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THE APPLICATION OF RISK MANAGEMENT PROCESS FOR INDUSTRIAL PROJECTS

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Abstract: Risk is inevitably embedded in the construction industry, especially in industrial projects where high impact risks occur due to the complex nature of those projects. The application of risk management process becomes necessary to mitigate the impact of numerous unique risks. This paper introduces a three-tier risk assessment framework for industrial projects with application to power plant construction projects in Egypt. The research introduces a risk management framework comprising the different steps in a risk management process, namely; risk identification, analysis, response and, monitoring. The research starts by conducting an extensive literature review to identify risk factors pertaining to industrial projects, the output is further enhanced using feedback from experts. Probability and impact of identified risks are deducted from available reports and structured interviews. Subsequently, risk scores for different risk types are calculated and used to recommend the expected risk classes, proactive actions to mitigate the risk, and, contingency actions in case the risk was accepted. The model is applied to a Power plant construction project in Egypt. The calculated risk index is compared against the actual risk index. The paper demonstrates the importance of the application of risk management process at the early stages and the practical methods to identify project risks and classes for industrial and power plant projects in Egypt.

1 INTRODUCTION

Construction industry is one of the most dynamic, risky and challenging businesses regardless of the project size (Hayes et al. 1986, Thompson and Perry 1992). Nonetheless, the industry acquired a very bad reputation in managing risks and consequently, many major projects fail to achieve their planned deadlines and cost targets (Hayes et al. 1986). Construction project risk factors include; project complexity, location, speed of construction, variations in weather, productivity of labor and plant, quality of material, and, familiarity with the type of work. Risks and their associated uncertainty are proven to cause damaging consequences for projects through affecting productivity, performance, quality, and the project budget (Mills 2001). According to (Hayes et al. 1986); construction risks are either ignored or dealt with in a complete arbitrary way through adding a fixed percentage to the estimated cost as a contingency. However, this approach is often inadequate for complex construction projects as expensive delays, litigation, and even bankruptcy are among the common consequences. Risk can only be minimized, transferred or retained but cannot be eliminated (Burchett et al. 1999). Therefore, a formal risk management plan ensures risks are managed in the most efficient manner to provide the best balance of cost, time, quality and performance for the parties involved while attaining the best value for money. This research conducts a risk management framework for a proactive assessment of Power Plant projects construction in Egypt. The assessment process begins with risks identification and classification based on previous historical data and experts' knowledge. Data is arranged and documented to an integrated risk register developed to contain all risk pertaining to power plants construction projects. Impact, probability and cost are identified for each risk. After the identification and classification phase; response management proceeds to identify the suitable response action, response action cost, contingency plan, and, response matrix to identify the responsible personnel for each stage. The analysis process proceeds to identify the correct additional cost which should be added to the project budget as a contingency to account for probable risks.

2 LITERATURE REVIEW

Risk management is described as a systematic way of looking at areas of risk and consciously determining how each should be treated. It is a management tool that aims at identifying sources of risk and uncertainty, determining their impact, and, developing appropriate management responses. A systematic process of risk management has been divided into five steps; risk classification, risk identification, risk analysis, risk response and risk monitoring and control (Uher 2003, Smith 2006). Risk management should be an important and integral part of any construction project management. It is currently well and widely recognized by the leading project management institutions (Simon et al. 1997).

2.1 Industrial Projects

Mega construction projects are usually described as projects complying with one or more of the following descriptions (Rodney 1999; Bruzalius et al. 2002; Flyvbjerg et al. 2003; Molenaar 2005);

a. having substantial investments (more than 1 billion dollars),
b. enduring long schedules (over two years),
c. being a public infrastructure, or invested in or commissioned by governments,
d. having a long design life span of 50 years or more,
e. generating multiple social impact.

