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Responsibility and Allocation for Risks Affecting Road's Construction

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Risk analysis, risk allocation, responsibility, Egypt, roads activities, and risk management

Abstract— **In many cases, due to the absence of risk allocation models, the owner tended to convey all risks to the contractor who attempted to transfer them to the suppliers and subcontractors. Such attitude is causing a series of conflicts and disputes which will eventually influence the success of the project. In this study, the risk factors associated with the implementation of roads projects were classified based on the responsibility and allocated to the party who can best control them as well as introducing the most effective risk management actions. The risk responsibility was introduced through classifying 88 identified risks into 7 responsibility groups.**

A Risk Allocation Model (RAM) was introduced for allocating the major risks to the suitable party (Owner, contractor, or shared responsibility between both). Furthermore, the model proposed the risk response to be assigned to each risk factor, i.e., the risk management action. In order to generate the RAM, the Delphi technique was adopted to allocate the risks to the appropriate party and to propose the proper risk response as well. The impacts on time, cost, and quality were determined and the top-ranked risks were identified based on the value of their Risk Factor Indices (RFI) values. The major risks were allocated based on Delphi results, 57% to the contractor, 10% to the owner while 33% were shared liability between both. Moreover, the percentages of risk management actions allocated to each risk factor were, the "risk control" represented 33%, and the "contract clause" represented 24%, However, both "avoidance" and "mitigation" represented 19% for each action while the "insurance" represented 5% only of the proposed risk responses. The proposed RAM shall help the decision-makers to take the proper decision in favor of the project and to compare between the projects as well.

I. INTRODUCTION

THE analysis of risks and uncertainties is considered one of the most inducing factors which affect the attainment of project objectives in terms of time, cost, and quality. Moreover, risk analysis and management is considered a key project management practice to promise that the least number of unforeseen events occur while the project is in growth [1]. Risk management includes managing risks with both negative and positive outcomes. It is a continuous process where the sources of uncertainties are systematically identified, their impact assessed and qualified, and their effect and probability managed to produce a satisfactory balance between

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the risks and opportunities [2]. The risk management process usually includes four steps, starting with risk identification, then the risk analysis stage followed by the choice of risk management method, and finally monitoring the selected management action and risk consequences [3]. Roadway's construction industry is subjected to more risks due to the complex nature of this industry which increases the likelihood and Possibility of risks that are involved in the roads construction environment. Risks associated with roadways construction projects (RCPs) incorporate, for example, external risks such as: economical risks, political risks, legal risks, extreme weather condition risk, general risks, etc. and internal risk e.g. financial risks, contractual risks, design-related risks, organizational risks, and technical risks. These risks are commonly creating losses related to project's time delay, cost overrun, poor quality, loss of income, physical damage to the project, physical injury to personnel, loss of reputation and business, and so on [4].

Owing to the uncertainty of risks in construction projects, the problems due to risks directly influence all project contributors' profits. Typically, in construction projects, the client tends to convey most of the risk consequences to the contractor. However, a one-sided attitude concerning risk allocation, in which one party attempts to dispatch all risk to other parties, possibly result in undesirable effects to all parties [5], [6]. Also, risks in many cases were found to be underestimated and were allocated to parties without the knowledge, resources, and abilities to manage them successfully [7]. Risk allocation is the process of identifying project risks and determining how they may be fairly and reasonably shared by all relevant parties in a construction project [8]. The allocation of construction risks between clients and contractors has an important impact on the construction project costs [5]. The allocation of the potential risk losses to the project parties helps them to improve and enhance their behavior towards the control and preventive measures that may reduce the cost of risk-taking. It also leads to mitigating contractual disputes in construction projects. Eventually, It will lead to achieving the project objectives with the maximum benefits to all parties in addition to good relationships and reputation beyond the project handing over [9].

Recently, many researchers studied the risk allocation principles as well as the contractual issues that may lead to disputes [10]. Allocation of project risks was and still a challenging problem that project risk management couldn't solve [11]. The different parties involved in a project regularly have different perspectives on the risks according to their background and benefits [12]. Client entities might be primarily concerned with the risks related to project schedule and budget, while contractors may concentrate on the project's revenue and the workers might be concerned about the health and safety of their daily activities and work environment [13]. The risks effects in a certain construction project might be allocated based on the risks' predictability. The risks, which could be anticipated by the experienced executors, should be undertaken by the contractor; while risks that couldn't be predicted should be addressed by the owner [14]. Due to the unfair allocation of risk responsibilities to some parties, the parties that these risks are imposed on are enforced to approve defensive policies. These defensive actions may include but are not limited to dropping the work quality, imposing exaggerated contingency charges, conservative design, and eventually will lead to claims, disputes, and litigation. Thus, it may lead to time and cost overruns, and poor quality [15].

Therefore, recent studies were more curious to study the risk responsibility and risk allocation concept to provide a proper approach and realistic scheme about who is responsible, to whom risks should be allocated, and what is the suitable action to control the effect of these risks as shown in figure (1). In this research, a set of potential risks, that might encounter roadways construction projects (RCPs) in Egypt, were consolidated and categorized. The weight of each risk was determined by using the risk factor indices (RFI) equations based on data collected through field survey to estimate the magnitude of every single risk factor impact on the project time, cost, and quality. Consequently, a risk allocation model (RAM) was introduced which helped to prepare a scheme of risk allocation to the project parties as fair as possible. Generally, the RAM introduced in this research may help project managers, decision-makers, and contract negotiators to effectively minimize the potential for unnecessary losses and disputes in addition to fair allocation of risks to the proper party. Eventually, that will lead to effectively controlling and mitigating the time delays and cost losses as well as delivering a successful project. (Style name: PP Body: Main text)

Fig. (1) the essential three questions for proper risk allocation

II. OVERVIEW OR RISK ALLOCATION PROCESS

Risk allocation can be characterised to qualitative and quantitative approaches. The qualitative approach can be represented by a standardized form of the contract specifying the responsibility of contractual parties. It introduces developing a risk allocation matrix, which classifies the responsible for each risk. On the other hand, the quantitative approach recognises how much of the risk is allocated [16]. The complexity of risks facing infrastructure projects and the difficulties in distributing them appropriately was presented and a set of recommendations to enhance managing risks in such projects were introduced [7].

