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ORIGINAL STUDY

Evaluation of the Risk Factors Impacting the Cost Overruns in the Construction of Roads in Egypt During the COVID-19 Pandemic

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Abstract

Cost overruns are a common problem in the global construction industry, which affects the development of road construction, particularly in developing countries. Moreover, many risk factors in road construction might result in project cost overruns, particularly during COVID-19. So, the research aimed to look into the new risk variables' severity when a corona virus infection was present. The primary goal of the study is to identify the most important risk variables affecting the construction of roads in Egypt, especially during COVID-19 to lessen the likelihood and impact of those risks. The likelihood and effects of the identified risks were determined by conducting a questionnaire survey on a set of 11 risk categories made up of 162 risks. The study's findings also indicate that the excessive and illegal loads on the roads, the fluctuating value of the Egyptian pound, and the accruing interest on loans to the contractor as a result of the work interruption caused by the corona virus are the high-risk factors that have the greatest impact on cost overruns for road projects. In addition, the cost matrix has also been used to display risk factor levels as a road map for responding quickly to high risks.

Keywords: Cost overruns, Qualitative risk analysis, Risk breakdown structures, Road projects

1. Introduction

Cost overruns are a frequent issue in the world's construction sector, which has an impact on the growth of road construction, especially in emerging nations (Donaldson, 2018). Moreover, several road construction risk factors could cause project cost overruns, especially during COVID-19. As far as we know, no previous research has investigated the effect of the corona virus on the cost overruns in the construction of roads in Egypt. Therefore, a broad range of risk factors was examined in the study to demonstrate how severe its impacts were, particularly during COVID-19. In addition, risk breakdown structures [RBS] have separated the risk factors into eleven groups. The RBS in the study includes operational, equipment, and the effects of the corona virus, as well as contract, design, material, owner, labor, contractor, and consultant. The research methodology starts with a comprehensive literature review to provide a list of the main risk factors. A final risk factor list also includes the factors that experts added especially during COVID-19. Therefore, the primary goal of this article is to identify the most important risk variables affecting the construction of roads in Egypt, especially during COVID-19 to lessen the likelihood and impact of those risks. The likelihood and effects of the identified risks were determined by conducting a questionnaire survey on a set of 11 risk categories made up of 162 risks. The cost matrix has also been employed as a tool for displaying the levels of risk factors, and as a result, it may be utilized to develop a road map for generating speedy responses for high risks.

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2. Literature review

Cost overruns are seen as an event or disturbance that pushes the project's cost over the budget. It may also result in estimates of time and cost that are incorrect. It can also be brought on by the absence of a thorough strategy to risk management. Project risk management refers to the procedures used in risk management planning, identification, analysis, responses, and project monitoring and control (Project Management, 2017). And, the goal of project risk management [RM] is to identify and prioritize risks that are likely to take place, focus on providing guidelines for risk response, and direct and manage project risks by raising the possibility and impact of the occurrence of favorable events (opportunities) and reducing the likelihood and impact of the occurrence of unfavorable events (threats) to the project (Borge, 2002). However, several projects are not prepared to manage risk because most firms' current project management methods do not take into account the expanding demands for risk management (Smith et al., 2014). There are several severe constraints to risk management methods used in project management. These constraints contain: A) the amount of time needed to use risk management techniques; B) Collecting input estimations and evaluating likelihood might be difficult; C) Organizational and individual reluctance to change D) inability to comprehend and evaluate results of risk management methods (Leung et al., 1998). The risk breakdown structures (RBS) can be used as a checklist to ensure that all risk sources are covered during risk identification, which speeds up the process. The RBS also offers a categorization of the discovered risks according to their sources, enabling the project team to give some risk sources more focus than others as they are more frequent in the project.

The size of the project, the expansion of the project's scope, inflation, the amount of time required to finish the project, the incompleteness of initial engineering and quantity surveys, external delays, the complexity of administrative structures, and the lack of management staff experience are the causes that lead to cost escalation. Also, the factors that contribute to cost escalation are project location, project specifics, environmental mitigation costs, work halts, strikes, bid expiration, stress from the local government, and political turbulence (Schexnayder et al., 2003). Mansfield showed that ineffective contract management, poor planning, faulty estimating, and general price fluctuations are the main causes of cost escalation (Mansfield et al., 1994).

Cost overruns affect the development of road construction, particularly in developing countries. Moreover, many risk factors in road construction might result in project cost overruns. Cost overruns can happen for a variety of reasons on different kinds of projects. If project costs end up being higher than anticipated, the funding profile would no longer be compatible with the demands of the budget. The consequences would be negative, especially for developing nations whose prosperity is measured in large part by how well they succeed in providing infrastructure through the construction industry, particularly on road construction projects, which make up a significant portion of the business (Kaliba et al., 2009). Most developing economies also deal with this issue; it does not only affect wealthy nations (Ahmed et al., 2002). Cost escalation is the phrase used to describe the increase in the sum of money needed to build a road project above and beyond the initially planned amount. Cost escalation happens when real expenses are higher than originally anticipated values. Schexnayder looked at some of the factors that contribute to cost growth and divided them into two categories: Uncontrollable and restraining factors (Schexnayder et al., 2003). Other investigations determined that issues including delays in land acquisition, unanticipated difficulties with the supply of raw materials, and illegal encroachment on land even during project implementation were to blame for the cost (Datta, 2002; Flyvbjerg et al., 2002).

To give stakeholders tools for risk identification, many researchers studied the factors that contribute to risks in the construction sector. Ehsan and Mirza illustrated risk factors common to the construction business, including time pressure, resource availability, history, design complexity, experience, management stability, and team size. Ehsan and Mirza categorize construction risks into technical, logistical, management, environmental, financial, and sociopolitical categories (Ehsan et al., 2010). On the other hand, technical, logistical, management, environmental, economic, social, and political risks were categorized as construction risks by Ehsan and Mirza (Tang et al., 2007). Yasser and Mostafa used fault tree analysis to pinpoint the primary factor causing building project delays (Gamal and Abd Elrazek, 2020). Additionally, inefficiencies in risk management lead to schedule and expense overruns (Raftery, 2003). Numerous studies have concentrated on creating approaches that take the effects of uncertainty on project cost overruns into account (Ammar et al., 2022; Leu et al., 2023; Osama et al., 2023; Vivek and Rao, 2022).

The primary goal of the study is to identify the most important risk variables affecting the construction of roads in Egypt, especially during COVID-19 to lessen the likelihood and impact of those risks. Therefore, the study has created a framework that will enable organizations to take the following actions in order to manage the risk factors that lead to cost overruns in Egyptian road projects: A framework contain: stage I: risk identification, stage II: risk assessment (evaluate risk factors in road construction projects and identify the biggest ones); Thorough involved literature review on risk management in relation to roads conducted in order to develop a questionnaire. Additionally, this list was expanded with the help of experts to include all potential risk factors for road construction projects. Also, it outlines the risks by surveying a panel of experts from various construction sectors using a questionnaire. Furthermore, Fig. 1 depicts the process of risk analysis for the attributes that affect the construction of roads in Egypt. The qualitative risk analysis was used to identify the high-risk factors for each category, followed by the cost matrix was employed to establish the different levels of risk for each category. After that, a risk response plan has been identified as an appropriate action for high-risk factors. Moreover, different scenarios have been chosen as a strategy for figuring out the best action for risks.

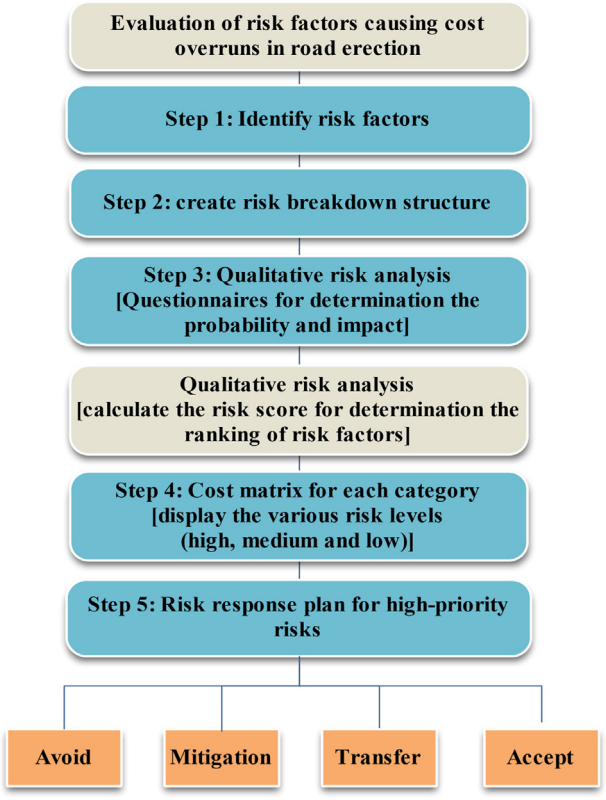

Fig. 1. Flow chart for the process of the risk analysis.

3. Research methodology

The suggested study analyses each identified risk and uses interviews and pre-structured questionnaires on a set of 11 risk categories made up of 162 risks to elicit the specific risk with as much expert opinion as possible. The cost matrix has also been employed as a tool for displaying the levels of risk factors, and as a result, it may be utilized to develop a road map for generating speedy responses for high risks. This can be done by taking the following actions.

(1) The research technique begins with a thorough literature analysis to give a prime risk factors list. This list was then supplemented with experience to produce a final risk factor list that encompasses all potential risks during road building.
(2) A brainstorming-directed questionnaire has been used to solicit the most prevalent risks facing road projects in Egypt. The impacts of each risk and its likelihood have been suggested by experts.
(3) The risk factors (RF) can be divided into several categories based on their attributes and kind. As a result, it can create RBS, which is a component of the risk management plan. A stratified classification of risks and the establishment of a nomenclature for characterizing project risks are based on the hierarchical risk breakdown structure that has been created. With the use of the HRBS, risks can be divided into those that are concerned with the control of the sources of risk factors.
(4) Finding the mean after obtaining the total probabilities for each risk from the questionnaires has been employed to calculate the value of probability. Additionally, the same approach can be used to determine the impact.
(5) Prioritizing identified risks based on risk score estimations created by calculating the cost impact and evaluating the probability of occurrence.
(6) Examining the prospective responses offered by experts to risks and selecting the most appropriate response even as a corrective or preventive action.