Mega construction projects pose great difficulties and challenges to project management (Rodney Turner 1999; Bruzalius et al. 2002; Flyvbjerg et al. 2003; Molenaar 2005). This is accounted back to their nature of having huge investments and long construction periods, as well as a number of uncontrollable factors during construction causing uncertainty to project management. In addition, the long-designed lifecycle and complex construction process requires high coordination level between construction methods due to the large number of participants and the required cross-professional works. Besides, mega construction projects are often composed of many individual project groups, each with its own objectives, which is usually different from each other. This creates conflicts, contradictions of resources, schedules, and, staff scheduling. Furthermore, with social and public property, mega projects often generate high public attention and strong government intervention intensity, therefore, external coordination is also a key to managing mega projects. Industrial construction projects are considered mega projects which involve several specialities related to industrial equipment and machinery. Consequently, multi-disciplinary collaboration is required in the implementation and construction process, and civil engineering works must be well-coordinated which requires managers to communicate in a more strategic and comprehensive manner.

2.2 Power Plants and Water Projects

Demands on Independent Water and Power Project (IWPP) are rapidly increasing throughout the globe. (Voelker et al. 2008) state that many countries face significant growth in the water and power demand, estimated at 7% annually for the coming decade and doubling approximately every ten years. In order to satisfy this demand, an urgent need exists for investment into water and power infrastructures. The subsequent increase in the number of IWPPs constructed (along with their high capital requirements) places considerable strain on economies; particularly those of developing countries (Zhao et al. 2009). IWPP projects are more risk intensive in the areas of finance, completion, operation, market, political and environment, with some risks being unique to this sector and a challenge to any industry (Wolfs and Woodroffe 2002).IWPP projects are regarded as particularly risky due to the fact that: (1) they require multiple, complex interdependent agreements between multiple private and public sector parties; (2) they have a lengthy lifecycle; (3) they require considerable investment with high upfront costs; (4) they have a long payback period; (5) they require considerable effort in their developmental stages, due to their complex structure and processes; (6) they are susceptible to political and economic risks; (6) they involve a complex contract mechanism, involving many participants with diverging interests, potentially imposing limitations (Thomas et al. 2006). In general, industrial/infrastructure projects have had a history of subjecting investors to major risks and (in some cases) cancellations (Harris et al. 2003). The success of many projects have been overshadowed by delayed start-ups, contract cancellations, and, legal disputes, partially due to the lack of any formalized approach to the project Risk Management (RM) process (Tah and Carr 2000). (Hlaing et al. 2008) point out that the formulation of an effective RM approach is crucial to minimizing such risks. Furthermore, the success of any IWPP project is based on effective RM between both public and private sectors (Tah and Carr 2000; Wibowo and Mohamed 2008; Thomas et al. 2006; VoelkerNet al. 2008).

2.3 Construction Risks of Industrial Projects

The literature shows numerous efforts have been done to identify and manage risks in industrial projects. (Zaripoura & Zaripour, 2016) Issued a questionnaire to assess potential risks which may occurs through the construction of any industrial project. The survey divided all risks into seven main classes as follows; 1- Embargo, 2- Economic, 3- Scheduling, 4- Weakness in management, 5- Cultural/Social, 6- Force majeure, and 7- Contract. Whereas, the research conducted by (Ameyaw & Chan, 2013) identified eight major risk categories in an effort to increase awareness of the risks that can erode or reduce potential benefits of industrial projects especially IWPP. The study identified and prioritized risks and its classes through a comprehensive literature review to identify the most critical risks as seen in Table 1.

