A Suggested Module for Risk Framework of Water Control Construction Projects using Qualitative and Quantitative Techniques

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I. INTRODUCTION

Risk is defined as an uncertain event or condition that, if it occurs, has a positive or negative effect on a projects objectives / deliverables due to limited knowledge of the projects consequences versus deliverables / objectives [7]. Projects are exposed to both internal risks such as financial, design, contractual, construction and operational risks, also external risks such as force majeure, bad weather conditions, and legalization problems. All the risks may influence the cost, time or quality of the projects in positive or negative ways [4]. Risk management is an important and vital part of the decision-making process in projects and widely accepted as an important tool in the management of complicated construction projects with interacted activities [10]. There are a lot of risks with multiple and complex manners found in construction industry, because of variety of elements for enterprise environmental factors (EEF) of these projects. The application of risk management used in solving problems that construction projects suffer from it in the past, as to create an alternative ways for proper functioning in execution of projects [5].

Project risk management (PRM) includes the processes of conducting risk management planning, identification, analysis, response planning, response implementation, and monitoring risk on a project in order to optimize the chances of project success and to achieve the project deliverables. According to the Project Management Institute (PMI) project risk management is one of the nine most critical parts of project management to achieve a successful commissioning and start-up phase. This indicates a strong relationship between managing risks and projects success [6].

In (figure 1), in construction industry, (PRM) related to Build-Operate-Transfer (BOT) projects should be considered depending on the impact of (EEF) and the organizational system.

A. Previous studies in risk management construction projects

Saeed (2018) [8] discuss the cost and time risk management in construction projects stating that business risk in general is the probability that an actual return of an investment will be less than the expected return. This research is aimed to reduce the influence of business risk in construction projects, by an accurate identifying and evaluating risk through (PRM) cycle.
Pooworakulchais (2018) discuss applied (PRM) in construction industry stating that risk management is applied to many organizations. The Author stated that there are three important things for the applying risk management process which are “Manpower, project data and continuous learning”. 

Sharma (2011) [9] aims to show a risk management framework for a construction projects and demonstrate its application in an ongoing construction project in Amaravati, Maharashtra, India. As through (EEF) the various risk factors encountered in construction projects and various risk management methods already in use were identified and then a framework was developed which combines the (AHP) and risk map methods.

B. Risk management related to water control structures in Egypt

Water Scarcity in Egypt: Egypt is a part of the Mediterranean basin is characterized by a very complex hydrological system, as its rainfall intensity is low where the capital Cairo average rain fall intensity is 30 mm/year and it almost depend on the Nile river flow as the main source of water.

The growth of the Egyptian population and tight economic situation in Egypt leads to an increase in the demand of water and the overall water allocation priority where basically goes to drinking water, industry and whatever is remaining will be available for agriculture and nature. Because the agricultural sector uses more than 80% of available water due to high water losses in this sector [2]. Water scarcity began in Egypt from almost at the beginning of Year 2000.

Limitation of study for the risk management related to water control structures projects in Egypt: There is a large number of hydraulic water control structures in the Nile valley and in the Nile Delta, which play an important role in controlling, distribution and allocation of water, but mostly these structures are in different stages of degradation. The main problems with these structures include hydraulic inefficiency resulting from leakage and dysfunctional of gate operating. Also these structures suffer from structural instability resulting from erosion for its foundation, differential settlement caused by high traffic loads which lead the necessity of re-habitation and construct a new water control structures on the water streams and channels in Egypt.

The limitation of this study is to conduct a total framework for risk management process in the construction of water control structures in Egypt, which are classified as follows:

- Head regulators at the off-takes of canals and drains.
- Intermediate regulators within water streams
- Hydraulic structures located within irrigation canals and drains such as box and pipe culverts

II. PROBLEM STATEMENT

Most of the owner project managers in Egypt still take their decisions based on their intuitions, judgment, and experience rather than systematic risk management process [11]. This leads to not achieve cost target and finish the project upon schedule because of this randomly process in taking decisions for any construction project [1].