(Issa et al., 2015) identified and assessed the significant risks in Yemen construction industry and addresses their proper allocation, the study allocated more risks to contractors or shared between contractors and owners while only two risks were allocated directly to the owners [16]. (K et al., 1997) studied the attitude of large U.S. construction companies toward risks and determines how these contractors conduct construction risk management [17]. The study showed that recently, contractors are more curious to presume risks that accompany contractual and legal problems in the form of risk-sharing with the owner. (Kangari, 1995) provided important advice and remarks to project managers and contract drafters, by providing a better understanding of where and how differences in risk perceptions are expected to arise [18]. (Khanzadi et al., 2012) studied the public construction projects in Jordan and identified 62 risk factors categorized into 14 groups [19]. The study identified, assessed, and allocated risks in public construction projects in Jordan in order to reduce the claims of additional costs and disputes. The study also identified the responsibility of each risk factor and 4 risk factors responsibilities were allocated to owners and 5 risk factors were allocated to contractors, while 42 risk factors were defined to be shared responsibility between the contracting parties [19]. (Khazaeni et al., 2012) introduced a study of risk allocation between standard contract agreement parties, and developed a hierarchy structure for risk allocation principles [20]. The main assumption of the research was that the risk should be allocated and accepted by the party who can properly manage and control the risk at the least cost. (Al-Bahar & Crandall, 1990) carried out a statistical analysis of articles that discussed the risk allocation among construction contract parties and the proposed methods from both contract parties' point of view were suitability evaluated [3].

(Lavanya & Malarvizhi, 2008) surveyed the major barriers to risk allocation in construction contracts and defined the several aspects, obligations, and relations among the contract parties that are essential to reach a common planned goal. According to (Lavanya & Malarvizhi, 2008) the improper allocation of risk factors might lead to many losses and disputes, the study stated 14 issues could take place in case of improper risk allocation e.g. 1) the contractor may tend to increase the price to absorb any arisen risks, 2) the project will face many delays as the contractor won't be able to handle all risks alone, 3) mostly more claims and disputes will take place, 4) the chance of project failure will be increased, 5) the likelihood of some risks which could be eliminated will be increased and it might occur, 6) the chance to utilize the positive risks and opportunities will be significantly decreased [21]. In addition to the previous major issues which could occur due to improper risk allocation, the following issued were stated by (Lavanya & Malarvizhi, 2008) and (Levitt et al., 1980) and as follows; 1) significant decrease in project control, 2) increasing the barriers to achieve the risk management plan which will be unrealistic and difficult to achieve, 3) decreasing the satisfaction level among the project stakeholder, 4) the project parties will pay more efforts towards the project more than the usual efforts in similar projects, 5) the employer might tend to replace the competent contractor with a less qualified one who mostly will accept unbalanced risk distribution. In this research, the researchers attempted to classify the risk factors based on the responsibility nature of each risk factor as well as identifying the liability of the stakeholders to take the proper risk management action [21], [22].

III. Problem Statement

The main objectives of a certain project are to deliver the project with acceptable quality on time and within the allocated budget in addition to a good relationship between the stakeholders i.e. without disputes [10]. Generally, in construction projects due to lack of risk allocation tools, risks might be underestimated as well as improper allocation to the appropriate party to address the risk event. In particular, RCPs in Egypt are more likely to encounter more risks due to the complex nature of RCPs execution, more risks simply mean more potential cost losses and delays. Eventually, the potential losses and delays will lead to disputes among project parties.

Generally, due to the absence of proper risk allocation models, the owner will attempt to convey the responsibility of the risks to the main contractor who will take the lead to convey the same issues to the lower grade of stakeholders e.g., subcontractors and supplies. Such cycle of blames and disclaimer of responsibilities will lead to formal and informal disputes which will generate more cost losses and more delays and finally it might result in project failure. Therefore, this research is basically focused on the need for either tools or a mechanism that can be utilized throughout the RCPs in Egypt; to effectively and efficiently answer the three vital questions shown in figure (1) to properly and fairly allocate the critical risk factors with the highest impact on the implementation of RCPs. Such an approach should mitigate the effect of improper risk allocation and will decrease the resulting problems, difficulties, and consequences of risks that influence the execution of RCPs in Egypt. Furthermore, it will increase the possibilities of delivering a successful project on time, within the budget, and with satisfactory quality to the end-user as well as increasing the reputation of the project parties and decreasing the disputes.

IV. Objectives of Study

The main objectives of this study can be summarised as follows:

- To introduce a risk, register of the risk factors affecting the execution of roads projects.
- To classify the risks into responsibility groups via identifying the responsible party for each risk factor whether

it's the contractor, the owner, the consultant, the suppliers, or if it's shared responsibility between more than one party.

- To specify the recurring major risk factors which are affecting more than one objective of the project outcomes e.g., time and cost or cost and quality, etc. based on the combined effect of the likelihood and impact on time, cost, and project quality for each risk factor.
- To generate risk allocation model RAM in order to allocate a certain risk to the proper party.
- To allocate the major risk factors to the appropriate party who can control and manage them i.e. the owner, the contractor, or be shared between both.
- To define the proper risk management action to each risk factor.

V. METHODOLOGY OF RISK ALLOCATION MODEL (RAM)

The methodology followed in this research was basically to allocate a certain risk to the proper party who is able to control and manage the risk factor and its impact, by using a proposed risk allocation model (RAM). In order to generate the desired RAM, a multi-stage process was followed as shown in figure (2).

