3.

Table 3. Description of activities, risk and strategy of response to the primary risk

Row	Activity description	Normal time	Risk No.	Risk	Response strategy No.	Response strategy
1	Selecting a foreign carrier company	14	1	Prolonging the implementation time due to selecting an unsuitable contractor	1	Selecting bidders from valid lists
2	Shipping from the manufacturer site to the port of origin	3	2	Increase the implementation cost due to selecting an unsuitable contractor	2	Pre-evaluation of bidders
3	Loading the tower on the ship	4	3	Prolongation of the implementation time due to the long time of the procedures	3	Employing experienced manpower
4	Sea transportation	30	4	Increased implementation cost due to the long time of the procedures	4	Employing experienced manpower
5	Selection of land transportation contractor	14	5	Damage to equipment due to road accidents	5	Compilation of transparent and perfect tender documents
6	Unloading the tower from the ship at the destination tower	2	6	Damage to equipment due to maritime accidents	6	Holding question and answer sessions
7	Transportation of the tower from the port to the installation site workshop	7	7	Increased time due to atmospheric effects	7	Buying equipment transportation insurance
8	Selecting the installation contractor	14	8	Increased time due to breakdown of ship lifting equipment	8	Suitable lashing
9	Unloading the tower near the installation site	1	9	Damage to equipment due to breakdown of ship lifting equipment	9	Use of professional fleet for escort
10	Providing a Lifting Plan and obtaining its approval	7	10	Damage to equipment due to human error	10	Predicting the purchase or booking a required technology

11	Examination of human factor competency certificates	4	11	Increased time due to inadequate access roads	11	Buying all installation risk insurance
12	Examination of crane qualification and lifting tools certificates	6	12	Increased cost due to inadequate access roads	12	Holding critical operation maneuvers
13	Padding and making the necessary preparations on the surface of the foundation	4	13	Increased time due to time consuming process of obtaining approvals	-	-
14	Holding a briefing and coordination meeting in presence of those involved	1	14	The entrance of low-skilled people due to the poor evaluation of the monitoring team	-	-
15	Lifting operations and placing the tower on the foundation	1	15	Increased time due to the involvement of unqualified people at work	-	-
16	Making adjustments and dispositions	1	16	Increase cost due to the involvement of low-skilled people at work	-	-
17	Fastening the nuts and beads	1	17	Increased time due to human error	-	-
18	Obtaining approval for installation operations	1	18	Increased cost due to human error	-	-
19	Molding and grouting	2	19	Increased cost due to human error	-	-
-	-	-	20	Increased time due to equipment failure	-	-
-	-	-	21	Increased time due to inaccessibility to the technology	-	-
-	-	-	22	Increased cost due to inaccessibility to the technology	-	-
-	-	-	23	Equipment damage due to operational error	-	-
-	-	-	24	Damage due to lack of calibration of measuring equipment	-	-

But the implementation of each activity has its chronology, which can be drawn in the form of a node network. This network is based on the requirements of each activity to perform pre- and post-activities. Accordingly, the following figure can be drawn, Figure 2.

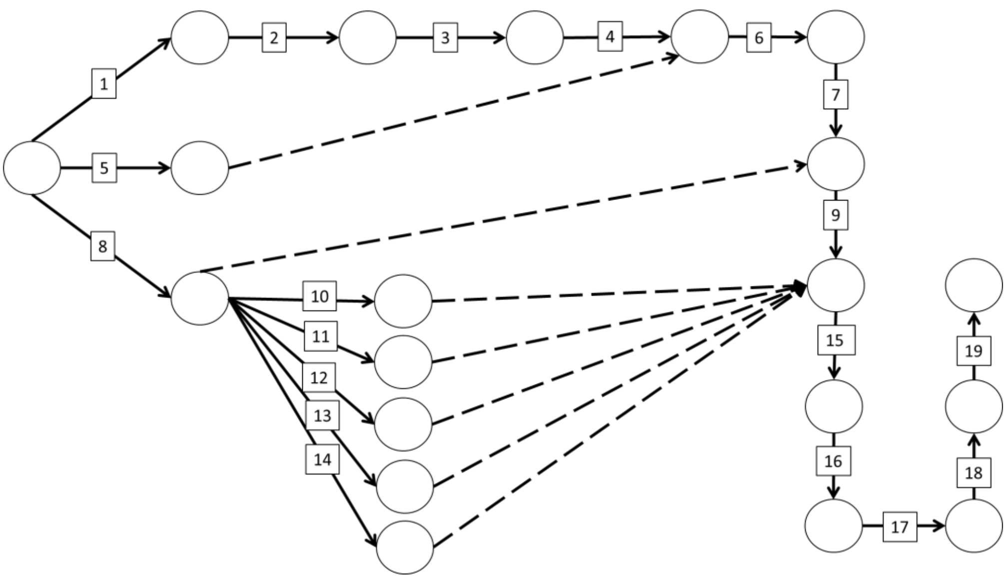

Figure 2. Network of transportation and installation activities of the 800-ton tower

We must first describe the values of the research parameters and then move on to the answers to the problem. To this end, we will first describe the time and cost impacts of risks on activities obtained through data collected from Nardis Co, Table 4.