Table 1 Classification of risks encountered in past/ongoing IWPP (adapted from Ameyaw & Chan 2013)

No.	Risk Category/Class
1	Political and regulatory risks
2	Operational risks
3	Market/revenue risks
4	Financial risks
5	Relationship risks
6	Project and private consortium selection
7	Social risks
8	Third party risks

On the other hand, (Zhao et al. 2012) identified risks related to industrial projects using a literature review survey. Risk prioritization was established based upon the repetition number of each risk. The model developed by (Aragonés-Beltrán 2013) constituted a three-level risk model. The model was developed to help the managing board of an important Spanish solar power investment company decide whether to invest in a particular solar-thermal power plant project and, if so, to determine the order of priority of the projects in the company's portfolio. In order to take such a decision, risks related to the construction of industrial projects were identified, weighted, and, managed. The three levels included;

1. **Level 1.** In which each new proposal submitted to the company is analyzed using a set of criteria called Level-1 criteria. Level-1 criteria only requires the direct management to have a basic knowledge of the project and this level involves relatively low engineering cost. In this level, a hierarchy model using the Analytical Hierarchy Process (AHP) can be used for project Acceptance or Rejection.
2. **Level 2.** The proposals that have been accepted in Level 1 are analyzed using a new set of criteria, called Level-2 criteria. These new criteria require the direct management to have a broader and deeper knowledge of the project as they are used to conduct project feasibility analysis. Once again, the alternatives of the decision problem are project Acceptance or Rejection.
3. **Level 3.** Accepted projects pass to Level 3, which means investing money in project execution.

Regardless of the method of analysis; common risks were identified by numerous authors. Based on the literature review conducted, those risks are considered the most repetitive and pertaining to industrial projects.

3 Methodology

3.1 Introduction

The methodology adopted in this research is illustrated in Figure 1. The literature review presented different methodologies for risk identification and accordingly different risk classes. A preliminary risk checklist was prepared from the literature review. The checklist contains the top five repeated risk classes and was the basis of the model analysis. The risk classes identified are as follow: 1- Political, Social & Legal Risks. 2- Construction & Scope Risks. 3- Financial & Market Risks. 4- Relationships & Third Parties Risks. 5- Force Majeure Risks. The probability, impact and range of responses for those risks were further identified using a questionnaire survey. A risk index was developed based on the collected data, class weights were computed using the Analytical Hierarchy Process. The calculated risk score is then used as the method of prioritization of the studied risks.