There are a unique and special risks related to water control construction projects such as “Variation in cost of material and equipment” and “Environmental incompatibility” and “Geotechnical issues and soil analysis troubles” are considered as special risks factors effecting on the cost and time targets for these projects in Egypt compared to other conventional construction projects.

The complex characteristics of these construction projects. Also facing of challenges, tight economic situations and a unique enterprise environmental situation in Egypt. This leads the necessity for predicting the project risks and an essential need to improve management performance and use these support techniques. This study shows the perception and attitude of the construction of water control structure projects in Egypt towards risks factors and categories. It is mainly concerned with the allocation
III. RESEARCH METHODOLOGY

The study methodology accomplished in this research is simply classified in the following chart as follows (figure 2):

A. Risk categories should adopted for risk management in the construction of water control structures in Egypt

- **Market and financial risks:** As market risks are related to the ability to forecast the quantities and prices of outputs and the services provide. And the financial risks is related to risks which involved in attracting investors and moving forward with a project, and includes inability to restructure financial arrangements and unexpected changes of cash flows.
- **Supply chain risks:** is related to the price and the availability of resources and materials supplied which used in execution of the project.
- **Technical risks:** include risks associated with unproven or complex technology, changes in technical methodology anticipated during the phases of the project.
- **Performance risks:** include labor and equipment productivity problems or lower than required. Also may include miss coordination between projects participants.
- **External risks:** includes those aspects that are external to the project, such as new laws or regulation, bad weather conditions and change foreign policies for projects performed in other countries.

B. List of significant risk factors effecting on cost and time for construction of water control structures in Egypt

The following table (I) & table (II) shows the list of significant risk factors effecting on cost and time which is identified by mean of studying related pervious publishing which concerned to risk management in construction projects and a questionnaire survey.

| Table- I: List of significant risk factors effecting on cost | Risk factors |
|------------------------------------------------------------|--------------|
| No. | Risk categories | Risk factors |
|-----|-----------------|--------------|
| 1   | Market and financial risks | Increase in rate of inflation than estimated |
|     |                  | Unexpected changes in cash flow |
|     |                  | Restructuring in financial agreements |
| 2   | Supply chain risks | Variation in the cost of materials |
|     |                  | Variation in the cost of equipment |
|     |                  | Vendors delaying |
|     |                  | Wrong methodology in material transportation to site |
| 3   | Technical risks  | Over-design of some project items |
|     |                  | Unproven technology to be applicate in site |
|     |                  | Electro-mechanical design is not compatible with hydraulic design |
|     |                  | Geotechnical issues and soil - analysis troubles |
|     |                  | Wrong estimation of constructability methods |
| 4   | Performance risks | Labor productivity lower than required |
|     |                  | Equipment productivity lower than required |
|     |                  | Wrong selection of an equipment type for a certain task in the project |
|     |                  | Deficiency of human resources for project participants (poor organization ) |
|     |                  | Not following safety regulation and Environmental impact not taken into consideration |
|     |                  | Commissioning and start-up problems |
| 5   | External risks   | Bad weather conditions |
|     |                  | Catastrophic natural phenomena and Force majeure |
|     |                  | Energy and water supply troubles |
|     |                  | Site accessibility troubles |

The table- I shows (22) significant risk factors subsidiary form risk categories effecting on the cost for construction of water control structures in Egypt, which constructed on water streams and these factors is identified mostly from similar executed projects in the past of ten years which stated by project managers and experts.
### Table II: List of significant risk factors effecting on time