Moreover, the risk category is included in the risk management plan. Whereas, the risk can be categorized using the risk breakdown structure (RBS) based on its attributes. As well, it displays a hierarchical chart that divides the project risks into higher-level and lower-level groups. As a result, the

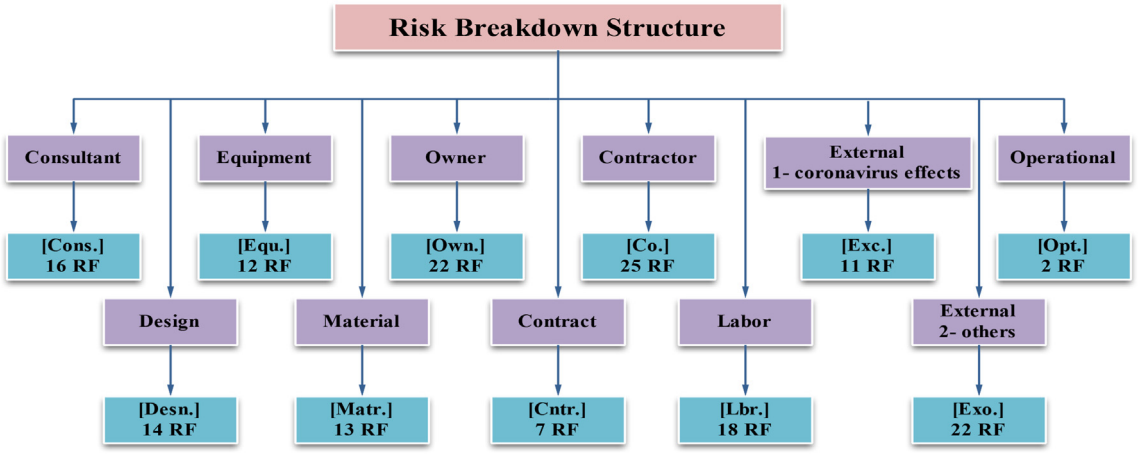

Fig. 2. Risk breakdown structure [RBS].

study divided the risks related to Egyptian road construction into eleven groups. These groups contain consultant, design, equipment, material, owner, contract, contractor, labor, external (corona virus effects), external (others), and operational. This phase is useful for figuring out the total risk factors (RF) associated with road projects. And, it has been created before risk identification. The risk of breakdown structure has been shown in Fig. 2.

They perform qualitative risk analysis process analyses and prioritize project risks based on the characteristics of each individually identified risk. The perform qualitative risk analysis process examines and ranks the characteristics of individual risks before prioritizing them according to those characteristics (Guide, 2001). Its objective is to rate and categorize the identified risks according to their impact (I) and probability of occurrence (P) to conduct a further study or take appropriate action. Consequently, high-priority risks in terms of threats are thought to be a key emphasis of the plan risk response process. Also, the following steps ought to be part of the analytical process: A subjective risk probability (P) value has been created using a scale from 0 to 1. In addition to producing a risk impact (I) on a scale, the standard impact evaluation approach for cost impacts is also produced, as illustrated in Table 1. Finding the mean after obtaining the total probabilities for each risk from the questionnaires has been employed to calculate the value of probability. Additionally, the same approach can be used to determine the impact. To get the risk score (RS), multiply the probability (P) by the impact (I). Following the risk score values assigned to each risk, risks are ranked and prioritized (RR). Using the likelihood and impact matrix presented in Table 2 (Guide, 2001), the risk factors have been categorized into high (H), moderate (M), and low (L) risks. The selection of high and moderate risks follows to get a response action.

Table 2. Probability and impact matrix (Guide, 2001).

P	Probability and Impact Matrix				
0.90	0.05	0.09	0.18	0.36	0.72
0.70	0.04	0.07	0.14	0.28	0.56
0.50	0.03	0.05	0.10	0.20	0.40
0.30	0.02	0.03	0.06	0.12	0.24
0.1	0.01	0.01	0.02	0.04	0.08
I	Very low/0.05	Low/0.10	Moderate/0.20	High/0.40	Very high/0.80

4. Data collection

Making a sample questionnaire is the first step in the data collection and questionnaire design procedures. A pilot study was carried out on Egyptian

Table 1. Standard of risk impact (Guide, 2001).

Impact scales					
Relative scales (numerical)					
Project Objectives	Very low/0.05	Low/0.10	Moderate/0.20	High/0.40	Very high/0.80
Probability scales					
	Very low/0.1	Low/0.30	Moderate/0.50	High/0.70	Very high/0.90
Cost	Insignificant cost increase	>5% Cost increase	5–10% Cost increase	10–20% Cost increase	<20% Cost increase

construction companies using an interview and a questionnaire to determine the risks contributing to cost overruns in the construction of the road projects in Egypt, especially during COVID-19. For this study, different factors have been used in choosing respondents, like the number of experience years [above 15: 15%, between 11 and 15: 15%, between 5 and 10: 58.33%, under 5 experience years: 11.67%]. Additionally, the respondents were chosen from a variety of work types to obtain realistic responses to the risk factors associated with Egypt's road construction projects. Where, they were represented (28.33% owners, 58.33% contractors, and 13.33% owners). In addition, the total number of responders who contributed to the study is sixteen practitioners. Consequently, a wide range of construction professionals is included. In the pilot survey, every question was based on an interview. A skilled interviewer interacts with the participants and offers definitions as needed to help with questionnaire responses. The following categories of responders were created based on the role of the companies (consultant, contractor and owner). The study made an effort to include the majority of the experience spectrum, from junior to expert. The information was received from 60 experts [see Fig. 3]. Furthermore, 162 risk factors are broken down into eleven primary categories. Also, Tables 3–13 breaks down each group into many risk factors. Compute risk ranking concerning category (RRC) and risk ranking for total risk factors (RRT).

5. Reliability analysis

The random sample was determined using Eq. (1) by (Hogg et al., 2009) in order to obtain a demonstration sample of the targeted participants. Where (n) refers to a limited sample size, (m) to an unlimited population sample size, and (N) to the largest population sample size that is currently available.

$$n = \frac{m}{1 + \left(\frac{m-1}{N}\right)} \qquad \text{Eq(1)}$$

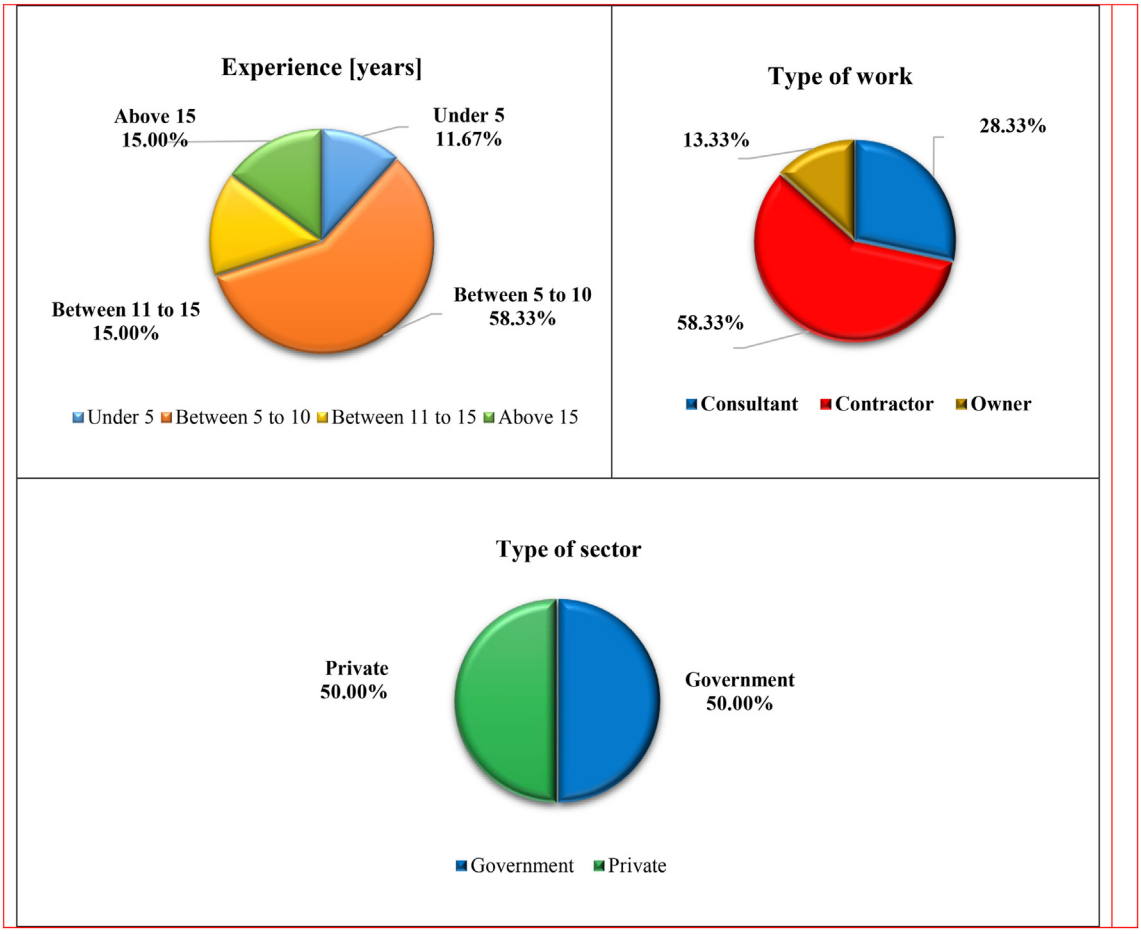

Fig. 3. Responder's type.

Table 3. Analysis of risk factors (Consultant).