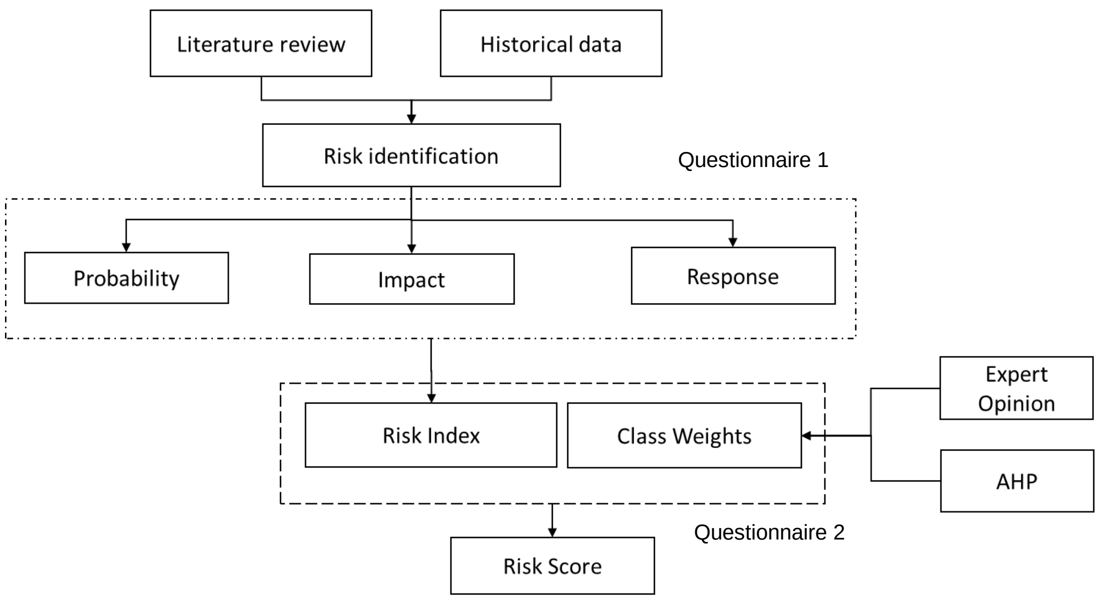
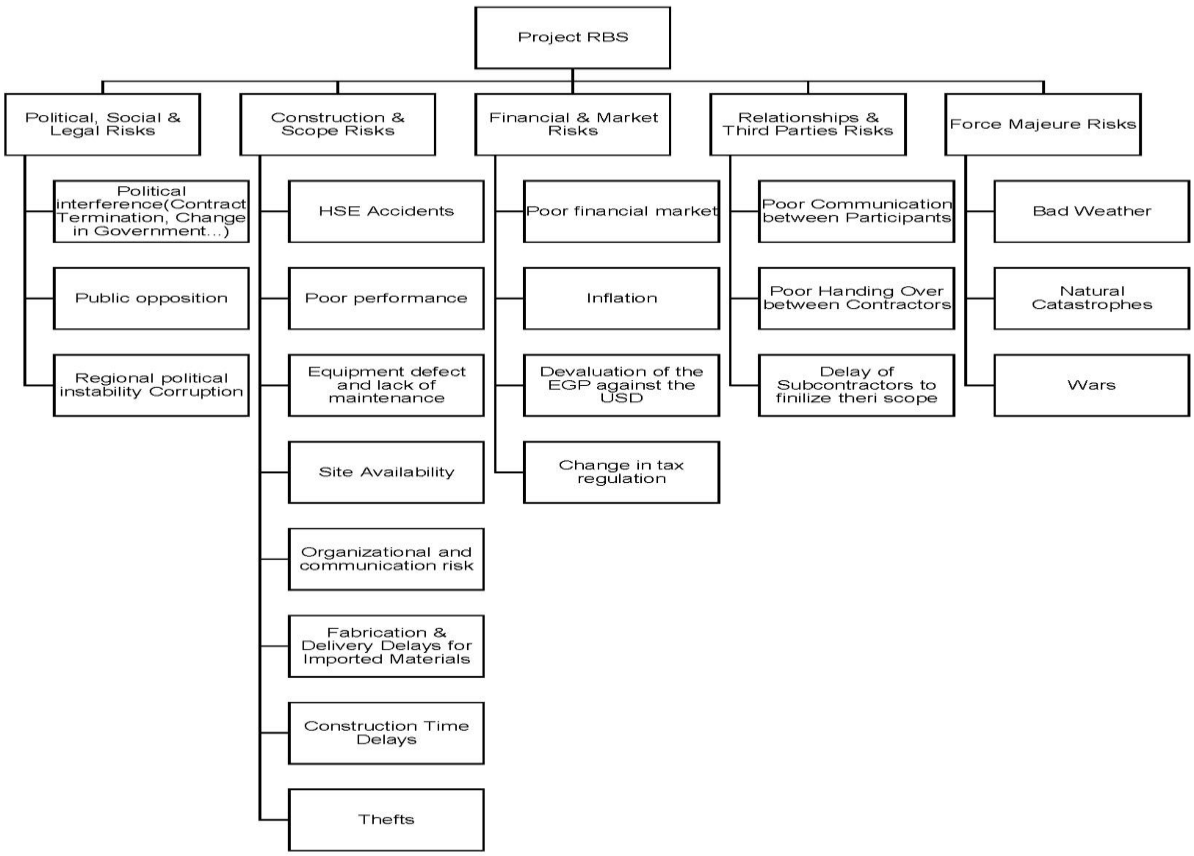


Figure 1 Research methodology framework

3.2 Risk Identification and Classification

Risk cannot be managed unless it is first identified. Accordingly, Risk Identification process is considered the first step in risk any management process. The fact that some risks are unknowable or emergent require the risk identification process to be iterative; repeating the risk identification process to find new risks which have become knowable since the previous iteration of the process. From the literature review, it can be concluded that risks have to be listed and categorized for better controlling and judgment. It is also determined that industrial projects have a lot of unique risk factors different from other types of projects. A filtering process has been applied to the above identified risks in order to: 1- Remove repeated risks from different sources, 2- Combine similar risks into one descriptive risk factor, 3- Remove any un-applicable risks for this research area. The final filtered risks related to construction of industrial projects in Egypt were compiled in a Risk Breakdown Structure as presented in Figure 2.