- *The first stage* of the proposed process includes the identification of risk factors affecting the implementation of RCPs. the researchers reviewed a risk-registers for risk factors affecting RCPs through a wide-ranging literature review. A series of semi-structured interviews and brainstorming sessions were conducted with experts in roadways construction projects in Egypt. The outcome of this stage was a risk register of 88 risk factors categorized into 7 groups based on the responsibility classification.
- *The second stage* of the process was to define the significant risks affecting the RCPs among the 88 risks, a consolidated list of 39 risks was selected by the experts and introduced by the researchers after a series of brainstorming sessions with professionals and roadways experts. Then, the weight of each risk factor was determined by calculating the risk factor indices (RFI) values for time, cost, and quality. In order to identify the major risks with the highest impact on time, cost, and quality based on their RFI values. The output of this stage is a list of 21 major risk factors with the highest impact on the project objectives, which will be processed through the Delphi method to allocate the risk factors to the proper party.
- *The third stage* was a decision-making step to determine the least risky project through comparing among different projects, hence the decision-makers would be able to select a suitable project. The final step of the model incorporates the allocation of risks to a suitable party based on the Delphi results. The developed RAM has allocated the risks into 3 categories nominated as follows: (1) owner, (2) contractor, and (3) shared risks between both owner and contractor. Eventually, appropriate risk management action, (mitigate, avoid, control, insurance, or contract clause) is assigned to each risk factor.

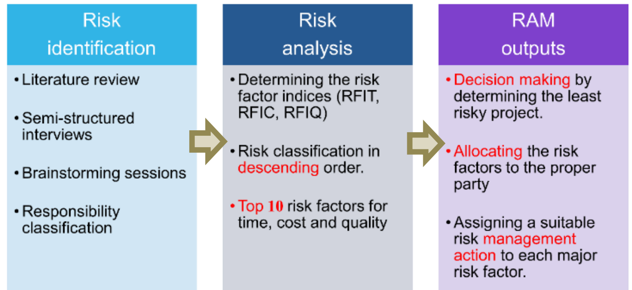

Fig. (2) Research methodology

VI. RISK IDENTIFICATION AND RESPONSIBILITY CLASSIFICATION.

Risk identification is a systematic and continuous process of identifying, categorizing, and assessing the initial significance of risks associated with a construction project [23]. During the risk identification process, the sources and type of risks are identified. The risk identification process is ideally undertaken throughout the appraisal of the project, even though it can be performed at any stage of the project and should be regularly and periodically revised during the project life cycle [24], [25]. The risk identification process consists of inputs, tools, and outputs. The tools that might be used for risk identification are numerous and varied such as; field survey, risk checklist, experts' opinions e.g. interviews and documents analysis [26]. The inputs should include the project objectives, project documents, historical data, and risk management plan [27]. The output of this process is a risk register or risk log that contains a list of identified risks [25].

The tools used to collect the inputs were brainstorming sessions and literature reviews of previous studies. In order to effectively identify the output risks, a hierarchical risk breakdown structure (HRBS) was used as recommended by [16]. The HRBS used for risk identification was divided into 2 levels namely: (1) internal risks (relatively controllable risks) and (2) external risks (relatively uncontrollable risks). The first level represents the internal risks, which are relatively more controllable and vary from one project to another such as: managerial risks, organizational risks, and owner-related risks. While the second level refers to the external risks, which are relatively difficult to control and require continuous monitoring and forecasting e.g. economic risks and political risks. Basically, risk factors were classified including risks related to politics and laws, economics and finance, design, contracts and bidding, construction, and owners and contractors as stated by [28].

In this study, the risk identification process was performed, and the output was a risk checklist consisting of 88 divided into internal and external risk factors associated with RCPs as shown in Figure (3). Table (1.8) is showing the external risk in one group while the internal risks were classified according to the responsibility, i.e. who is the responsible party, into 7 groups as shown in tables (1.1.2,3,4,5,6, and 7);

1. Group I - the owner’s responsibility.
2. Group II - the contractor’s responsibility.
3. Group III - the consultant’s responsibility.
4. Group IV - personnel & laborers’ responsibility.
5. Group V - suppliers and subcontractors’ responsibility.
6. Group VI - mutual responsibility among (owner-contractor).
7. Group VII - mutual responsibility among (contractor-consultant).

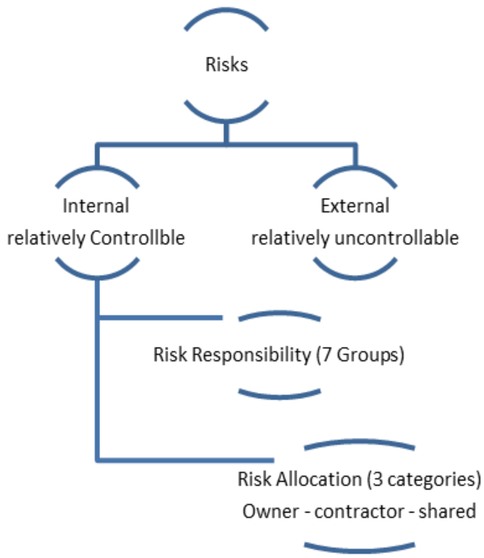

Fig. (3) classification of the identified risks

Figure (4) indicates the percentage of risks located at each responsibility group, the highest percentage of risks were located at (group II) contractor’s responsibility group i.e. 26.1% while the owner’s responsibility group (group I) contained 15.9% of the total identified risks. The 3rd highest percentage of risks belonged to (group VI) mutual responsibility among (owner-contractor) i.e. 14.8%. However, group III, group V and group VII contained equal percentages of risks i.e. 10.2% for each group while group IV (personnel & laborers’ responsibility) contained 12.5% of the total identified risks. Consequently, it can be inferred that 56.8% of the project’s risks are under the responsibility of the owner, contractor, or both. Whereas the uncontrollable risks represented 5.7% of the project-related risks.