Risk Code	Risk Factor	*P*	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Consultant		TRS = 0.091							
Cons. 1	The owner's meddling with the consultant's decisions	0.451	0.215	0.097	Moderate	3	92	MIT.	Determine the roles and responsibilities in the contract conditions.
Cons. 2	Conflicts between the designer and the consultant	0.375	0.205	0.077	Moderate	4	122	MIT.	Organize a periodic meeting for design work between the consultant and designer.
Cons. 3	The contractor's tardiness in responding to questions	0.318	0.201	0.064	Moderate	10	143	AV.	It should include the duration cycle of the submittal process of correspondence in the contract conditions.
Cons. 4	The oversight team's lack of experience	0.431	0.250	0.108	Moderate	1	75	MIT.	Contract with a company that has experience in these types of work.
Cons. 5	rigidity in supervision	0.438	0.243	0.106	Moderate	2	80	MIT.	Determine the details of specifications as a part of the contract
Cons. 6	System weaknesses in the consultant office's documentation	0.358	0.193	0.069	Moderate	9	133	AV.	Using Document Control Center [DCC]
Cons. 7	Lack of Quality Control/Assurance	0.280	0.210	0.059	Low	13	149		
Cons. 8	The oversight team is only present temporarily on the project	0.210	0.169	0.035	Low	16	162		
Cons. 9	Disregard for the project timetable and failure to follow it	0.305	0.196	0.060	Low	12	147		
Cons. 10	Delay in the approval of amendments while the work is being done	0.321	0.228	0.073	Moderate	5	127	AV.	Determine the duration cycle for approval of change orders in contract conditions.
Cons. 11	Taking too long to examine and approve the design documentation	0.319	0.227	0.072	Moderate	6	128	AV.	It should include the duration cycle of the submittal process of design documentation in the contract conditions
Cons. 12	The design documents are being examined and approved too slowly	0.291	0.246	0.072	Moderate	7	129	AV.	It should include the duration cycle of the submittal process of design documentation in the contract conditions
Cons. 13	Taking too long to approve the material samples	0.272	0.229	0.062	Moderate	11	145	AV.	It should include the duration cycle of the submittal process for approving the material samples in the contract
Cons. 14	Incorrect or insufficient soil assessment	0.257	0.279	0.072	Moderate	8	130	MIT.	Soil confirmation probes should be executed before starting the work.
Cons. 15	The schedule is not being updated regularly	0.319	0.177	0.056	Low	14	154		
Cons. 16	Lack of a date given in the notice to proceed	0.280	0.160	0.045	Low	15	160		

Due to the lack of specific information or data regarding the owners, contractors, consultants, managers, and site engineers of road construction companies, the owner, contractors, and consulting firms are chosen. Hence, 600 specialists from various companies are the estimated total number of experts. Equation No. (2) is used to calculate the m value, and Z is the statistical value used to represent the used confidence level. Z can be different according to the level of confidence, where Z is equal to 1.645, which represents a 90% confidence level. It can be 1.96, which represents a 95%

Table 4. Analysis of risk factors (Design).

Risk Code	Risk Factor	*P*	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Design		TRS = 0.099							
Desn. 1	Lack of comprehension of the owner's expectations	0.291	0.275	0.080	Moderate	10	117	MIT.	Organize meetings between owners, consultants, contractors, and designers at the early stages.
Desn. 2	The owner's constant meddling can lead to changes in the designer's choices	0.480	0.325	0.156	Moderate	2	17	MIT.	Organize meetings between owners, consultants, contractors, and designers at the early stages.
Desn. 3	Lack of topographic survey and information-gathering processes	0.351	0.290	0.102	Moderate	6	88	AV.	Hire specialists to do a topographic survey
Desn. 4	The length of time to approve the design for the hydrological studies (the discharge of rainwater and torrential rain)	0.318	0.223	0.071	Moderate	12	131	MIT.	It should include the duration cycle of the submittal process of design documentation in the contract conditions
Desn. 5	The delaying of the design documents	0.332	0.175	0.058	Low	14	151		
Desn. 6	Taking a long time to respond to the contractor's queries	0.316	0.188	0.059	Low	13	148		
Desn. 7	The drawings' specifics are not clear.	0.362	0.226	0.082	Moderate	9	115	MIT.	The specifications of the design drawings should be involved in the design documentation.
Desn. 8	Constructability analysis is not present.	0.365	0.247	0.090	Moderate	8	100	AV.	Constructability analysis should be involved as a document before starting the work.
Desn. 9	The start and end dates of the design are not included in the timetable.	0.372	0.207	0.077	Moderate	11	123	AV.	The start and end dates of the design should be included in the schedule.
Desn. 10	Designs that do not take the effects of natural factors like floods and rain into account	0.371	0.302	0.112	Moderate	4	69	AV.	The effects of the environmental conditions should be included in the design.
Desn. 11	At the start of the project, the design is not complete.	0.519	0.293	0.152	Moderate	3	18	AV.	Ending the design early before starting the executions
Desn. 12	Conflicts between the specification and the drawing	0.337	0.279	0.094	Moderate	7	94	MIT.	The specification should be involved as a part of contract documentation
Desn. 13	Improper design (such as not taking into account the type of quarries in the region, which led to the contractor's inability to deliver the necessary materials, etc.)	0.426	0.369	0.157	Moderate	1	16	MIT.	Before execution of the works, site visits should occur to check the conditions of the site [types of materials, quarries …].
Desn. 14	The obstacles to road implementation are due to different reasons such as [the numerous accidents on the roads being developed if alternative routes are not designed to carry traffic on them during the implementation process].	0.437	0.237	0.103	Moderate	5	85	AV.	Alternative routes should be a part of the design requirements.

confidence level. On the other hand, the values of Z can reach 2.575 to represent a high confidence level with a percentage of 99%. P represented the calculated population proportion, while (e) represented the point estimate sampling error.

$$m = \frac{z^2 x\, P\, x\, (1-P)}{e^2} \qquad \text{Eq(2)}$$

To acquire the necessary sample size (Sincich et al., 2001), proposed using 0.50 as a cautious

Table 5. Analysis of risk factors (Equipment).

Risk Code	Risk Factor	*P*	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Equipment		TRS = 0.124							
Equ. 1	Lack of spare parts and frequent equipment failures	0.442	0.306	0.135	Moderate	5	35	MIT.	The daily inspection report should be submitted periodically to project managers to keep them informed of the condition of the equipment to take quick actions for fixing the equipment
Equ. 2	Low equipment productivity and efficiency	0.431	0.285	0.123	Moderate	7	53	MIT.	An inspection report for equipment that arrives on site should be introduced to measure the efficiency of the equipment.
Equ. 3	Delays in equipment repair	0.477	0.306	0.146	Moderate	3	29	MIT.	Daily inspection report for stand-up the conditions of equipment and assign the maintenance crews on site to fix any equipment if required.
Equ. 4	The company doesn't investigate the technical state of the equipment or its suitable distribution following work requirements.	0.453	0.274	0.124	Moderate	6	50	MIT.	An inspection report for equipment that arrives on site should be introduced to measure the efficiency of the equipment.
Equ. 5	Insufficient equipment	0.467	0.292	0.136	Moderate	4	34	MIT.	Contract with equipment company for hiring the needs of the project from equipment
Equ. 6	Moving equipment can be difficult, whether it's to locations for routine maintenance or to work on another area of the project.	0.420	0.245	0.103	Moderate	10	86	MIT.	Provide a means for quickly transporting the equipment.
Equ. 7	The carelessness in obtaining or renewing the equipment's license	0.397	0.216	0.086	Moderate	12	106	MIT.	The situation of the equipment licenses should be mentioned in the maintenance report for renewing the equipment licenses.
Equ. 8	A lack of modern mechanical equipment	0.520	0.283	0.147	Moderate	2	24	MIT.	Hire modern equipment to increase productivity.
Equ. 9	The site of the asphalt mixer and the crushers are far apart from the project.	0.372	0.320	0.119	Moderate	8	58	MIT.	Providing highly efficient trucks
Equ. 10	Lack of technical and engineering expertise in asphalt mixers and crushers	0.401	0.251	0.101	Moderate	11	89	MIT.	Hire specialists
Equ. 11	Equipment distribution issue	0.442	0.236	0.104	Moderate	9	84	MIT.	The project manager should monitor and control the distribution of crews on the road path according to the approved schedule.
Equ. 12	Using outdated equipment with low productivity rates and neglecting routine maintenance on this equipment	0.509	0.329	0.168	Moderate	1	12	MIT.	An inspection report for equipment that arrives on site should be introduced to measure the efficiency of the equipment.

estimate for P. Z is equal to (1.645) at the 90% level of confidence, and the m infinite sample size is roughly equivalent to:

$$m = \frac{(1.645^2)x0.5x(1-0.5)}{0.1^2} = 67.65$$

Table 6. Analysis of risk factors (Material).

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Material		TRS = 0.114							
Matr. 1	Vendor materials don't adhere to the requirements	0.419	0.359	0.150	Moderate	2	20	AV.	The inspection of the samples of the materials should be done before the execution.
Matr. 2	inadequate vendors	0.347	0.270	0.094	Moderate	10	97	MIT.	The procurement department inside the organization should expand the vendor list by evaluating others.
Matr. 3	The damage to materials	0.284	0.275	0.078	Moderate	12	121	MIT.	Procedures for storing the materials should be included in the quality plan. And, the project should follow up on all instructions to maintain the materials from damage.
Matr. 4	Taking too long to prepare the material request	0.342	0.220	0.075	Moderate	13	125	MIT.	The design should be early to reduce the time for calculating the quantity. And, the creation of quantity survey teams should be at the beginning of the project to expedite the calculation of quantity and hence submit the material order.
Matr. 5	changes made to the specs and types of materials during construction	0.382	0.303	0.116	Moderate	6	62	MIT.	The specification and the design should be submitted early in the project.
Matr. 6	Increased costs for materials	0.533	0.380	0.202	High	1	5	ACC.	Accept [Contingency reserve]
Matr. 7	Inadequate methods for obtaining construction materials	0.404	0.306	0.124	Moderate	4	52	MIT.	creation of the construction methods as a part of the studies of the project
Matr. 8	Low-quality materials	0.371	0.259	0.096	Moderate	9	93	MIT.	Inspection report for the materials
Matr. 9	shortage of production of the base layer or other asphalt-related elements	0.405	0.282	0.114	Moderate	7	65	MIT.	Agreement with the subcontractor to supply the required quantity
Matr. 10	Due to the project's distance from the fabrication and supply area, it is challenging to deliver supplies to the working area.	0.406	0.330	0.134	Moderate	3	37	MIT.	Provide a means for quickly transporting the fabrication materials.
Matr. 11	The existence of mud in the quarries and the lack to adopt effective mud removal techniques	0.357	0.337	0.120	Moderate	5	57	MIT.	Quality control work to prevent the mud and the project manager returns the matter to the designer to re-design according to the surrounding conditions
Matr. 12	The inadequacies of the quality assurance	0.351	0.225	0.079	Moderate	11	118	MIT.	Hire a quality assurance specialist for the project to perform an audit periodically on the project.
Matr. 13	Asphalt leaching may occur if the RC3000 or MCO adhesive is improperly impregnated, there is a high bitumen content in the mixture, or the air is too hot.	0.357	0.286	0.102	Moderate	8	87	MIT.	The experimental tests should be created to confirm the validity.

Table 7. Analysis of risk factors (Owner).