. Figure 2 Developed Risk Breakdown Structure

3.3 Risk Modeling

Risk modeling process is conducted to identify probability, impact and suitable response actions for each identified risk factor. The value of these factors depends heavily on the individual circumstances for each project such as geographical location, project conditions, contract type, and political environment. The model is developed to be applied for IWPP projects in Egypt and accordingly, expert's judgement are required to identify which of the defined factors pertain to the Egyptian environment and what are their expected values. Questionnaire 1 is developed and launched in order to gather and utilize experts' judgments to identify the required information about risks related to the construction of industrial projects in Egypt.. The questionnaire will mainly collect data regarding the expected values for risk probability, impact and response action, defined as follows:

Risk Probability: the likelihood of a risk occurrence. A unified scale from 1 to 5 is proposed to represent risk probability as shown in Table 2.

Risk Impact: defined as the severity of risk in case of occurrence. When a risk occurs, it affects the project on different perspectives. Risks may affect project objectives in terms of cost, time, scope, Health, safety and environment (HSE), company reputation, quality …etc. Based on literature review and expert's opinion, four areas of risk impacts were selected, those are, impact of risk on time, cost, project scope or HSE. In an effort to simplify the model, only two areas of impacts are measured per each risk factor.

However, the impact of each field is measured differently, hence, cost is measured in currency units, time in time units, scope in currency units and HSE in number of incidents. Therefore, a unified scale was also introduced to identify the severity of each risk as shown in Table 2.

Table 2 Proposed probability and impact score

Score	Probability Score definition	Impact score definition
1	Never	Insignificant
2	Often	Minor
3	Likely	Moderate
4	Very Likely	Major
5	Certain	Critical

Risk Response Action: defined as the action which shall be implemented in order to avoid, transfer or mitigate the impact of risk before its occurrence. Such action is completely dependent on the experts' judgment and experience gained from participating in previous similar projects. Accordingly, this section was left to each participant to state the most suitable response action for each risk in order to avoid, transfer or mitigate the impact of risk.

3.4 Risk Index

Risk index (RI) is a score given for each identified risk which represents the importance and priority of each risk taking into consideration its probability and impact scores. Accordingly, risk index shall be calculated using "Equation 1":

[1] $\text{Risk Index (RI)} = \text{Porbability Score} \times \frac{\sum \text{Impact Fields}'\text{Scores}}{\text{No.of Impact Fields}}$

3.5 Class weights

The importance of each risk category differs based upon the unique nature of each project location and the nature. In order to identify such importance, a weighting system shall be developed for all identified classes by comparing classes to each other. A pairwise comparison shall be issued through a matrix by using experts' judgment to identify the total weight of each class. A comparison scale shall be used and adopted from (Saaty 2001) pairwise comparison scale as shown in Table 3.

Table 3 Saaty pairwise comparison scale

Intensity of Importance	Definition
1	Equal Importance
3	Weak Importance of over another
5	Essential or Strong Importance
7	Demonstrated Importance
9	Absolute Importance

In order to calculate the weighting score based on pairwise comparison the Analytical Hierarchy Process (AHP) was selected. AHP carries out both deductive and inductive thinking through taking several factors into consideration simultaneously and allowing for dependence and feedback among criteria and sub-criteria. This helps perform numerical trade-offs between different criteria to arrive at a synthesis or a conclusion (Saaty 2008). There are several assumptions when the AHP is applied to make decisions; the independence between higher level elements and lower level elements, the independence of the elements within a level, and the hierarchy structure of the decision problem (Saaty 1994).