| No. | Risk categories               | Risk factors                                                                 |
|-----|-------------------------------|-----------------------------------------------------------------------------|
| 1   | Market and financial risks    | Change in market demands                                                     |
|     |                               | Restructuring in financial agreements                                       |
|     |                               | Change in stockholders orders or views                                       |
| 2   | Supply chain risks            | Un-availability of some materials                                            |
|     |                               | Un-availability of some equipment                                            |
|     |                               | Delaying in vendor supplying                                                |
|     |                               | Electro-mechanical design is not compatible with hydraulic design            |
|     |                               | Geotechnical issues and soil - analysis                                      |
|     |                               | Wrong estimation of constructability methods                                 |
| 4   | performance risks             | Labor productivity lower than required                                       |
|     |                               | Equipment productivity lower than                                             |
|     |                               | Wrong bidding items or tendering documents                                    |
|     |                               | Change in managerial philosophy                                              |
|     |                               | Deficiency of human resources for project participants (poor organization)   |
|     |                               | Commissioning and start-up problems                                          |
| 5   | External risks                | Bad weather conditions                                                       |
|     |                               | Catastrophic natural phenomena and Force majeure                             |
|     |                               | Energy and water supply troubles                                             |

The table-II shows (18) significant risk factors subsidiary form risk categories effecting on the time for construction of water control structures in Egypt, which constructed on water streams and these factors is identified mostly from similar executed projects in the past of ten years which stated by project managers and experts.

### IV. QUALITATIVE ANALYSIS OF RISK FACTORS

In this stage after identification of risk factors, The Analysis of risk factors taking place as the list of significant risk factors shown is assessed by project managers and experts whom fill the questionnaire.

The influence of each significant risk factor calculated by the following Equation:

$$R.I = \Sigma I/N$$  \hspace{1cm} (1)

Where (R.I) is the mean value of the influence of risk factor.

(I) influence of risk factor in each questionnaire.

(N) Number of questionnaire.

**Qualitative probability and severity risk matrices:**

A qualitative risk analysis is conducted, and the aim to do risk analysis is to isolate the critical risk factors and exclude those have a lower impact. Using Probability and Severity risk matrix (S/P matrix).

### Table III: Qualitative risk analysis matrix concerning cost

| Severity | From 0 to 3% | From 3% to 10% | From 10% to 20% | From 20% to 30% | More than 30% |
|----------|--------------|----------------|-----------------|-----------------|---------------|
| Rare     | 1            | 2              | 3               | 4               | 5             |
| (1)      | (2)          | (3)            | (4)             | (5)             |
| Unlikely | 2            | 4              | 6               | 8               | 10            |
| (2)      | (3)          | (4)            | (5)             |
| Possible | 3            | 6              | 9               | 12              | 15            |
| (3)      | (4)          | (5)            |
| Likely   | 4            | 8              | 12              | 16              | 20            |
| (4)      | (5)          |
| Certain  | 5            | 10             | 12              | 20              | 25            |
| (5)      |               |                |                 |

Increase in budget

### Table IV: Qualitative risk analysis matrix concerning time

| Severity | From 0 to 3% | From 3% to 10% | From 10% to 20% | From 20% to 30% | More than 30% |
|----------|--------------|----------------|-----------------|-----------------|---------------|
| Rare     | 1            | 2              | 3               | 4               | 5             |
| (1)      | (2)          | (3)            | (4)             | (5)             |
| Unlikely | 2            | 4              | 6               | 8               | 10            |
| (2)      | (3)          | (4)            | (5)             |
| Possible | 3            | 6              | 9               | 12              | 15            |
| (3)      | (4)          | (5)            |
| Likely   | 4            | 8              | 12              | 16              | 20            |
| (4)      | (5)          |
| Certain  | 5            | 10             | 12              | 20              | 25            |
| (5)      |               |                |                 |

Increase in Duration

Where: The probability when it is:

- (Rare) it means that the risk may happen from zero to one time all over the project.
- (Unlikely) it means that the risk may happen from two times all over the project.
- (Possible) it means that the risk may happen from three times all over the project.
- (Likely) it means that the risk may happen from four times all over the project.
- (Certain) it means that the risk may happen from five or more times all over the project.