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Owner				TRS = 0.089					
Own. 1	The owner's financial situation is precarious.	0.260	0.259	0.067	Moderate	16	136	AV.	The contract should be mentioned the progress payment procedures and determine the steps in case of delaying the invoice payment.
Own. 2	The progress payment delay	0.412	0.257	0.106	Moderate	8	81	AV.	The contract should be mentioned the progress payment procedures and determine the steps in case of delaying the invoice payment.
Own. 3	There aren't any incentives for the contractor to finish earlier.	0.353	0.167	0.059	Low	19	150		
Own. 4	Choosing the contractor with the lowest bid regardless of whether they have the skills necessary to execute the project on schedule and to the acceptable standard	0.509	0.280	0.142	Moderate	2	30	MIT.	The organization's policy should be to increase the percentage of technical experience for awarding the tender.
Own. 5	The timeline is not reasonable in light of the contract's requirements.	0.424	0.207	0.088	Moderate	10	103	MIT.	Organize meetings periodically with contractors to provide all requirements and measure the progress of the project.
Own. 6	Ineffective delay penalties	0.277	0.194	0.054	Low	21	156		
Own. 7	Lack of strict adherence to the contract terms by the owner	0.289	0.235	0.068	Moderate	14	134	MIT.	Increasing the penalty values to commit to the terms of a contract
Own. 8	Increasing the amount of work being executed because there weren't enough studies done before beginning the project	0.337	0.297	0.100	Moderate	9	90	MIT.	The study of the project should take time during the project life cycle and should be involved as a part of the schedule.
Own. 9	Increased changes to project plans throughout implementation as a result of the study's flaws	0.446	0.327	0.146	Moderate	1	28	MIT.	The studies of the project should be introduced early in the project to mitigate changes in the project.
Own. 10	Project managers change frequently	0.330	0.172	0.057	Low	20	153		
Own. 11	Many requests for changes from the owner during the execution	0.424	0.305	0.129	Moderate	4	46	MIT.	The studies of the project should be introduced early in the project to mitigate changes in the project.
Own. 12	Scope creep refers to the addition of things or works that are not specified in the contract.	0.430	0.309	0.133	Moderate	3	38	AV.	Contract terms should prevent scope creep.
Own. 13	The owner and other partners don't communicate well enough	0.263	0.203	0.053	Low	22	157		

(*continued on next page*)

Table 7. (continued)

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Own. 14	The difficulty in resolving the dispute between the execution groups	0.280	0.227	0.063	Moderate	17	144	MIT.	Organize meetings between all partners
Own. 15	Decision-making taking too long	0.299	0.226	0.068	Moderate	15	135	MIT.	Organize meetings between all partners to expedite the decision-making and use the multi-criteria decision software to reduce the time spent choosing the best solutions.
Own. 16	Owner's lack of ability to lead	0.338	0.244	0.082	Moderate	11	112	MIT.	The PMO [project management office] in the organization can interfere in the decision in case of a weakness in the owner's ability to manage the project.
Own. 17	Excessive bureaucracy in project management and imposition of the owner's viewpoint	0.453	0.240	0.109	Moderate	7	72	MIT.	Change the decision-making process inside the organization to reduce excessive bureaucracy in the project.
Own. 18	Bias or unjust treatment practices between the owner's executing companies	0.386	0.211	0.081	Moderate	12	116	MIT.	Organize meetings between all partners
Own. 19	Weakness in overcoming the challenges faced by the executing company, such as the challenge of providing bitumen when payments are late	0.426	0.265	0.113	Moderate	5	67	MIT.	Reducing the procedures for payment to expedite the execution of work
Own. 20	Owner's weak point in terms of supervision	0.346	0.174	0.060	Moderate	18	146	MIT.	Contract with the consultant office to perform the supervision duties.
Own. 21	Owner delaying the delivery of documents (design-correspondence, etc.)	0.420	0.267	0.112	Moderate	6	68	MIT.	It should include the duration cycle of the submittal process of documentation in the contract conditions
Own. 22	Delay in handing over the site without hindering	0.331	0.238	0.079	Moderate	13	119	MIT.	A site visit should be done before starting the work to determine the obstacles before handover.

$$n = \frac{67.65}{1 + \left(\frac{67.65-1}{600}\right)} \approx 60$$

The above equation indicates that the required minimum sample size is (60).

6. Total risk score

The risk rating (RR) has been established using the risk score (RS). However, the total risk score (TRS) for each primary risk category has been determined as the total of all risk scores for that category divided by the number (n) of risk factors in each category. In descending order, the following risk categories were given the highest priority: operational, external (corona virus effects), external (others), contract, equipment, material, contractor, design, owner, labor, and consultant, with TRS of 0.212, 0.147, 0.139, 0.125, 0.124, 0.114, 0.103, 0.099, 0.089, 0.082, and 0.070, respectively, as shown in Fig. 4. In conclusion, the biggest influences on cost overruns of road projects are operational risk and external risk brought on by the impact of the corona virus.

Therefore, the following are the high-risk factors that impact the project cost: Excessive and illegal

Table 8. Analysis of risk factors (Contract).

Risk Code	Risk Factor	*P*	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Contract		TRS = 0.125							
Cntr. 1	Reducing the severity of the contractor's penalties for contract violations.	0.286	0.226	0.065	Moderate	7	141	MIT.	Increasing the penalty values in the terms of a contract, furthermore, the restriction must be added in the conditions to carry out all the required tasks
Cntr. 2	Weakness of the price difference equation (unfairness of price differences)	0.335	0.255	0.085	Moderate	6	107	MIT.	Adjust the equation of changing prices to the market conditions.
Cntr. 3	Requesting more work outside the project's scope	0.459	0.343	0.157	Moderate	2	15	MIT.	The contract should adjust the limitation of increasing the quantities to prevent scope creep.
Cntr. 4	Modifications to contract quantity	0.477	0.349	0.167	Moderate	1	13	MIT.	The contract should adjust the limitation of increasing the quantities to prevent scope creep.
Cntr. 5	Without knowing the costs and quantities of the items, the contractor is first assigned to complete the work.	0.467	0.315	0.147	Moderate	3	27	MIT.	The studies of the project should be sufficient before execution.
Cntr. 6	Forcing the contractor to carry out terms that are more than 125 percent of the contract	0.419	0.291	0.122	Moderate	5	55	AV.	Contract terms should prevent that.
Cntr. 7	Delayed payment to subcontractors for price disparities	0.514	0.263	0.135	Moderate	4	36	AV.	Contract terms should prevent that.

loads on the roadways being used [RR = 1], Float Egyptian currency [RR = 2], Accruing interest on loans to the contractor as a result of the Corona pandemic work interruption [RR = 3], The inflation rate and how it affects price increases [RR = 4], Increased costs for materials [RR = 5], Due to the shutdown, supplies have been delayed and stopped [RR = 6], Increasing taxation [RR = 7], Pipeline, electrical, and instrumentation cables interfering with the paths of the roads [RR = 8], Difficulty getting money from banks in foreign currencies to pay for products that are unavailable in Egypt [RR = 9], The modification of the lending financial strategy [RR = 10].

7. Risk response plan

The goal of the risk response planning phase is to provide choices and specify appropriate measures to address threats, reduce them, and explore opportunities while taking into account the importance of individual and global risks to the project. An overview of the risk response strategies created for the project risks, as well as the monitoring and control of the identified risks, are shown in Tables 3–13. The low risks are ignored and the total number of low risks is 16 risk. Only high and moderate risks are expected to necessitate a response, and each risk should have a solution to maximize risk response efforts. Threats can be handled in four different ways; Avoidance (AV.): removing the threat by removing its source; mitigation (MIT.): lowering the risk score by minimizing its likelihood of happening and/or effect; transference (TR.): transferring the risk package to a different party by subcontracting or purchasing insurance who is better equipped to manage the risk; Acceptance (ACC.): applying contingency reserves Tables 3–13 demonstrates that the project management team prepared the appropriate risk responses in some circumstances to guard against the likelihood of a delay in the initial risk response or an unexpected outcome. As a result, 20 avoidance strategies, 89 mitigation plans, 2 transference plans, and 35 acceptance plans were created.

8. Cost matrix

Cost matrices can be used to display the various risk levels (high, medium, and low). As illustrated in

Table 9. Analysis of risk factors (Contractor).

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Contractor		TRS = 0.103							
Co. 1	Difficulties with the contractor's financial funding	0.513	0.293	0.150	Moderate	1	19	MIT.	Studying the situation of the finances for the contractors as a part of the tendering documents.
Co. 2	Lack of managerial ability	0.414	0.299	0.124	Moderate	4	51	MIT.	The PMO [project management office] in the organization can interfere in the decision in case of a weakness in the owner's ability to manage the project.
Co. 3	Contractor experience is insufficient	0.395	0.308	0.122	Moderate	5	54	MIT.	Requirements for tendering should add the previous experience of the contractors.
Co. 4	Contractors' incorrect price to win the bid	0.359	0.306	0.110	Moderate	9	70	MIT.	Studying the cost baseline from the owner to confirm that the contractor can achieve the project
Co. 5	Contractor's breach of contract	0.359	0.229	0.082	Moderate	21	113	MIT.	Increasing the penalty values in the terms of a contract
Co. 6	Technical personnel shortage	0.394	0.266	0.105	Moderate	14	82	MIT.	Hire specialists
Co. 7	Project management offices (PMO) are absent	0.517	0.251	0.130	Moderate	3	44	AV.	Creating the PMO
Co. 8	The deficiencies in engineering departments' training	0.521	0.266	0.138	Moderate	2	31	MIT.	Training plan for each project
Co. 9	The pre-handover inspection was inadequate and the contractor review was inadequate	0.414	0.221	0.091	Moderate	18	98	MIT.	A site visit should be a commitment for all partners.
Co. 10	Rework brought on by improperly completed work	0.400	0.269	0.108	Moderate	11	76	MIT.	A quality assurance specialist should be included in the organization breakdown structure of the project.
Co. 11	Improper scheduling of the project	0.431	0.252	0.109	Moderate	10	73	MIT.	The meetings for creating the schedule between all partners should be done at the beginning of the project to create the proper schedule.
Co. 12	Failure to establish priorities following the schedule	0.426	0.251	0.107	Moderate	12	77	MIT.	Increasing the role of the planning department inside the project for adherence to the schedule
Co. 13	Not predicting productivity, not monitoring the daily rates of implementation, and not comparing them to what is necessary per the plan	0.329	0.255	0.084	Moderate	20	109	MIT.	Increasing the role of the planning department inside the project for monitoring and controlling the project
Co. 14	The contractor's delay in generating shop drawings and material samples	0.343	0.187	0.064	Moderate	25	142	MIT.	It should include the duration cycle of the submittal process for approving the shop drawing and material samples in the schedule

(*continued on next page*)

Table 9. (continued)