TABLE (1.1)
THE OWNER’S RESPONSIBILITY-RELATED RISKS (GROUP I)

1.	Shortage of project socuments, data, and details during the design phase & lack of pre-studies.
2.	Poor investigation of the project soil.
3.	Mismatching of the actual NGL, and NGL mentioned in tinder drawings.
4.	Changing the scope during the preparations phase.
5.	Inaccurate setting out of the project’s control points and bench marks.
6.	Client's slow response, and slow decision-making.
7.	Issues related to owner’s organization e.g., Bureaucracy, and lack of specialists.
8.	Financial issues e.g., Delay in releasing the interim payments to the contractor or consultant.
9.	Owner’s late demands e.g., Additional works, and change orders.
10.	Deficiencies, and changes in project scope.
11.	Contractor assignment before consultant.
12.	Unfair contract terms, and biases in favor of the owner.
13.	Incompetent owner’s representative.
14.	Owner interference.

TABLE (1.2)
THE CONTRACTOR’S RESPONSIBILITY-RELATED RISKS
(GROUP II)

1.	Usage of old version surveying instruments
2.	Shortage of fuel stock in the site due to high prices or oil crisis.
3.	Poor management of the site resources, plant and machinery
4.	Poor arrangement of the site logistics, access, and egress
5.	utilizing a proper compaction equipment with proper capacity to achieve the compaction ratio.
6.	Non-compliance with the code principles, and international standards of road marking.
7.	Delay in handing over the road furniture works e.g. curbstones, and road barricades.
8.	Non-compliance with global HSE (health, safety and environment) measures standards.
9.	Commencement of work execution despite the incomplete project documents.
10.	Lack of contractor's personnel experience.
11.	Poor management of the site team.
12.	Poor management of the site resources.
13.	Poor condition of laborer’s welfare facilities e.g., Accommodation, and transportation.
14.	Conflicts between contractors, and other parties.
15.	Reworks due to execution errors.
16.	Incompetent or unprofessional tendering team.
17.	Lack of modern equipment, and usage of old model equipment.
18.	Assignment of incompetent subcontractors.
19.	Poor operational safety management.
20.	Cash flow management.
21.	Involving in many projects exceeding the capabilities of the contractor resources.
22.	Incidents, and injuries during construction.
23.	Poor organizational structure of the contractor’s team.

TABLE (1.3)
THE CONSULTANT’S RESPONSIBILITY-RELATED RISKS
(GROUP III)

1.	Delay of laboratory results for material testing, and approval of samples.
2.	Poor organizational structure of the consultant's team.
3.	Lack of the Consultant ’Engineer’ experience.
4.	Delay in reviewing, and approving design, & inspection requests.
5.	Slow decision-making.
6.	Delay of approval of major scope changes.
7.	Lack of experience of the consultant's QA/QC team.
8.	Poor management, and inadequate progress follow-up.
9.	Unprofessionalism, and subjective behavior towards the contractor.

TABLE (1.4)
PERSONNEL, AND LABORERS' RESPONSIBILITY- GROUP IV

1.	lack of experience and competentency of the plant and machinery operators.
2.	Lack of competent /experienced surveyors.
3.	Lack of experience of the in-charge engineers, and other staff members
4.	Low productivity, and low performance of the execution team
5.	Lack of competent laborers, and technicians.
6.	Lack of experience, and incompetency of labors.
7.	Personal conflicts, and disputes between laborers
8.	Non-compliance with the site safety regulations, and instructions.
9.	Careless, and laziness in case of absence of supervision
10.	Performing unsafe work
11.	Unskilled, and incompetent laborers

TABLE (1.5)
THE SUPPLIERS, AND SUBCONTRACTORS' RESPONSIBILITY-RELATED RISKS - GROUP V

1.	Delay in materials delivery to the site.
2.	Delay in subcontractor's scope.
3.	Poor grading of the supplied crushed stones.
4.	Delay or irregular supply of crushed stones.
5.	Unavailability of nearby source to supply the granular soil " crushed stone.
6.	lack of storing, and suppling diesel due to high oil prices or unavailability.
7.	Unskilled subcontractor's laborers, and incompetent supervision.
8.	Fluctuations in the material's prices after signing the agreement.
9.	unavailability or high prices of oil products/ Bitumen

TABLE (1.6)
MUTUAL RESPONSIBILITY (OWNER-CONTRACTOR) – GROUP VI

1.	Existence of Horizontal or Vertical obstacles in the road route
2.	Existence of poor types of soil at the roadway route.
3.	Lack of water sources along the roadway route.
4.	Adverse weather conditions.
5.	Unavailability of a nearby source of appropriate filling soils.
6.	Lack of local authority control on the water resources, and soil stocks e.g., desert roads.
7.	Poor coordination among the project parties, including the infrastructure works.
8.	Environmental side effects due to the execution activities e.g., noise, and pollution.

TABLE (1.7)
MUTUAL RESPONSIBILITY (CONTRACTOR- CONSULTANT) - GROUP VII

1.	Poor eeview of design concept, drawings, and study diffirent sections of the road.
2.	Non-compliance with the code of practice, and international standards.
3.	Lack of experience of the QA/QC team.
4.	Delay in applying the next layer of the road leads to erosion of the existing layer.
5.	Lack of coordination, and effective communication.
6.	using raw materials with low-quality.
7.	Poor quality of the supplied construction materials.
8.	Poor QA/QC at the batch plant.
9.	Unreal planning, and ineffective scheduling.

TABLE (1.8)
EXTERNAL (RELATIVELY UNCONTROLLABLE) RISKS

1.	Unforeseen site conditions.
2.	Force majeure e.g. (floods, earthquakes,).
3.	Political instability.
4.	Changes in country's laws, regulations, inflation rates, and tax rates.
5.	Revolutions, disorders, and global pandemics e.g., covid-19.