Table 4. Time and cost effect intensities of activities that are affected by risk

Temporal effect	**Financial effect**	**Effect intensity (Time)**	**Effect intensity (currency)**	**Probability of risk occurrenc**	**Risk No.**	**Crash cost per day**	**Activity No.**
4	0	10	0	0.4	1	0.02	1
0	12	0	30	0.4	2		
7	0	14	0	0.5	3		
0	7	0	14	0.5	4		
4.5	5	90	100	0.05	5	0.08	2
0.15	0.25	3	5	0.05	7		
2.1	0	14	0	0.15	11		
0	1.5	0	10	0.15	12		
0.02	0	2	0	0.01	17		
0	0.02	0	2	0.01	18		
0.02	0	2	0	0.01	8	M	3
0.9	1	90	100	0.01	9		
0.1	0.1	10	10	0.01	10		
0.45	0.25	180	100	0.0025	6	0.1	4
1	0	5	0	0.2	7		
2.8	0	7	0	0.4	1	0.02	5
0	4	0	10	0.4	2		
3.5	0	7	0	0.5	3		
0	2.5	0	5	0.5	4		
0.14	0.03	14	3	0.01	8	0.07	6
1.1	1	110	100	0.01	9		
0.1	0.2	10	20	0.01	10		
0.8	0	4	0	0.2	13		
Temporal effect	**Financial effect**	**Effect intensity (Time)**	**Effect intensity (currency)**	**Probability of risk occurrenc**	**Risk No.**	**Crash cost per day**	**Activity No.**
4.5	5	90	100	0.05	5	0.05	7
0.15	0.25	3	5	0.05	7		
2.1	0	14	0	0.15	11		

0	1.5	0	10	0.15	12		
0.02	0	2	0	0.01	17		
0	0.02	0	2	0.01	18		
8	0	20	0	0.4	1	0.02	8
0	16	0	40	0.4	2		
7	0	14	0	0.5	3		
0	15	0	30	0.5	4		
0	0.3	0	1	0.3	14	M	9
0.4	0	2	0	0.2	15		
0	0.4	0	2	0.2	16		
0.02	0	2	0	0.01	17		
0	0.02	0	2	0.01	18		
0.01	0.02	1	2	0.01	19		
1.5	0.9	5	3	0.3	20		
0	2	0	20	0.1	21		
3	0	30	0	0.1	22		
0.2	0	2	0	0.1	17	0.03	10
0	0.2	0	2	0.1	18		
0.2	0	2	0	0.1	13		
0.2	0.4	2	4	0.1	14	0.02	11
0.5	0.7	5	7	0.1	19	0.04	12
0.01	0	1	0	0.01	17	0.05	13
0	0.01	0	1	0.01	18		
0	0					M	14
Temporal effect	**Financial effect**	**Effect intensity (Time)**	**Effect intensity (currency)**	**Probability of risk occurrenc**	**Risk No.**	**Crash cost per day**	**Activity No.**
2	1	10	5	0.2	20	M	15
4.5	5	90	100	0.05	23		
0	0					M	16
0.01	0	1	0	0.01	17	M	17
0	0.01	0	1	0.01	18		
0.02	0.02	1	1	0.02	24		
0.9	0.9	3	3	0.3	13	M	18
0.01	0	1	0	0.01	17	0.06	19
0	0.04	0	4	0.01	18		

It is not possible to use a specific strategy for each existing risk, so according to project managers' idea, some strategies are considered to deal with each of the existing risks, which are described in the table below, Table 5.