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Co. 15	Incorrect construction techniques	0.430	0.274	0.118	Moderate	7	61	MIT.	Hire specialists
Co. 16	Lack of High-Technology	0.484	0.245	0.119	Moderate	6	59	MIT.	It should include advanced technologies in the project management plan.
Co. 17	Delay in resource mobilization	0.394	0.254	0.100	Moderate	16	91	MIT.	The commitment of the senior management in the organization to save all required resources.
Co. 18	The failure to adhere to the project's safety regulations and guidelines	0.496	0.189	0.094	Moderate	17	96	MIT.	The commitment of the organization to save all requirements of safety
Co. 19	Disadvantages of extra and night work (poor quality - work fatigue, lack of workers incentives)	0.454	0.230	0.104	Moderate	15	83	ACC.	The contingency reserve for time and cost in the projects should be increased to remedy the shortage in productivity during the working shifts.
Co. 20	Conflicts between subcontractors when the program is being carried out, as well as their lack of cooperation to adhere to the planned schedule's sequence	0.379	0.208	0.079	Moderate	22	120	MIT.	The planning department should distribute the tasks for all subcontractors and follow up on the progress and adhere to the schedule.
Co. 21	Subcontractors on the work site are not coordinated enough	0.354	0.199	0.070	Moderate	23	132	MIT.	Organize meetings periodically with subcontractors.
Co. 22	Delay in the subcontractor's work	0.399	0.267	0.106	Moderate	13	78	MIT.	The planning department should follow up on the progress of the subcontractors
Co. 23	Untrustworthy subcontractor	0.341	0.195	0.067	Moderate	24	137	MIT.	Check the efficiency of the subcontractor before starting the work.
Co. 24	Subcontractors are frequently changed because of their poor performance	0.401	0.288	0.116	Moderate	8	63	MIT.	Check the efficiency of the subcontractor before starting the work.
Co. 25	Difficulty in directing a sub-contractor	0.382	0.224	0.085	Moderate	19	108	MIT.	The commitment of the subcontractors to adhere to the schedule

Figs. 5–15, the curves can be used to determine the different risk levels [high, medium, low]. All points above the HR-curve is high risks. And the points between HR-curve and MR-curve is the medium risks. Finally, we neglect that the points under MR-curve are low risks. Additionally, it can be regarded as a useful tool for identifying the primary risk so that immediate action can be taken for the priority risks. Therefore, it could be the next step after determining the risk score.

A visual basic program for an Excel spreadsheet was created to construct the cost matrix for all risk categories. And, it can be used as a tool to update the risk score periodically to measure the highest and lowest risk during the project life cycle. It helps expedite the appropriate action during the execution of the project.

Fig. 5 Graph presents a level of risk factors for the consultant category which medium risks are (Cons. 1, Cons. 2, Cons. 3, Cons. 4, Cons. 5, Cons. 6, Cons. 10, Cons. 11, Cons. 12, Cons. 13, and Cons. 14).

Fig. 6 Graph presents a level of risk factors for the design category which medium risks are Desn. 1, Desn. 2, Desn. 3, Desn. 4, Desn. 7, Desn. 8, Desn. 9, Desn. 10, Desn. 11, Desn. 12, Desn. 13, and Desn. 14.

Fig. 7 Graph presents a level of risk factors for the equipment category which medium risks are Equ. 1, Equ. 2, Equ. 3, Equ. 4, Equ. 5, Equ. 6, Equ. 7, Equ. 8, Equ. 9, Equ. 10, Equ. 11, and Equ. 12).

Table 10. Analysis of risk factors (Labor).

Risk Code	Risk Factor	*P*	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Labor		TRS = 0.082							
Lbr. 1	inadequate labor supply, especially skilled labor for the contractor	0.424	0.297	0.126	Moderate	2	48	MIT.	Contract with a human resources company to increase the ability to save resources [labor and equipment].
Lbr. 2	Labor is lost as a result of resignation, especially among highly skilled professionals, technicians, or engineers.	0.457	0.276	0.126	Moderate	1	47	MIT.	Increasing the role of the HR department to save the high qualified resources
Lbr. 3	Personal disputes, strikes, and labor disputes	0.313	0.184	0.058	Low	14	152		
Lbr. 4	The conflict between the staff team and the labor	0.309	0.172	0.053	Low	16	158		
Lbr. 5	Working without commitment and sincerity	0.325	0.205	0.066	Moderate	11	138	MIT.	Increasing the incentive and motivation for HR
Lbr. 6	Workplace ethics-contradictory behavioral risks	0.250	0.145	0.036	Low	18	161		
Lbr. 7	Wages fluctuate and salaries not being paid on time	0.383	0.245	0.094	Moderate	6	95	MIT.	Related the wages to the economic conditions
Lbr. 8	lack of motivation for employees to complete tasks on time	0.473	0.240	0.113	Moderate	4	66	MIT.	Linkage of the work progress with the motivation
Lbr. 9	Low labors morale	0.424	0.211	0.090	Moderate	8	101	MIT.	Spread the work ethics
Lbr. 10	Low labor productivity	0.402	0.288	0.115	Moderate	3	64	MIT.	Increasing the training plan for labor
Lbr. 11	The absence of assessments to choose the best labor for the project	0.421	0.258	0.109	Moderate	5	74	MIT.	The process of selecting the best labor should involve the HR management plan
Lbr. 12	Discriminatory behavior among project participants	0.442	0.202	0.089	Moderate	9	102	MIT.	Spread the work ethics
Lbr. 13	The conflict between decisions made differently in the work	0.395	0.207	0.082	Moderate	10	114	MIT.	Organize periodic meetings to reach a consensus on the decision
Lbr. 14	The laborers' late arrival at the work site	0.317	0.208	0.066	Moderate	12	139	MIT.	provide transporting means for working site
Lbr. 15	Workplace injuries and accidents	0.251	0.180	0.045	Low	17	159		
Lbr. 16	The medical issues for labors	0.330	0.199	0.066	Moderate	13	140	TR.	Medical insurance
Lbr. 17	Work fatigue may result from long hours at the work.	0.420	0.217	0.091	Moderate	7	99	ACC.	The contingency reserve for time and cost in the projects should be increased to mitigate the effect of work fatigue
Lbr. 18	Absenteeism	0.303	0.183	0.055	Low	15	155		

Fig. 8 Graph presents a level of risk factors for the material category which medium risks are Matr. 1, Matr. 2, Matr. 3, Matr. 4, Matr. 5, Matr. 7, Matr. 8, Matr. 9, Matr. 10, Matr. 11, Matr. 12, and Matr. 13, and high risk is Matr. 6.

Fig. 9 Graph presents a level of risk factors for the owner category which medium risks are Own. 1, Own. 2, Own. 4, Own. 5, Own. 7, Own. 8, Own. 9, Own. 11, Own. 12, Own. 14, Own. 15, Own. 16, Own. 17, Own. 18, Own. 19, Own. 20, Own. 21, and Own. 22.

Fig. 10 Graph presents a level of risk factors for the contract category which medium risks are Cntr. 1, Cntr. 2, Cntr. 3, Cntr. 4, Cntr. 5, Cntr. 6, and Cntr. 7.

Fig. 11 Presents a level of risk factors for the contractor category which medium risks are Co. 1, Co. 2, Co. 3, Co. 4, Co. 5, Co. 6, Co. 7, Co. 8, Co. 9, Co. 10, Co. 11, Co. 12, Co. 13, Co. 14, Co. 15, Co. 16,

Table 11. Analysis of risk factors (External [corona virus effects]).

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
External (corona virus effects)		TRS = 0.147							
Exc. 1	The effects of corona virus on productivity decline and cessation	0.404	0.321	0.130	Moderate	9	45	ACC.	Accept [contingency reserve]
Exc. 2	The corona pandemic has forced the suspension of numerous projects.	0.440	0.339	0.149	Moderate	3	22	ACC.	Accept [contingency reserve]
Exc. 3	Reduction of employment for both the owner and the contractor to 50%, as decided by the Council of Ministers	0.463	0.318	0.147	Moderate	4	25	ACC.	Accept [contingency reserve]
Exc. 4	Government legislation is constantly being changed	0.447	0.306	0.137	Moderate	5	33	ACC.	Accept [contingency reserve]
Exc. 5	Due to the shutdown, supplies have been delayed and stopped	0.523	0.383	0.200	High	2	6	ACC.	Accept [contingency reserve]
Exc. 6	Difficulty performing work tasks in light of the Corona pandemic	0.456	0.285	0.130	Moderate	8	43	ACC.	Accept [contingency reserve]
Exc. 7	The regular absence from work, whether brought on by health issues, transportation challenges, a fear of being fined for violating a curfew, etc. (during the Corona pandemic)	0.472	0.277	0.131	Moderate	7	42	ACC.	Accept [contingency reserve]
Exc. 8	Employees have low morale and poor health as a result of the work site's seclusion as a result of the Corona outbreak.	0.426	0.257	0.109	Moderate	11	71	ACC.	Accept [contingency reserve]
Exc. 9	Workers' incapacity to take proactive steps to stop the spread of the Corona virus and infection, as well as their lack of desire in doing so	0.571	0.231	0.132	Moderate	6	39	ACC.	Accept [contingency reserve]
Exc. 10	Owner's hesitation in making decisions amid the corona pandemic	0.472	0.256	0.121	Moderate	10	56	ACC.	Accept [contingency reserve]
Exc. 11	Accruing interest on loans to the contractor as a result of the Corona pandemic's work interruption	0.542	0.433	0.235	High	1	3	ACC.	Accept [contingency reserve]

Co. 17, Co. 18, Co. 19, Co. 20, Co. 21, Co. 22, Co. 23, Co. 24, and Co. 25.

Fig. 12 Presents a level of risk factors for the labor category which medium risks are Lbr. 1, Lbr. 2, Lbr. 5, Lbr. 7, Lbr. 8, Lbr. 9, Lbr. 10, Lbr. 11, Lbr. 12, Lbr. 13, Lbr. 14, Lbr. 16, and Lbr. 17.

Fig. 13 Presents a level of risk factors for the external (corona virus) category which medium risks are Exc. 1, Exc. 2, Exc. 3, Exc. 4, Exc. 6, Exc. 7, Exc. 8, Exc. 9, and Exc. 10. In addition, the high risks are Exc. 5, and Exc. 11.

Fig. 14 Presents a level of risk factors for the external (others) category which medium risks are Exo. 1, Exo.2, Exo. 3, Exo. 4, Exo. 6, Exo. 7, Exo. 8, Exo. 9, Exo. 10, Exo. 11, Exo. 16, Exo. 17, Exo. 18, Exo. 19, Exo. 21, and Exo. 22. In addition, the high risks are Exo. 5, Exo. 12, Exo. 13, Exo. 14, Exo. 15, and Exo. 20.

Fig. 15 Graph presents a level of risk factors operational category which medium risks are Opt. 2. And, the high risk is Opt. 1.

9. Discussion, analysis, and practical implications

Only medium and high risk situations are addressed in a risk response plan, which should

Table 12. Analysis of risk factors (External [others]).