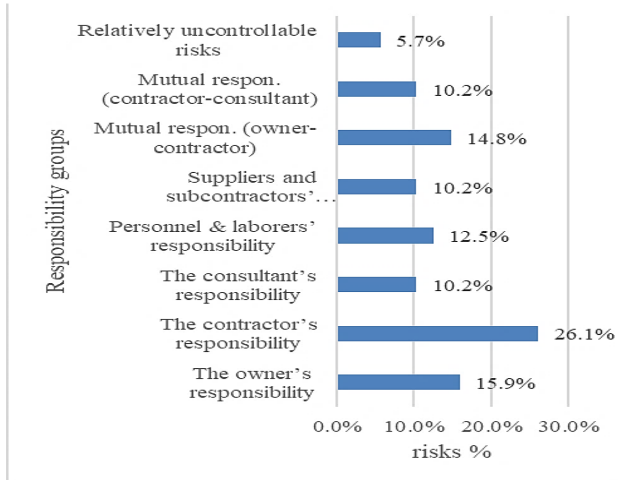

Fig. (4) percentage of risks located at each responsibility group

VII. RISK FACTORS ANALYSIS

The risk analysis process is the essential connection between systematic identification of risks and rational management of the significant risks. Traditional risk assessment techniques for construction projects have been synonymous with probabilistic analysis [29]. The aim of the risk analysis process is to evaluate the consequences accompanying the risks and to assess the impact of these risks via utilizing risk analysis and suitable evaluation techniques [30]. Recently, the ultimate goal of any organization is to mitigate the potential impacts associated with the potential risks via quantifying the identified risks and implementing corrective measures to manage them [29].

In order to proceed with risk calculations, the risk factors must be analyzed. Risk analysis for a construction project can be defined as the determination of the quantitative and qualitative value of the risk factor, (Peckiene et al., 2013) introduced three indices for the process of risk analysis, these three indices are Probability Index (PI), Impact index for Time (IIT), Impact index for Cost (IIC) and Impact index for quality (IIQ), same indices will be used in this study as well [31]. Qualitative risk analysis is the process of assessing the impact and likelihood of identified risk while quantitative risk analysis is a way to numerically estimate the probability that a project might meet its objectives i.e. time, cost, and quality. Quantitative analysis is basically a synchronized evaluation of the influence of all identified and quantified risks [32].

In order to identify the major risk factors to be considered in the risk allocation process, the risk factors will be ranked according to their risk factor index values i.e. the combined effect of the probability of occurrence multiplied by the impact index for time IIT, impact index for cost IIC, and impact index for quality IIQ [33]. The severity of a certain risk factor on the project's objectives i.e. time, cost, and quality can be determined through Equations (1), (2), and (3) respectively [34]. The severity of risks will be denoted as the risk factors indices for time, cost, and quality i.e. RFIT, RFIC, and RFIQ respectively, and the results are shown in table (1).

*RFIT=PI*IIT where, RFIT is the risk factor index for time. Eq. (1)*

*RFIC=PI*IIC where, RFIC is the risk factor index for cost. Eq. (2)*

*RFIQ=PI*IIQ where, RFIQ is the risk factor index for quality. Eq. (3)*

The experts who participated in the field survey identified 39 significant risk factors to be considered in the analysis step, the total number of the survey questionnaires responded by experts was 84 whereas the distributed questionnaires were 110. The average years of experience of the participants was 15 to 20 years [43]. Figure (5) is showing the calculated risk factor indices values for the significant 39 factors. According to brainstorming sessions held to discuss the results of risk significance, the experts decided to select the top 10 risk factors ranked according to their values of RFIT, RFIC, and RFIQ as shown in table (2). Then, the list was reviewed, and the replicated factors were identified. The approach followed to rank the risks is based on the effect of the risk factor on the project objectives i.e. the risk factor which affects the three objectives was considered as the most important, then the risks which are affecting two objectives e.g. time and cost or cost and quality then the factors which are affecting one objective i.e. time, cost and quality respectively. Table (3) is showing the most critical risk factors ranked in descending order based on the pre-described approach according to the RFIT values then RFIC then RFIQ. RF1 is affecting the three objectives of the project hence it's considered the riskiest factor, While RF78 and RF16 are considered key risk factors for time and cost. Moreover, RF80, RF62, and RF66 are considered key risk factors for time and quality. Whereas RF52 is solely affecting both cost and quality. The list includes 21 risk factors that will be considered in the risk allocation phase using the Delphi Technique.

TABLE (2)
TOP TEN RISK FACTORS ACCORDING TO RFIT, RFIC, AND RFIQ

Rank	RFIT	Risk factor
1	0.378	RF78
2	0.346	RF16
3	0.322	RF1
4	0.318	RF5
5	0.310	RF70
6	0.306	RF75
7	0.305	RF73
8	0.305	RF72
9	0.302	RF66
10	0.297	RF62

Cont. table (2)

Rank	RFIC	Risk number
1	0.728	RF60
2	0.718	RF82
3	0.698	RF1
4	0.678	RF17
5	0.668	RF69
6	0.648	RF68
7	0.645	RF48
8	0.644	RF16
9	0.642	RF52
10	0.640	RF78

Rank	RFIQ	Risk number
1	0.713	RF61
2	0.681	RF76
3	0.678	RF62
4	0.675	RF52
5	0.673	RF80
6	0.648	RF1
7	0.636	RF66
8	0.600	RF75
9	0.597	RF69
10	0.594	RF4