Table 5. Monetary benefit amounts when responding to the primary risk

Activity no.	Risk no.	RRS no.	RRS	Cost benefit of RRS to primary risk	Time benefit of RRS to primary risk	Cost of implementing the RRS
i	l	k		$ecosts_{ilk}$	$etime_{ilk}$	$cactions_{ilk}$
1	1	1	Selecting bidders out of qualified vendor lists	0.05	2	0.05
		2	Pre-evaluation of bidders	0.02	0.5	0.2
		3	Considering technical appraisal scores when determining the winner	1	0.5	1
	2	1	Selecting bidders out of qualified vendor lists	8	0	0.05
		2	Pre-evaluation of bidders	2	0	0.2
		3	Considering technical appraisal scores when determining the winner	1	0	1
	3	4	Employing experienced personnel	0.5	2	0.5
		5	Preparing clear and flawless tender documents	0.3	3	0.3
		6	Holding Q&A sessions	0.3	1	0.3
	4	4	Employing experienced personnel	2	0	0.5
		5	Preparing clear and flawless tender documents	5	0	0.3
		6	Holding Q&A sessions	1	0	0.3
2	5	7	Buying insurance coverage for equipment transport	4	0	1
		8	Suitable leaching	0.5	3	0.3
		9	Using professional fleet for escort	0.5	1	0.2
5	1	1	Selecting bidders out of qualified vendor lists	0.05	1.5	0.05
		2	Pre-evaluation of bidders	0.2	0.4	0.2
		3	Considering technical appraisal scores when determining the winner	1	0.5	1
	2	1	Selecting bidders out of qualified vendor lists	2.5	0	0.05
		2	Pre-evaluation of bidders	0.6	0	0.2
		3	Considering technical appraisal scores when determining the winner	0.3	0	0.5
	3	4	Employing experienced personnel	0.5	1	0.5
		5	Preparing clear and flawless tender documents	0.3	1.5	0.3
		6	Holding Q&A sessions	0.3	0.5	0.3
7	5	7	Buying insurance coverage for equipment transport	4	0	1
		8	Suitable leaching	0.5	3	0.3
		9	Using professional fleet for escort	0.5	1	0.2
8	1	1	Selecting bidders out of qualified vendor lists	0.05	4	0.05
		2	Pre-evaluation of bidders	0.2	2	0.2
		3	Considering technical appraisal scores when determining the winner	1	1	1
	2	1	Selecting bidders out of qualified vendor lists	12	0	0.05
		2	Pre-evaluation of bidders	3	0	0.2
		3	Considering technical appraisal scores when determining the winner	1	0	1
	3	4	Employing experienced personnel	0.5	2	0.5
		5	Preparing clear and flawless tender documents	0.3	3	0.3
		6	Holding Q&A sessions	0.3	1	0.3
	4	4	Employing experienced personnel	4	0	0.5
		5	Preparing clear and flawless tender documents	10	0	0.3
		6	Holding Q&A sessions	2	0	0.3
9	22	10	Purchasing or leasing the required technology	0.3	2	0.3
15	23	11	Buying insurance coverage for whole installation risk	3	0	0.6
		12	Holding sensitive operation maneuvers	0.5	3	0.1

While the primary risk response strategy, its financial, time and implementation cost are described in the table above, it should be noted that the action related to the primary risk response would create a secondary risk, which is effective on time, and cost is.

In doing so, the values of cost and time effect and secondary risk response strategy are specified in the table below, Table. 6.

Table 6. Time and cost effect values and temporal/monetary benefit values of secondary risk response

Activity no.	**Risk no.**	**RRS no.**	**RRS**	**Cost impact**	**Time impact**	**Cost of implementing the RRS**	**Cost benefit**	**Time benefit**
i	l	k		$qcosts_{ilk}$	$qtimes_{ilk}$	$cactions_{ilk}$	$ecosts_{ilk}$	$etimes_{ilk}$
1	2	1	SR1	5	2	0.5	4	1.5
1	4	4	SR2	2	1.5	0.5	2	5
8	2	1	SR3	4.5	2	0.01	4	1.5
8	4	4	SR4	5	0.4	SR4	5	0.4
9	22	10	SR5	2	0.2	0.05	5	0.1
1	2	1	SR1	5	2	0.5	4	1.5

As found in the research modeling, we must also specify the parameter values, which are described in the table below, Table 7.

Table 7. The rate of improvement in primary and secondary risk values

Total anticipated primary risk	**Optimal cost of primary risk**	**Improvement obtained upon responding to primary risk**	**Total anticipated secondary risk**	**Optimal cost of secondary risk**	**Improvement obtained upon responding to secondary risk**
84.540	29.090	55.45	8.50	3.060	5.44

The results of Table 7 show that the response to primary and secondary risk has reduced the risk by approximately 64%, which is a very good result for the model and can be examined at the management level of these results. Therefore, after determining the improvement rate of the model, it is necessary to determine the total cost of the system, which is shown in Table 8.

Table 8. All project costs

Primary risk cost	**Secondary risk cost**	**Crash cost**	**Total cost**
29.090	3.060	0.630	32.780

As it can be seen, the cost of primary and secondary risks is 29,090 and 3,060 monetary units, respectively. Finally, the cost of failure of activities is equal to 0.630 monetary units. Similarly, some strategies can be assigned to secondary risks applied to activities. In other words, the response strategies that cost more than the existing risk have been eliminated, indicating the high efficiency of the model.