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
External (others)		TRS = 0.139							
Exo. 1	The challenge of seizing land that is in the way of roadways	0.492	0.281	0.138	Moderate	11	32	ACC.	Accept [contingency reserve]
Exo. 2	When the road pathways of different parties cross, there are complicated and numerous procedures. (Antiquities-Electricity-Roads-Water)	0.560	0.303	0.170	Moderate	7	11	ACC.	Accept [contingency reserve]
Exo. 3	Many industrial challenges (military installations - mosques - houses -etc.) in the path of the road	0.343	0.240	0.083	Moderate	20	111	ACC.	Accept [contingency reserve]
Exo. 4	Site's remote location	0.433	0.345	0.149	Moderate	8	21	ACC.	Accept [contingency reserve]
Exo. 5	Pipeline, electrical, and instrumentation cables interfering with the paths of the roads	0.561	0.332	0.186	High	4	8	ACC.	Accept [contingency reserve]
Exo. 6	The challenge of getting work permits	0.469	0.281	0.132	Moderate	13	41	ACC.	Accept [contingency reserve]
Exo. 7	It is challenging to pinpoint the facilities along the project's path with high accuracy because there is no map of them.	0.528	0.250	0.132	Moderate	12	40	ACC.	Accept [contingency reserve]
Exo. 8	The climate effects such as wind, rain	0.357	0.233	0.083	Moderate	19	110	ACC.	Accept [contingency reserve]
Exo. 9	Utilities not being available on-site (such as water, electricity, telephone, etc.)	0.435	0.272	0.118	Moderate	15	60	ACC.	Accept [contingency reserve]
Exo. 10	The alterations to government laws and legislation	0.351	0.246	0.086	Moderate	18	105	ACC.	Accept [contingency reserve]
Exo. 11	Exchange rate fluctuations	0.444	0.333	0.148	Moderate	9	23	ACC.	Accept [contingency reserve]
Exo. 12	Float Egyptian currency	0.564	0.422	0.238	High	1	2	ACC.	Accept [contingency reserve]
Exo. 13	Difficulty getting money from banks in foreign currencies to pay for products that are unavailable in Egypt	0.506	0.360	0.182	High	5	9	ACC.	Accept [contingency reserve]
Exo. 14	The modification of the lending financial strategy	0.491	0.368	0.180	High	6	10	ACC.	Accept [contingency reserve]
Exo. 15	Increasing taxation	0.531	0.367	0.195	High	3	7	ACC.	Accept [contingency reserve]
Exo. 16	Revolution, strikes, war, and closed regions	0.315	0.277	0.087	Moderate	17	104	ACC.	Accept [contingency reserve]
Exo. 17	Natural disasters (torrents, earthquakes, etc.)	0.248	0.307	0.076	Moderate	21	124	ACC.	Accept [contingency reserve]
Exo. 18	Accidents during implementation	0.331	0.228	0.075	Moderate	22	126	TR.	Medical insurance
Exo. 19	Implementation is challenging due to traffic (maintenance projects)	0.469	0.227	0.106	Moderate	16	79	ACC.	Accept [contingency reserve]
Exo. 20	The inflation rate and how it affects price increases	0.534	0.393	0.210	High	2	4	ACC.	Accept [contingency reserve]

(*continued on next page*)

Table 12. (continued)

Risk Code	Risk Factor	P	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Exo. 21	A challenge finding construction supplies at current official costs	0.473	0.311	0.147	Moderate	10	26	ACC.	Accept [contingency reserve]
Exo. 22	The delay in getting supplies from suppliers	0.438	0.286	0.125	Moderate	14	49	ACC.	Increasing the contingency reserve in the projects

include [avoid, mitigation, transfer, or accept] options and a description of the strategy to be used. On the other hand, the risk factors for a consultant, design, equipment, material, owner, contract, contractor, labor, external (corona virus effects), external (others), and operational can be categorized according to the risk response plan, which can help the decision-makers in choosing suitable risk response plan strategies. It can be sorted as follows:

For consultant: the risk response plan for a contractor can be divided into different strategies [avoidance for six factors (Cons. 3, Cons. 6, Cons. 10, Cons. 11, Cons. 12, and Cons. 13), mitigation for five factors (Cons. 1, Cons. 2, Cons.4, Cons. 5, and Cons. 14)]. Therefore, the main solution for facing risk factors of a consultant is avoidance and mitigation which can be represented 54.55% and 45.45%, respectively of the other risk response plans.

For design: the risk response plan for a contractor can be divided into different strategies [avoidance for six factors (Desn. 3, Desn. 8, Desn. 9, Desn. 10, Desn. 11, and Desn. 14), mitigation for six factors (Desn. 1, Desn. 2, Desn. 4, Desn.7, Desn. 12, and Desn. 13)]. Therefore, the main solution for facing risk factors of design is avoidance and mitigation which can be represented 50% of the other risk response plans.

For equipment: the risk response plan for a contractor can be divided into different strategies [mitigation for twelve factors from (Equ. 1: Equ. 12)]. Therefore, the main solution for facing risk factors of equipment is mitigation which can be represented 100% of the other risk response plans.

For the material: the risk response plan for a contractor can be divided into different strategies [avoidance for one factor (Matr. 1), mitigation for eleven factors from (Matr. 2: Matr. 5) and from (Matr. 7: Matr. 13), and acceptance for one factor (Co. 19)]. Therefore, the main solution for facing risk factors of material is mitigation which can be represented 84.62% of the other risk response plans.

For the owner: the risk response plan for a contractor can be divided into different strategies [avoidance for three factors (Own. 1, Own. 2, and Own. 12), mitigation for fifteen factors Own. 4, Own. 5, Own. 7, Own.8, Own.9, Own.11, and from (Own. 14: Own. 22)]. Therefore, the main solution for facing risk factors of the owner is mitigation which can be represented 83.33% of the other risk response plans.

For contract: the risk response plan for a contractor can be divided into different strategies [avoidance for two factors (Cntr. 6, and Cntr. 7), mitigation for five factors from (Cntr. 1: Cntr. 5)]. Therefore, the main solution for facing risk factors of the contract is mitigation which can be represented 71.43% of the other risk response plans.

For contractor: the risk response plan for a contractor can be divided into different strategies [avoidance for one factor (Co. 7), mitigation for twenty-three factors from (Co.1:Co. 6), from (Co. 8:Co. 18), and from (Co. 20:Co. 25), and acceptance for one factor (Co. 19)]. Therefore, the main solution for facing risk factors of contractor is mitigation which can be represented 92% of the other risk response plans.

Table 13. Analysis of risk factors (Operational).

Risk Code	Risk Factor	*P*	I	RS	Risk Case	RRC	RRT	Risk Response Plan	Risk Response Plan
Operational		TRS = 0.212							
Opt. 1	Excessive and illegal loads on the roadways being used	0.635	0.418	0.266	High	1	1	AV.	Do not allow illegal loads to pass through, and instructions must be put in place to take legal action to prevent overloads
Opt. 2	Linking the project to accident records is weak.	0.530	0.300	0.159	Moderate	2	14	MIT.	Integration between the special section for studying accident records and designing projects

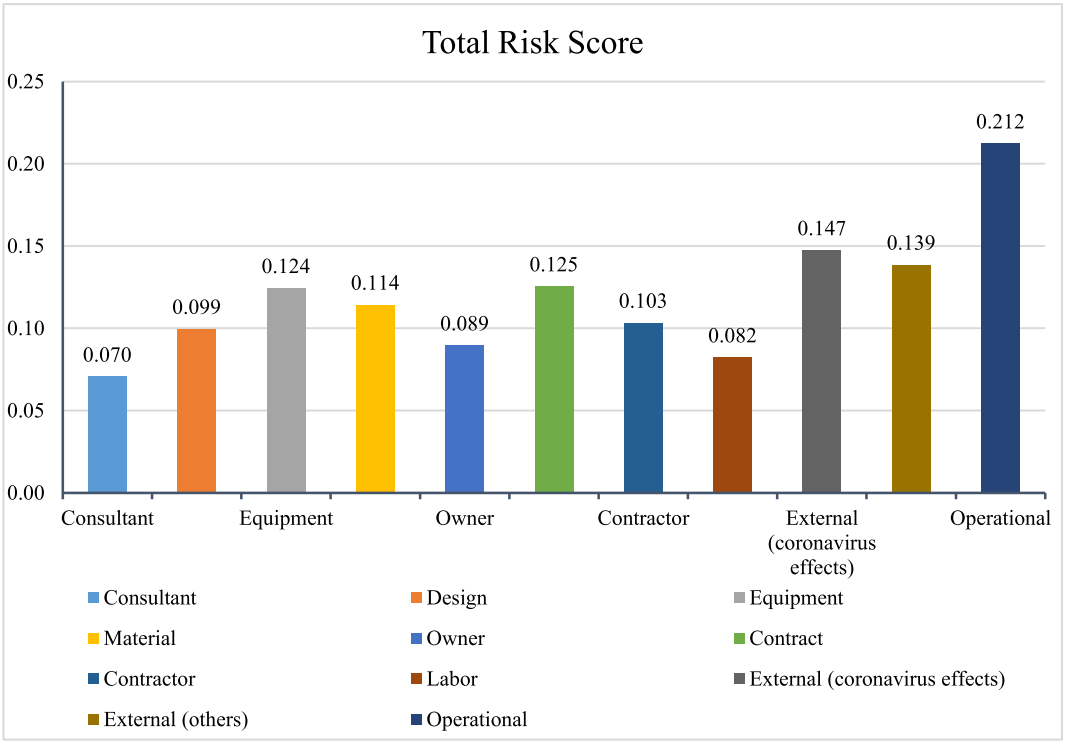

Fig. 4. Total risk score [TRS].

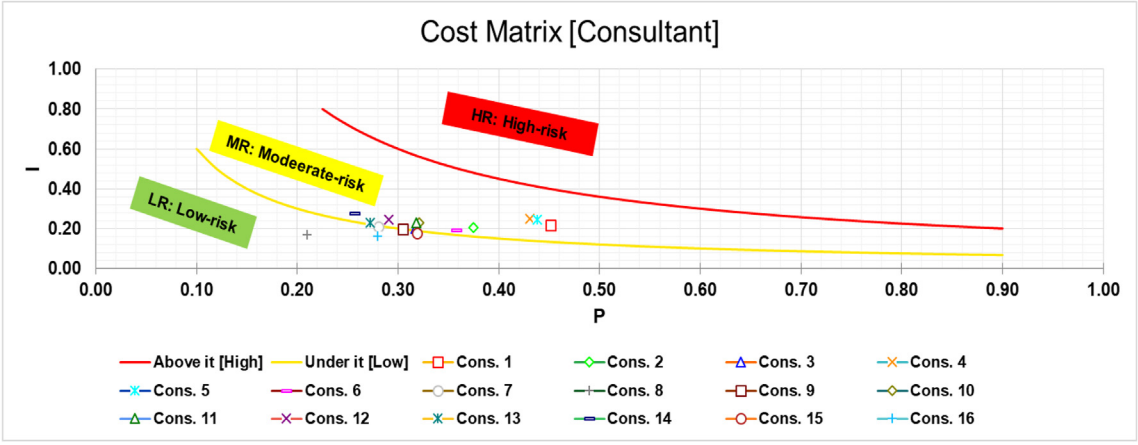

Fig. 5. Cost matrix for the categories of risk (Consultant).