TABLE (3)
THE MOST CRITICAL RISK FACTORS BASED ON THEIR RFIT, RFIC, AND RFIQ

Risk number	Risk Factor	Rank
RF1	Shortage of project socuments, data, and details during the design phase & lack of pre-studies.during design stage.	**1**
RF78	Delay in starting the next layer of the backfilling layers leads to rework due to erosion of the current layer.	**2**
RF16	Shortage of fuel stock in the site due to high prices or oil crisis.	**3**
RF75	Review of design drawings and study diff. Sections of the roadway.	**4**
RF62	Unavailability of nearby source to supply the granular soil " crushed stone".	**5**
RF66	Unavailability or high prices of oil products/ Bitumen.	**6**
RF52	Lack of experienced and competent laborers.	**7**
RF5	Inaccurate setting out of the main control points of the project.	**8**
RF70	A Shortage of diesel stock in the site due to high prices or oil crisis. Shortage of diesel	**9**
RF73	Poor coordination between the project different parties, including the infrastructure	**10**
RF72	Lack of local authority control on the water resources and soil stocks e.g. desert roadways.	**11**
RF60	Poor grading of the granular soil.	**12**
RF82	Poor quality control at the batch plant.	**13**
RF17	Poor management of the available resources and equipment.	**14**
RF69	Lack of water sources along the roadway route.	**15**
RF68	Existence of poor types of soil at the roadway route.	**16**
RF48	Lack of competent /experienced surveyors.	**17**
RF61	Discontinuity or delay in crushed stones	**18**
RF76	Non-compliance with code of practice and standards.	**19**
RF75	Usage of low-quality raw materials.	**20**
RF4	Change in project scope during the preparations stage.	**21**

VIII. DELPHI METHOD

The Delphi technique is a formalized tool used to gather data and attain consensus on an issue. An advantage of this technique is that it's not necessary for all experts to be physically located in one place, which facilitates the process of data collection and helps to overcome geographic constraints [35]. (Thanh Nguyen et al., 2020) stated that the Delphi technique is basically designed to collect the most reliable consensus from a group of experts through conducting a series of questionnaires accompanied with controlled opinion feedback, and each new round is getting its data from the results of the previous round. Another advantage of Delphi method is the ability to gather the data from individuals or relevant specialists irrespective to their backgrounds of expertise and experience which might be varied [36]. Moreover, Delphi method has been designed to be a communication technique which allows to collect the maximum amount of unbiased judgements from a group of experts [36]. A thesis, published on 2000, stated that in the case of collecting subjective opinions from some professionals who participated in the Delphi method, it will also lead to objective outcomes [37]. Therefore, the Delphi technique is considered one of the best-known consensus-reaching methodologies.

The Delphi method typically incorporates the selection of appropriate professional participants, upgrading the questions to be asked to them and analyzing their responses. The participants' selection process is very important to the reliability of the outcomes and the experts should be carefully selected among those who have relevant trusted experience [38]. The number of rounds may reach seven and could be achieved by single or double rounds, while the majority of the studies ended up using three rounds in order to achieve a satisfactory and steady degree of consensus. Regarding the required number of participants in the Delphi method, commonly it's required to engage fifteen to twenty participants while in some cases a small group of fewer than fifteen participants can achieve reliable results in case of homogeneity [38], [39]. The experts participating in the Delphi should meet four "expertise" requirements: 1) knowledge and experience with the survey issue; 2) capacity and readiness to participate; 3) sufficient time for participation; and, 4) effective communication skills [40].

The Delphi method is well suited as a research tool when there is incomplete or partial knowledge about an issue or phenomenon. It's well known that the Delphi method is an extremely popular instrument to build up a framework, forecast, prioritize the alternatives, and for decision-making as well [41]. (Vidal et al., 2011) stated that many researchers have surveyed a variety of studies that have utilized the Delphi method such as Adler & Ziglio, 1996; Linstone & Turloff, 1975; Rowe & Wright, 1999 [39]. Moreover, a team of academics used the Delphi method to identify the principal legal problems facing the computer forensics discipline in Australia. (Vaughan & Vaughan, 1997) and (Yamaguchi et al., 2001) used the Delphi method to identify the significant parameters that measure the degree of project complexity[38] and [41]. (Zaghloul, 2005) utilized a Delphi method for Identifying and assessing future challenges for supply chain security in a multi-stakeholder environment based on risk analysis [42].

IX. DELPHI RESULTS AND FINDINGS

In this study, the panel of experts who were selected to participate in the Delphi method were selected among the wide range of experts in the field of RCPs in Egypt. A panel of 13 experts with average years of experience exceeding 15 years of experience were selected, the same panel of experts participated in the two rounds of the Delphi technique. The participants represented a wide range of roadways experts as some of them were owner representatives, consultants, and contractors as well. The outcome of each round was analyzed, and brainstorming sessions were conducted to attain the final results of the Delphi method. At the first round of the Delphi method, the experts were asked to allocate the risks to the party who can best manage them. The survey proposed 3 risk allocation categories to bear the liability of taking the suitable risk management action towards a certain risk factor. The three categories were, 1) the owner, 2) the contractor, or 3) shared between the owner and the contractor. The results of the first round were analyzed and confirmed through brainstorming sessions, the experts allocated the risk factors to the party who is able to manage and control the risk factor better than the other party. In the second round of the Delphi method, the participants were asked to allocate the risks again and they were given the choice to change their minds and to change their selections in the first round. Also, they were asked to define and select the proper risk response or risk management action among one of the following actions: 1) risk Mitigation, 2) risk Avoidance, 3) Insurance, 4) Control, and 5) Contract Clause. A high level of consensus regarding the liability of risk allocation was achieved in the second round. The consensus was achieved by considering the party that has more than 50% of the experts' votes, the results of the Delphi survey are shown in table (4) including the proper risk management actions from the experts' point of view.

The readings in table (4) i.e. the findings of the Delphi method are showing that 12 risk factors were allocated to the contractor i.e. 57% and 2 risk factors were allocated purely to the owner i.e. 10%, while 7 risks were allocated as shared liability between the owner and the contractor i.e. 33% of the major risk factors, as shown in figure (5). Furthermore, figure (6) is showing the percentages of the risk management actions allocated to each risk factor, the "risk control" action represented 33% of the risk actions allocated to the major risk factors while the "contract clause" action represented 24%. Moreover, both "avoidance" and "mitigation" represented 19% for each action while the "insurance" represented 5% of the proposed risk response.