3.6 Risk Score

After identifying classes weights and risks indices for each factor, a risk score can be calculated for each factor representing the total and overall importance, probability and severity. Accordingly, risk score (RS) shall be calculated through the following "Equation 2":

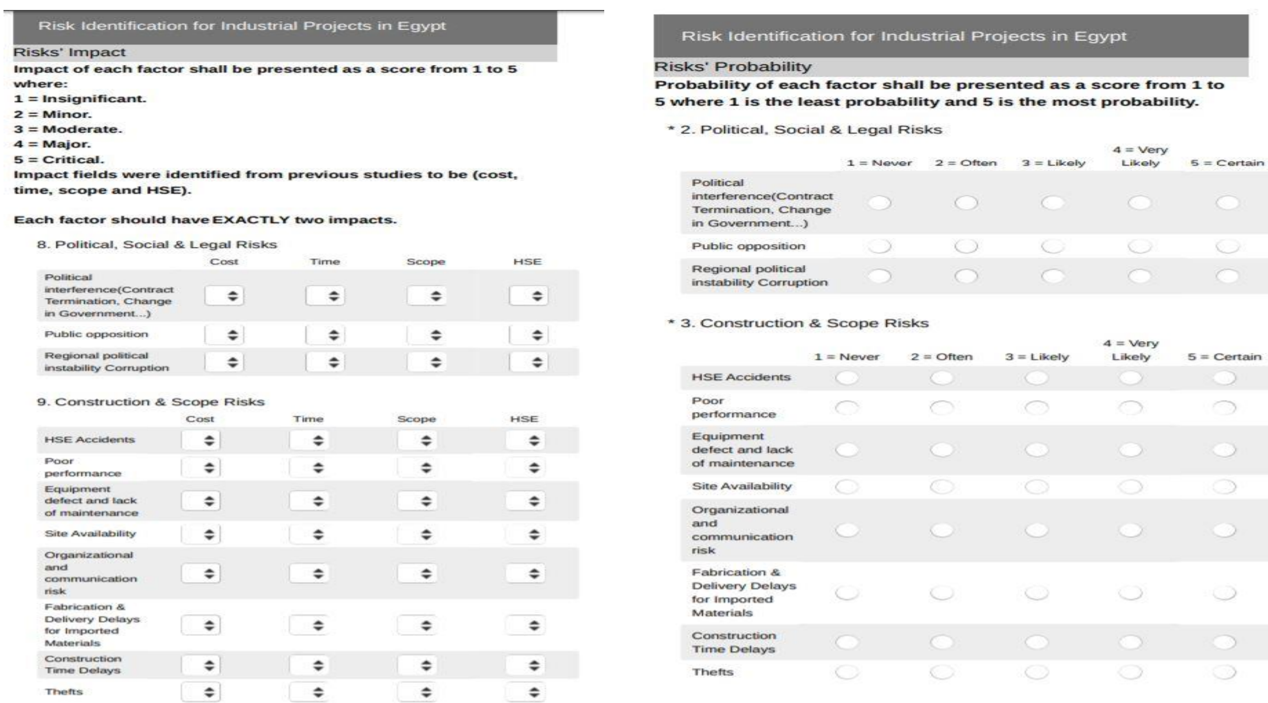
[2] Risk Index (RS) =Risk Index (RI) × Relative Class Weight

4 APPLICATION

The proposed risk model is demonstrated using data from the construction of a power plant project in Egypt. The project objective is to convert an existing single cycle power station into a combined cycle station. The scope of the targeted project includes building of all required facilities, infrastructures and services for the power plant stations. Five experts with more than ten years of experience in construction project management and participated in the targeted project were recruited to participate in the case study.