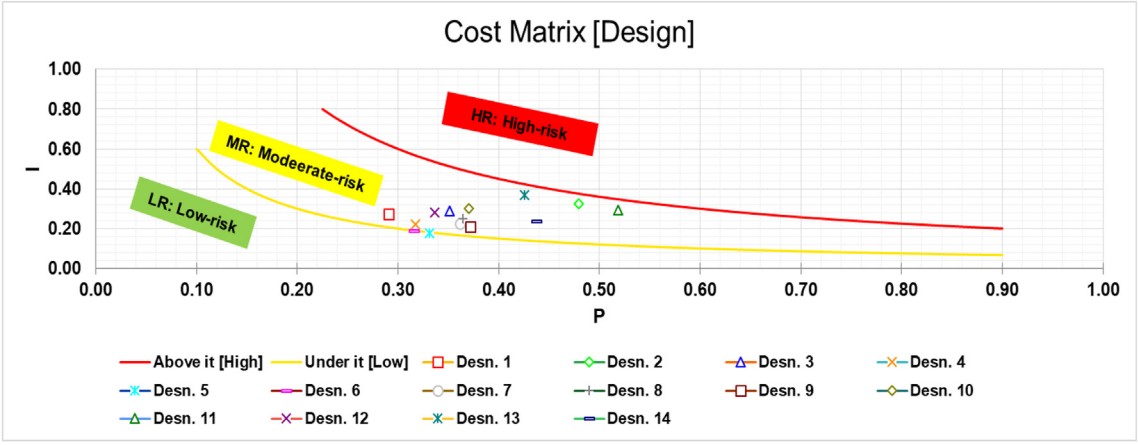

Fig. 6. Cost matrix for the categories of risk (Design).

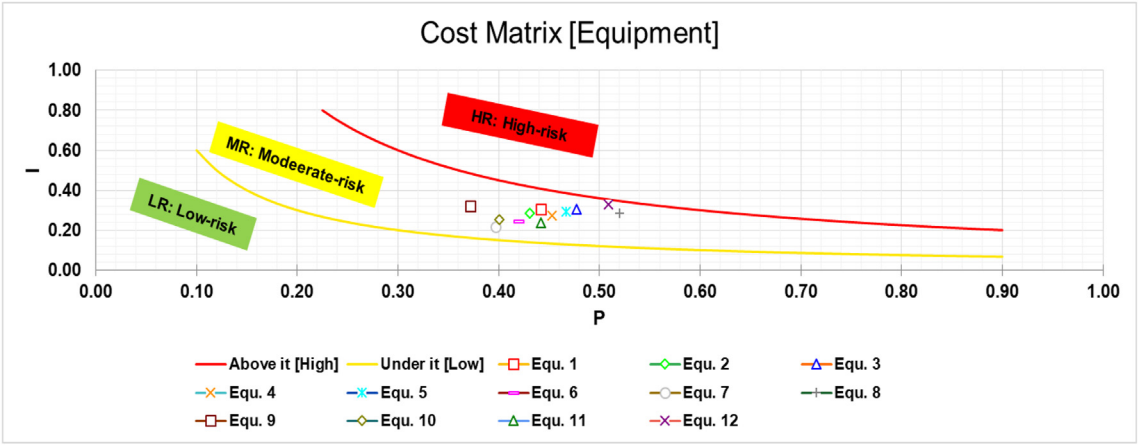

Fig. 7. Cost matrix for the categories of risk (Equipment).

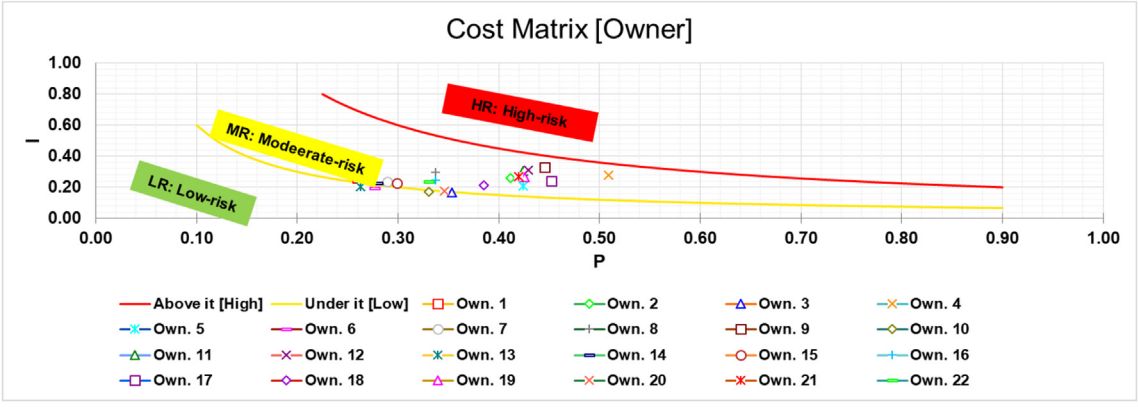

Fig. 8. Cost matrix for the categories of risk (Material).

For labor: the risk response plan for a contractor can be divided into different strategies [mitigation for eleven factor (Lbr. 1, Lbr. 2, Lbr. 5, and from (Lbr. 7: Lbr. 14)), transferring for one factor (Lbr. 16), and acceptance for one factor (Lbr. 17)]. Therefore, the main solution for facing risk factors of labor is mitigation which can be represented 84.62% of the other risk response plans.

For external (corona virus effects): the risk response plan for a contractor can be divided into

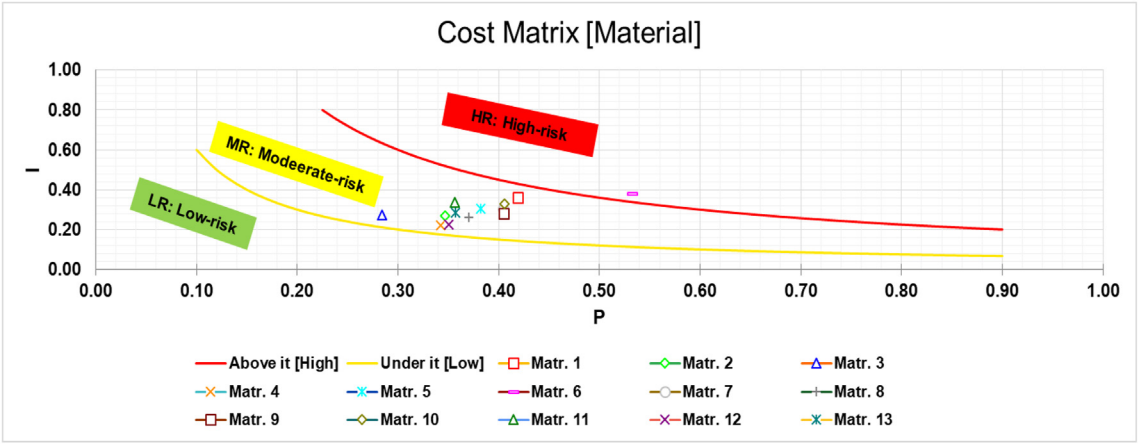

Fig. 9. Cost matrix for the categories of risk (Owner).

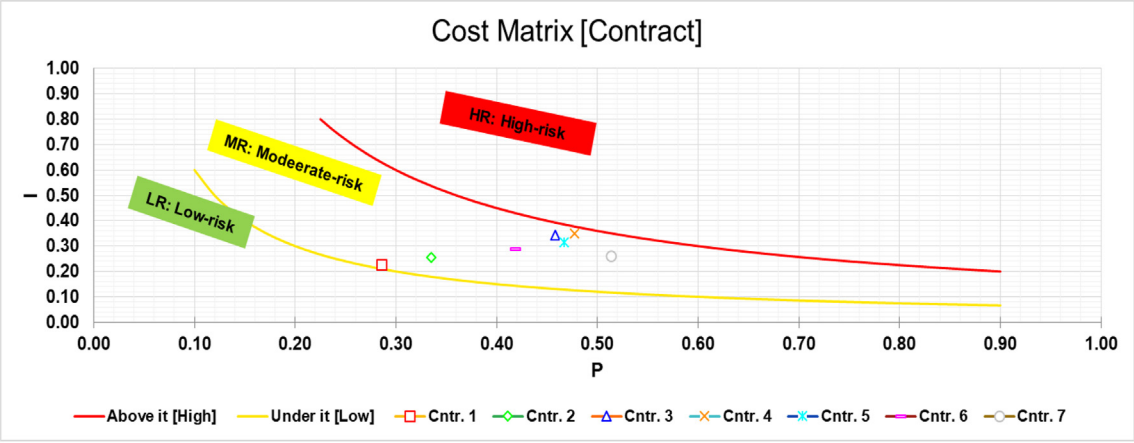

Fig. 10. Cost matrix for the categories of risk (Contract).

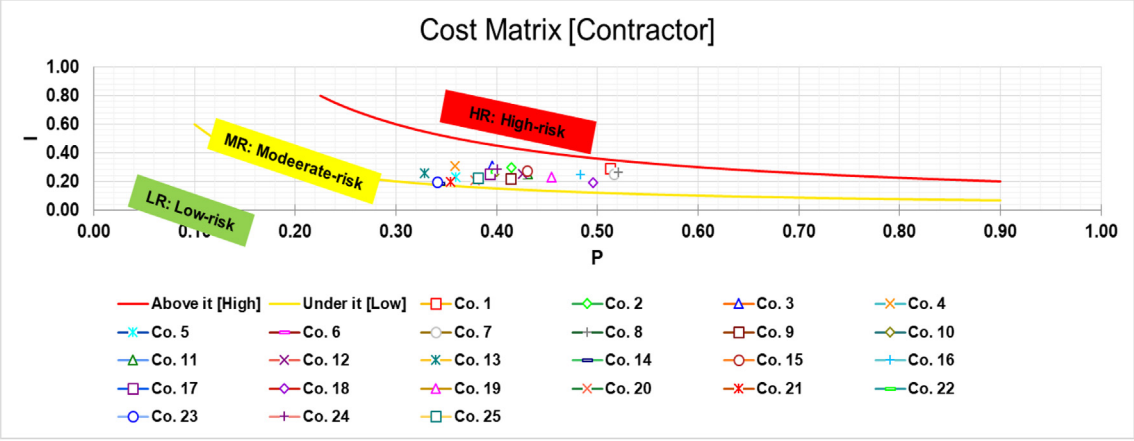

Fig. 11. Cost matrix for the categories of risk (Contractor).

different strategies [acceptance for eleven factor from (Exc. 1: Exc. 11)]. Therefore, the main solution for facing risk factors of external (corona virus effects) is acceptance which can be represented 100% of the other risk response plans.