The statistics of table (4) and Figures (5&6) are indicating the importance of the risk factors control to manage and control the risk factors as well as the importance of the contractual clauses which are decreasing the disputes among the project parties. In addition to increasing the likelihood of project success in terms of time, cost, and quality since the control measures and contract clauses represent 57% of the risk management actions. While, the "insurance" will be very important towards the force majeure risks e.g. extreme bad weather conditions, and sandstorms

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TABLE (4)
DELPHI RESULTS IN ROUND 1 AND ROUND 2

	Delphi 1			Delphi 2			Allocated	Risk Action
Risk number	**Owner**	**Cont.**	**Shared**	**Owner**	**Cont.**	**Shared**		
RF1	30.8%	46.2%	23.1%	23.1%	53.8%	23.1%	Contractor	Avoidance
RF78	23.1%	38.5%	38.5%	15.4%	23.1%	61.5%	Shared	Mitigation
RF16	46.2%	23.1%	30.8%	53.8%	15.4%	30.8%	Owner	Contract clause
RF75	7.7%	15.4%	76.9%	15.4%	23.1%	61.5%	Shared	Avoidance
RF62	23.1%	23.1%	53.8%	15.4%	30.8%	53.8%	Shared	Insurance
RF66	30.8%	38.5%	30.8%	15.4%	53.8%	30.8%	Contractor	Control
RF52	23.1%	38.5%	38.5%	23.1%	30.8%	46.2%	Shared	Control
RF5	15.4%	15.4%	69.2%	23.1%	15.4%	61.5%	Shared	Mitigation
RF70	23.1%	30.8%	46.2%	30.8%	15.4%	53.8%	Shared	Contract clause
RF73	38.5%	30.8%	30.8%	23.1%	61.5%	15.4%	Contractor	Mitigation
RF72	15.4%	46.2%	53.8%	23.1%	53.8%	23.1%	Contractor	Control
RF60	15.4%	38.5%	46.2%	23.1%	61.5%	15.4%	Contractor	Avoidance
RF82	23.1%	38.5%	38.5%	23.1%	53.8%	23.1%	Contractor	Control
RF17	30.8%	23.1%	46.2%	15.4%	15.4%	69.2%	Shared	Contract clause
RF69	23.1%	46.2%	30.8%	23.1%	53.8%	23.1%	Contractor	Contract clause
RF68	30.8%	46.2%	23.1%	15.4%	61.5%	23.1%	Contractor	Control
RF48	23.1%	53.8%	23.1%	15.4%	53.8%	30.8%	Contractor	Avoidance
RF61	15.4%	61.5%	23.1%	23.1%	61.5%	15.4%	Contractor	Mitigation
RF76	38.5%	46.2%	15.4%	30.8%	53.8%	15.4%	Contractor	Control
RF80	7.7%	53.8%	38.5%	15.4%	61.5%	23.1%	Contractor	Control
RF4	53.8%	23.1%	23.1%	61.5%	23.1%	15.4%	Owner	Contract clause

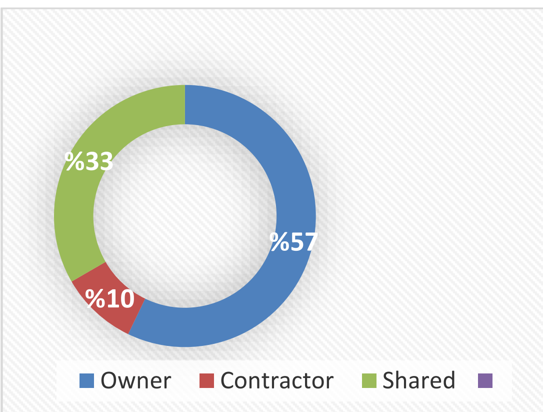

Figure (5) risk allocation percentages

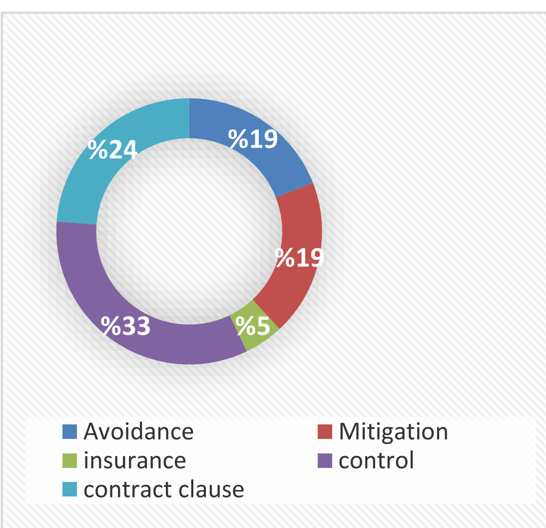

figure (6) risk response percentages

X. Conclusions

Roadway's construction industry is subjected to plenty of risks due to the complex nature of this industry which increases the likelihood and possibility of risks that are involved in the roadways construction environment. Risks associated with RCPs include external risks such as; economical risks, political risks, etc. and internal risk e.g. financial risks, contractual risks, design-related risks, and technical risks. These risks are commonly creating losses relevant to project objectives i.e., project delay, budget overrun, poor quality. Usually, in construction projects, the client tends to convey most of the risk consequences to the contractor. However, a one-sided attitude regarding risk allocation, in which one party tries to dispatch all risk to other parties, probably result in undesirable effects to all parties. The allocation of the potential risk losses to the project parties helps them to improve and enhance their behavior towards the control and preventive measures that may reduce the cost of risk-taking. It also leads to mitigating contractual disputes in construction projects. Eventually, it will lead to achieving the project objectives with the maximum benefits to all parties in addition to good relationships and reputation beyond the project handing over. Therefore, this study utilized and presented RAM model in order to properly and effectively allocate the risk factor to the proper party, the main results of the study can be summarized as follows:

- Introducing a risk register of the risk factors affecting RCPs execution contains 88 risk factors.
- Classifying the risks into 7 groups according to the responsible party for each risk factor whether it's the responsibility of 1) the owner, 2) the contractor, 3) the

consultant, 4) personnel & laborers, 5) suppliers & subcontractors, 6) mutual responsibility among (owner-contractor), or 7) mutual responsibility among (contractor-consultant).