Sensitivity analysis of the problem

In this section, since the sensitivity analysis should be performed on a parameter with a variable coefficient in the problem, we will first perform the sensitivity analysis on the amount of cost response to the primary strategy. The analysis is such that the response cost of the activities on which the risk is located will be changes as follows, Table 9.

Table 9. Values of cost and benefit of risk response before and after a change

After model change						**Before change**					
$ecost_{ilk}$			$caction_{ilk}$			$ecost_{ilk}$			$caction_{ilk}$		
k	l	i	k	l	i	k	l	i	k	l	i
9	5	2	8	5	2	9	5	2	8	5	2
6			1			2			0.3		
3	1	8	2	1	8	3	1	8	2	1	8
3			1			0.7			0.2		
12	23	15	11	23	15	12	23	15	11	23	15
4			0.5			3.5			0.6		

Given the values in the table above, we intend to see what effect it will have on the cost of the primary risk and the change in the assigned strategies, the results of which are shown in Table 10.

Table 10. Response strategy to the primary risk before changing the cost and benefit of the response strategy

Activity	**Risks**	**Strategy**											
		K1	**K2**	**K3**	**K4**	**K5**	**K6**	**K7**	**K8**	**K9**	**K10**	**K11**	**K12**
I1	R1	1	-	1									
I1	R2	1	1	1									
I1	R3				1	1	1						
I1	R4				1	1	1						1
I2	R5							1	1	1			
I7	R5							1	1				
I8	R1	1	1	1									
I8	R2	1	1	1									
I8	R4					1	1						
I9	R22										1		
I15	R23											1	

According to Table 11. after increasing the response cost, a change in the optimal allocation strategy occurred, indicating the model's correct operation**.**

Table 11. Response strategy to the primary risk after changing the cost and benefits values of the response strategy

activity	risks	strategy											
		K1	K2	K3	K4	K5	K6	K7	K8	K9	K10	K11	K12
I1	R1	1	-	1									
I1	R2	1	1	1									
I1	R3				1	1	1						
I1	R4				1	1	1						1
I2	R5							1	0	1			
I7	R5							1	1				
I8	R1	1	0	1									
I8	R2	1	1	1									
I8	R4					1	1						
I9	R22										1		
I15	R23											0	1

Results of meta-heuristic algorithm

More detailed numerical analyses will be applied to the results in this section. To compare the results, 9 numerical examples were randomly generated and then the results of solving the meta-heuristic algorithm and GAMS software were examine, Table 12**.**

Table 12. Results of the meta-heuristic algorithm

Example	**Dimension**			**GAMS Software**	**GA**	
	i	**l**	**k**	**Total cost**	**Total cost**	**Processing time**
Case study	19	24	12	32.780	32.780	14.8
2	40	48	20	250365	250,365	11.7
3	60	80	30	-	456,365	13.0
4	80	120	40	-	655.365	12.9
5	100	160	50	-	896.329	12.0
6	120	190	60	-	1234,456	11.9
7	140	200	70	-	2451.325	13.9
8	160	230	80	-	2675.315	11.6
9	180	250	90	-	3535.236	14.3
10	200	300	100	-	4562.320	14.9

The results of Table 12. show that by increasing the size of numerical examples, GAMS software can no longer solve the problem.

CONCLUSION

In this study, initially, 24 possible risks collected by experts were implemented on the activities of 800-ton tower and the first step was to implement strategies to respond to the primary risks. As identified in the results, primary risk costs were reduced from 84,540 to 29,090, and secondary risks were created in response to the primary risk, which imposed a cost of 8,500 units to the system. Still, with the allocation of secondary strategies, this cost was reduced to 3,060 units. In addition, the optimum activity failure cost was 0.630, but with the sensitivity analysis performed, the maximum time that the project could be completed was calculated to be 78 days, longer than which would reduce the activity failure cost to zero. The genetic metaheuristic algorithm was also used to solve the problem in above dimensions, which the results showed an acceptable performance of this algorithm in reducing the problem solving time.

Some suggestions for future research include:

- Using multi-criteria decision-making methods such as PROMETHEE, ELECTRE, etc., to rank and perform more accurate sensitivity analysis
- Applying the problem to other private and public companies dealing with risk management.
- To achieve and consider all dimensions of the problem more carefully and avoid conservative response by experts, future research is recommended to use a combination of interview and questionnaire in all stages, because more useful information can usually be obtained during the interview process due to two-way communication. It should be noted that in the present study, this method has been used only in the section of risk response strategies.

(Received October 2022, accepted November 2022)

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