For external (others): the risk response plan for a contractor can be divided into different strategies [transferring for one factor (Exo. 18), and acceptance for twenty-one factor from (Exo. 1: Exo. 17), and from (Exo. 19:Exo. 22)]. Therefore, the main solution

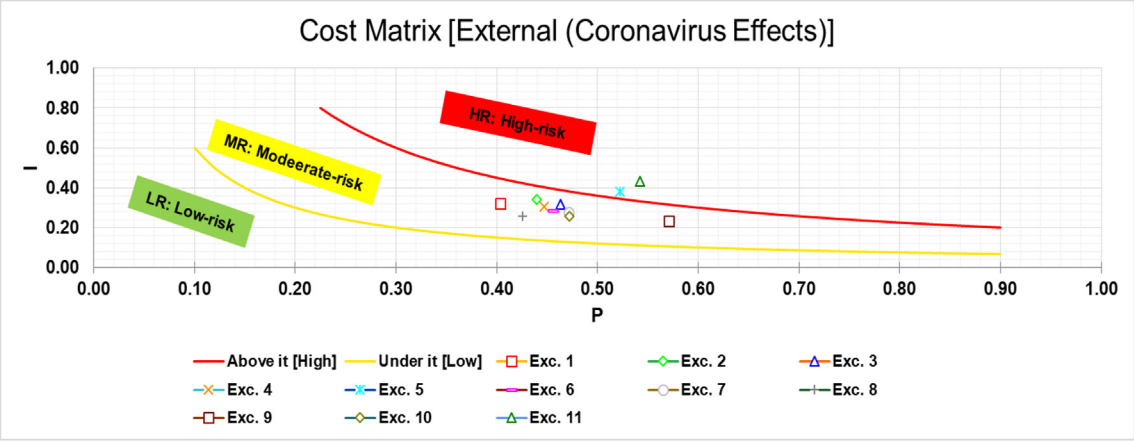

Fig. 12. Cost matrix for the categories of risk (Labor).

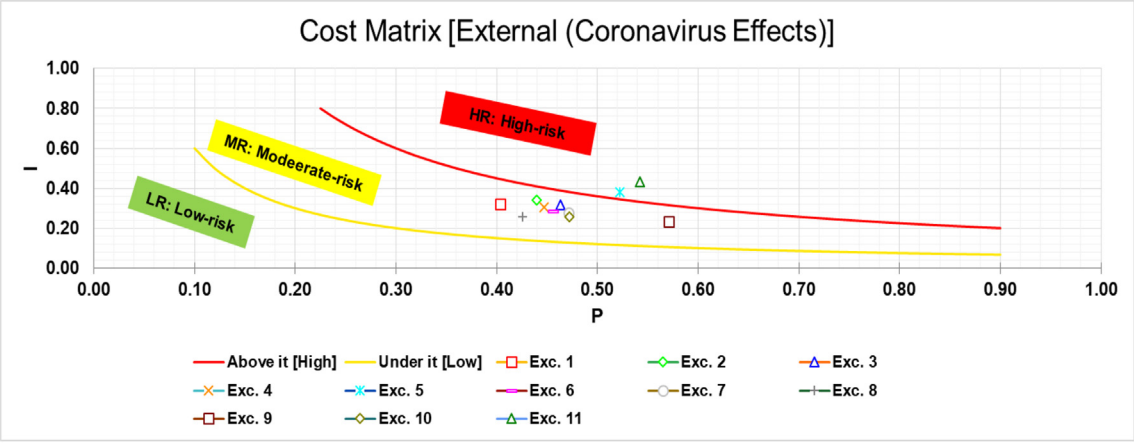

Fig. 13. Cost matrix for the categories of risk (External [corona virus effects]).

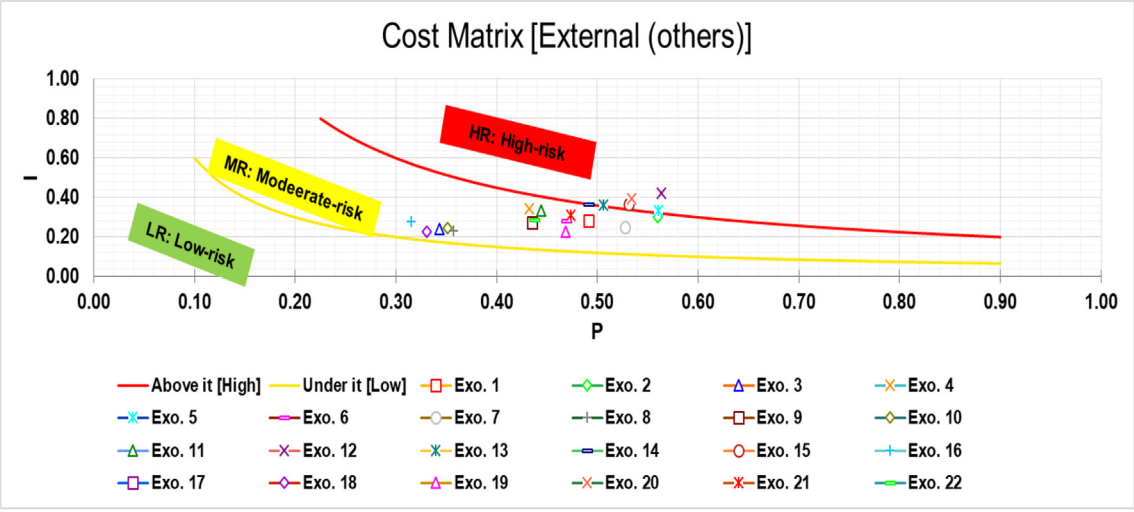

Fig. 14. Cost matrix for the categories of risk (External [others]).

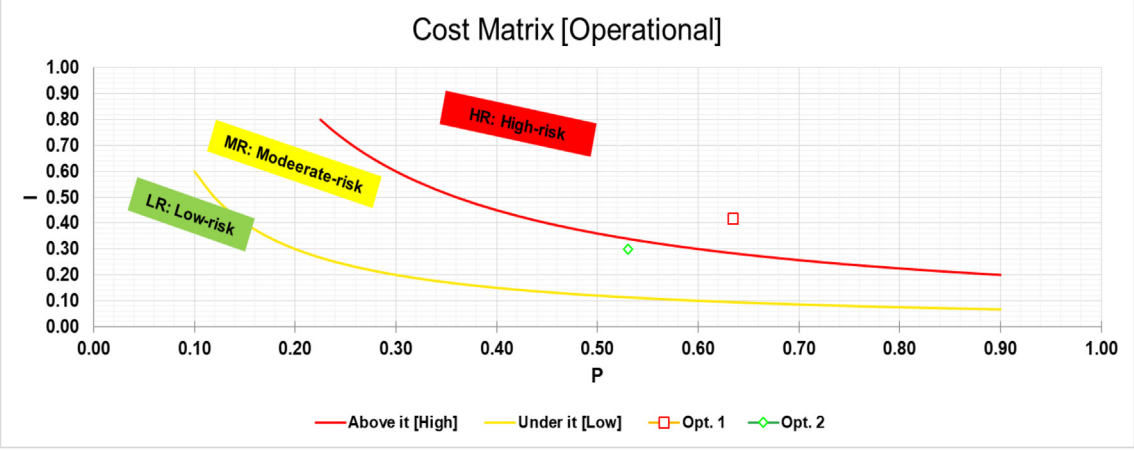

Fig. 15. Cost matrix for the categories of risk (Operational).

for facing risk factors of external (others) is acceptance which can be represented 95.45% of the other risk response plans.

For operational: the risk response plan for a contractor can be divided into different strategies [avoidance for one factor (Opt. 1), and mitigation for one factor (Opt. 2)]. Therefore, the main solution for facing risk factors of operational is avoidance and mitigation which can be represented 50% of the other risk response plans.

10. Conclusions

Road construction is a challenging process with many crucial steps and risk variables that could cause cost overruns especially during COVID-19. Also, the impact of numerous risk factors exacerbated cost overruns in road construction as the COVID-19 epidemic spread throughout the world. Therefore, the study takes into account new unknown risk factors (corona virus impacts) and looks at the new level of risk factors due to it.

The analysis divided the risks connected to Egyptian road construction into eleven groups. It comprises design, consultant, owner, contractor, material, equipment, contract, labor risk, external (corona virus effects), external (others), and operational. Additionally, 162 risk variables are broken down into eleven major categories.

Overall, the research's conclusions demonstrate that: Excessive and illegal loads on the roadways being used [RR = 1], Float Egyptian currency [RR = 2], Accruing interest on loans to the contractor as a result of the Corona pandemic's work interruption [RR = 3], The inflation rate and how it affects price increases [RR = 4], Increased costs for materials [RR = 5], Due to the shutdown, supplies have been delayed and stopped [RR = 6], Increasing taxation [RR = 7], Pipeline, electrical, and instrumentation cables interfering with the paths of the roads [RR = 8], Difficulty getting money from banks in foreign currencies to pay for products that are unavailable in Egypt [RR = 9], The modification of the lending financial strategy [RR = 10].

In descending order with TRS, the following risk categories were given the highest priority: operation risk, external risk [Corona virus effects], external risk [Others], contract risk, equipment, material, contractor, design risk, owner, labor risk and consultant risk. In conclusion, the biggest influences on cost overruns of road projects are operational risk and external risk brought on by the impact of the corona virus.

A visual basic program for an Excel spreadsheet was created to construct the cost matrix for all risk categories. And, it can be used as a tool to update the risk score periodically to measure the highest and lowest risk during the project life cycle. In addition, the study focused on high and medium risk factors in putting a risk response plan and neglecting low risk to guide the organization in facing the risk factors. A risk response plan is only intended for medium and high risk by [avoid, mitigation, transfer, or accept] and describing the risk response plan for each risk.

Also, the study's findings indicate that the excessive and illegal loads on the roads, the fluctuating value of the Egyptian pound, and the accruing interest on loans to the contractor as a result of the work interruption caused by the corona virus are the high-risk factors that have the greatest impact on cost overruns for road projects. In addition, the cost matrix has also been used to display risk factor levels as a road map for responding quickly to high risks.

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Conflict of interest

There are no conflicts of interest.

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