4.1 Data Gathering

In order to collect the required data from experts, an online based questionnaire was developed and distributed by e-mails. The questionnaire was sent to 49 experts who previously participated in an industrial projects including mainly; project managers & superintendents, department's managers, project controls engineers & senior site engineers, while 40 questionnaires were completed and received from the experts. The online questionnaire's structure consists of four major sections explained as follows and illustrated in Figure 3.



Risk Identification for Industrial Projects in Egypt

Risks' Impact

Impact of each factor shall be presented as a score from 1 to 5 where:
1 = Insignificant.
2 = Minor.
3 = Moderate.
4 = Major.
5 = Critical.
Impact fields were identified from previous studies to be (cost, time, scope and HSE).

Each factor should have EXACTLY two impacts.

8. Political, Social & Legal Risks

	Cost	Time	Scope	HSE
Political interference(Contract Termination, Change in Government...)				
Public opposition				
Regional political instability Corruption				

9. Construction & Scope Risks

	Cost	Time	Scope	HSE
HSE Accidents				
Poor performance				
Equipment defect and lack of maintenance				
Site Availability				
Organizational and communication risk				
Fabrication & Delivery Delays for Imported Materials				
Construction Time Delays				
Thefts				

Risk Identification for Industrial Projects in Egypt

Risks' Probability

Probability of each factor shall be presented as a score from 1 to 5 where 1 is the least probability and 5 is the most probability.

* 2. Political, Social & Legal Risks

	1 = Never	2 = Often	3 = Likely	4 = Very Likely	5 = Certain
Political interference(Contract Termination, Change in Government...)					
Public opposition					
Regional political instability Corruption					

* 3. Construction & Scope Risks

	1 = Never	2 = Often	3 = Likely	4 = Very Likely	5 = Certain
HSE Accidents					
Poor performance					
Equipment defect and lack of maintenance					
Site Availability					
Organizational and communication risk					
Fabrication & Delivery Delays for Imported Materials					
Construction Time Delays					
Thefts					

Figure 3: Sample Online Questionnaire for section 2 and section 3

<u>Section 1:</u> includes the questionnaire introduction where the researcher is introduced, the purpose of the questionnaire is presented, and, the questionnaire structure is described. Section 1 also contains the personal data required from each participant in addition to communication methods.

Section 2: includes questions to identify probability for each risk where all identified risks are listed with their respective classes. The probability is measured on a five-point scale as explained in Methodology section. Each participant was requested to read the listed risks carefully and select any box from 1 to 5 indicating the probability of each risk.

Section 3: includes questions to identify impact for each risk where, all identified risks are listed with their respective classes. Each participant was requested to read the listed risks carefully and select 2 impact fields for each risk then type a score from 1 to 5 for each selected field based on the scoring scale identified.

Section 4: includes questions to identify the Response Action for each risk, where, all identified risks are listed with their class. The questions in this section are open ended to allow for the different types of response action based upon the experts' past experience. Moreover, a response action is identified per decision to avoid, transfer, or mitigate the impact of each risk.

4.2 Data Analysis

The data collected from experts was summarized and analysed. The outcome of this phase is the preliminary risk register shown in Table 4.

Table 4: Preliminary Risk Register (Risk Index RI)