- Identifying the key risk factors affecting RCPs based on the combined effect of the likelihood and impact on time, cost, and project quality for each risk factor i.e., according to the values of risk factors indices (RFIT, RFIC, and RFIQ).
- Specifying the major risks affecting the project objectives and might be a reason for future disputes i.e., the recurring key risk factors which are affecting multiple objectives of the project outcomes e.g. time and cost or cost and quality. 21 risks were identified as major risk factors.
- Generating risk allocation model RAM in order to allocate a certain risk to the proper party who can manage and control that risk.
- Allocating the major risk factors to the appropriate party who can address them. The risks were allocated to one of three categories i.e., the contractor, the owner, or shared liability between both.12 major risk factors were allocated to the contractor i.e. 57% and 2 risk factors were allocated to the owner i.e. 10%, while 7 risks were allocated as shared liability between the owner and the contractor i.e. 33% of the major risk factors.
- The suitable risk management action to each risk factor was identified. the percentages of the risk management actions allocated to each risk factor, the “risk control” action represented 33% of the risk actions allocated to the major risk factors while the “contract clause” action represented 24%. Moreover, both “avoidance” and “mitigation” represented 19% for each action while the “insurance” represented 5% of the proposed risk response.
- The proposed RAM is simple, flexible, and can be easily utilized by the parties involved in RCPs.
- The RAM is useful to decision-makers to take the appropriate decision while comparing between the projects, particularly at the tendering stage as well as controlling the ongoing projects.
- The application of the proposed RAM will help the project parties to effectively control the risks, achieve project success, and decrease disputes.

AUTHORS CONTRIBUTION

1. Conception or design of the work ***(Dr. Usama H. Issa- 40%- Engr. Khaled G. Marouf 30%-Dr. Hamdy Badee Faheem** 30%)*
2. Data collection and tools (***Engr. Khaled G. Marouf*** 50***% - Dr. Hamdy Badee Faheem*** *50%)*
3. Funding Acquisition: N/A
4. Data analysis and interpretation ***(Dr. Usama H. Issa- 40%- Engr. Khaled G. Marouf 30%-Dr. Hamdy Badee Faheem** 30%)*
5. Investigation ***(Dr. Usama H. Issa- 40%- Engr. Khaled G. Marouf 30%-Dr. Hamdy Badee Faheem** 30%)*
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10. Supervision ***(Dr. Usama H. Issa- 60%- Dr. Hamdy Badee Faheem** 40%)*
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12. Critical revision of the article ***(Dr. Usama H. Issa- 40%- Engr. Khaled G. Marouf 30%-Dr. Hamdy Badee Faheem** 30%)*
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Title Arabic

المسئوليات و توزيع المخاطر المؤثرة علي مشروعات الطرق

Arabic Abstract

بسبب قلة وجود نماذج لتوزيع المخاطر في مشروعات التشييد، يهدف المالك عادةً إلى نقل جميع المخاطر إلى المقاول الذي يحاول نقلها إلى الموردين والمقاولين من الباطن. ويكون هذا سببا لكثير من النزاعات والخلافات التي تؤثر في النهاية على نجاح المشروع. في هذه الدراسة ، تم تصنيف عوامل المخاطر المرتبطة بتنفيذ مشاريع الطرق بناءً على المسؤوليات وتم تحديدها للطرف الذي يمكنه التقليل منها بشكل أفضل بالإضافة إلى اقتراح خطة أكثر فاعلية لإدارة المخاطر. تم تقسيم مسؤوليات المخاطر من خلال تصنيف 88 عامل من عوامل المخاطر من خلال 7 مجموعات للمسئوليات و تم تقديم نموذج لتوزيع المخاطر الرئيسية علي الطرف المناسب (المالك أو المقاول أو المسؤولية المشتركة بين الطرفين). علاوة على ذلك ، من خلال النموذج المقترح تم اقتراح الاجراء المناسب للتعامل مع كل عامل من عوامل المخاطر. ومن أجل إنشاء نموذج توزيع المخاطر، تم اعتماد واستخدام طريقة دلفي لتخصيص المخاطر للطرف المناسب واقتراح الاستجابة المناسبة للمخاطر. يمكن استخدام النموذج للمقارنة بين عدد من المشاريع لدعم متخذي القرار في اختيار المشروع الأقل خطورة. من خلال إجراء مراجعة مكثفة للدراسات السابقة وسلسلة من جلسات العصف الذهني، تم تحديد مسؤوليات كل عامل من عوامل المخاطر المحدده سابقا. تم تحديد التأثير المتوقع على الوقت والتكلفة والجودة وتم تحديد المخاطر ذات التصنيف الأعلى بناءً على قيمة مؤشرات عوامل المخاطرة وتم تحديد نسب المخاطر الرئيسية بناءً على نتائج طريقة دلفي كالاتي : 57٪ للمقاول ، 10٪ للمالك بينما 33٪ كانت مسؤولية مشتركة بين كليهما. علاوة على ذلك ، فإن النسب المئوية لإجراءات إدارة المخاطر المخصصة لكل عامل كانت، "التحكم في المخاطر" يمثل 33٪ ، و "اضافة بند في العقد" يمثل 24٪ ، ومع ذلك ، فإن كلا من "التجنب" و "التخفيف" يمثلان 19٪ لكل إجراء بينما يمثل "التأمين" 5٪ فقط من الاستجابات المقترحة للمخاطر. وأخيرا فإن نموذج توزيع المخاطر المقترح يساعد صانعي القرار على اتخاذ القرار المناسب لصالح المشروع والمقارنة بين المشاريع أيضًا.