Risk Class	Risk Factor	Prob.	Impact				Risk Index	Response Action
			Cost	Time	Scope	HSE		
Political, Social, and, Legal Risks	Political interference	3	0	4	4	0	12	Add penalties in case of contract termination
	Public opposition	2	0	0	3	4	7	Increase the risk OH in the tender phase
	Regional political instability Corruption	3	3	4	0	0	11	Increase the risk OH in the tender phase
Construction and Scope Risks	HSE Accidents	3	3	0	0	4	11	Increase safety officers with high performance
	Poor performance	3	4	4	0	0	12	Hire qualified staff & manpower
	Equipment defect and lack of maintenance	2	3	4	0	0	7	Hire maintenance group standing by any time
	Site Availability	3	0	4	3	0	11	Increase the risk OH in the tender phase
	Organizational and communication risk	3	0	3	3	0	9	Hold weekly internal meeting
	Fabrication & Delivery Delays for Imported Materials	4	5	5	0	0	20	Finalise the procurement process within 60 days
	Construction Time Delays	4	0	5	5	0	20	Develop a complete and revised project plan.
	Thefts	2	3	3	0	0	6	Increase the security staff
Financial & Market Risks	Poor financial market	3	4	5	0	0	14	update the cash flow Bi-weekly
	Inflation	5	4	4	0	0	20	Close monitoring of movements in the market through market studies
	Devaluation of the EGP against the USD	4	5	0	4	0	18	Increase the risk OH in the tender phase
	Change in tax regulation	4	5	0	3	0	16	Increase the risk OH in the tender phase
Relationships and Third Parties Risks	Poor Communication between Participants	3	0	4	3	0	11	Hold weekly internal meeting
	Poor Handing Over between Contractors	3	3	3	0	0	9	Hire a coordinator Engineer
	Delay of Subcontractors to finalize their scope	4	0	5	5	0	20	Employ more than one subcontractor for each item
Force Majeure Risks	Bad Weather	2	0	4	0	4	8	Work on holidays
	Natural Catastrophes	1	0	5	0	4	5	Increase the risk OH in the tender phase
	Wars	1	0	0	5	5	5	Study the political situation before project

For impact fields, only the most two impacted fields were accounted for. Risk Index was calculated using Equation 2 for each risk factor. The research is still in the development stage and accordingly, more expert feedback is expected to enhance the model. Nevertheless, the collected data so far has been analyzed and it displayed that the top 5 risks with highest combination of probability and severity were:

1- Fabrication & Delivery Delays for Imported Materials,
2- Construction Time Delays,
3- Inflation,
4- Devaluation of the EGP against the USD,
5- Delay of Subcontractors to finalize their scope (mainly considered other stakeholders' responsibility).

In addition, Construction & Financial risks are the most severe risks due to its direct relation with the project objectives.

For response actions, it was found that most of experts are dealing with probable risks proactively and before project start. Most of experts identified the tendering phase as the most effective phase while studying probable risks and setting its suitable response actions. Also, better project's monitoring and controlling techniques is advised and recommended by experts through project's execution in order to identify the probable and unforeseeable risks in an early stage.
These results prove that a proactive response action implemented before the project's start are more valuable and effective than other actions implemented through the project.

Increasing the number of participants will be included in order to gather more accurate descriptive data. Also, experts' judgment will be required and gathered through a pairwise comparison questionnaire in order identify the overall weights of each class. Subsequently, a risk score will be calculated for each factor by in order to represent the total and overall importance, probability and severity.

5 CONCLUSION

Industrial projects are characterized by high complexity and interdisciplinary phases leading to increased risks affecting the main project objectives of time, cost and scope. Nevertheless, the current approach for addressing risk in industrial projects is mainly reactive, depending upon including a contingency value in the contract price and dealing with risks after they have occurred. Interestingly, the literature identifies several areas of expected risk factors for industrial project, specifically IWPP projects which have increased in the past decade. Nevertheless, the occurrence and severity of risk factors is largely dependent upon the project characteristics and environment in which the project is undertaken. This paper adopts the formal risk management framework for assessing and managing risk in industrial projects with focus on IWPP. Preliminary risk identification is done using data collected from literature review. This data is rectified using expert's opinion and a formal RBS for IWPP is presented. Risk probability and score are collected using a questionnaire survey using a five-point scale for normalization and simplification purposes. The suitable risk response action is identified by means of expert's opinion. The framework albeit in the development stage, was partially applied to data gathered from of a water and power plant construction project in Egypt. It can be concluded that top risks expected are mainly caused by other stakeholders which participate in the project. The identified risks have great impact on the project objectives, however, their impacts can be significantly minimized if an action is taken proactively. This research urges the importance of applying a risk management plan in construction project especially before the start of the project and through the tendering phase.

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