And then from the qualitative matrices the risk is classified into the following according their influences, where:

- From (15 to 25) considered as Critical Risks: These should be reduced or eliminated with preventative controls and should be subjected to continuous evaluation and testing. These risks pose maximum risk to the project.
From (6 to 12) considered as High Risks: These are significant, but are less likely to occur. They need to be monitored on a rotational basis. These risks are second priority after critical risks.

From (3 to 5) considered as Moderate Risks: They are less significant, but have a higher likelihood of occurring. These risks should be monitored to ensure that they are being appropriately managed.

From (1 to 2) considered as Low Risks: They are both unlikely to occur and not significant. They require minimal monitoring.

The completed risk assessment map should give the manager a basis for assessing risks and addressing each one in accordance with its potential impact on business strategy and risk mapping is shown in (figure 3):

![Risk Mapping](image)

Fig .3 Risk Mapping classified into four parts

V. QUANTITATIVE ANYLSIS OF CRITICAL RISK FACTORS

In the qualitative stage the Critical risk factors effecting on cost and time is isolated to enter AHP. The Steps of quantitative analysis adopted in this research using AHP are

- The Critical risk factors are then arranged in a hierarchical tree structure.
- Elements in each level are compared pairwise on a scale of 1-9 with respect to their importance in making the decision under consideration. 1 – Equally preferred, 3 – moderately preferred, 5 – strongly preferred, 7 – very strongly preferred and 9 – extremely preferred. If the manager feels that the importance lies in between the given preferences, he can use the middle values of 2, 4, 6 and 8.
- The composite weights of the decision alternatives are then determined by aggregating the weights through the hierarchy. This is done by following path from the top of the hierarchy to each alternative at the lowest level and multiplying the weights along each segment of the path.

And the critical risk factors concerning cost are:
1- Variation in the cost of materials.
2- Variation in the cost of equipment.
3- Geotechnical issues and soil - analysis troubles.
4- Force majeure.
5- Commissioning and start-up problems.
6- Labor productivity lower than required.

And the analysis shows the cost and the time contingency is calculated from the qualitative matrices referring to the value of the combined critical risks influences which shows that
1- The cost contingency is 12.35%.
2- The time contingency is 11.25%.

And the critical risk factors concerning time are:
1- Un-availability of some materials.
2- Un-availability of some equipment.
3- Geotechnical issues and soil - analysis troubles.
4- Force majeure.
5- Commissioning and start-up problems.
6- Labor productivity lower than required.

And the following tables (V) & (VI) shows the analytical

| Table-V: Using (AHP) to measure cost contingency |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | Normalize Criteria weight |
| 1 | 1 | 1/4 | 5 | 4 | 3 | 0.24 |
| 2 | 1/3 | 1/2 | 1/2 | 3 | 2 | 0.11 |
| 3 | 4 | 2 | 1 | 3 | 5 | 0.36 |
| 4 | 1/5 | 2 | 1/3 | 1 | 6 | 0.19 |
| 5 | 1/4 | 1/3 | 1/5 | 1/6 | 1 | 0.05 |
| 6 | 1/3 | 1/2 | 1/7 | 1/7 | 1 | 0.05 |

Combined Critical Risks influence =17.666

| Table-VI: Using (AHP) to measure time contingency |
|---|---|---|---|---|---|---|
| 1 | 2 | 3 | 4 | 5 | 6 | Normalize Criteria weight |
| 1 | 1 | 1/3 | 4 | 4 | 3 | 0.24 |
| 2 | 1/2 | 1 | 1/2 | 1/2 | 3 | 1/2 | 0.11 |
| 3 | 3 | 2 | 1 | 3 | 5 | 0.36 |
| 4 | 1/4 | 2 | 1/3 | 1 | 5 | 0.19 |
| 5 | 1/4 | 1/3 | 1/5 | 1/5 | 1 | 0.05 |
| 6 | 1/3 | 2 | 1/5 | 1/5 | 1 | 0.05 |

Combined Critical Risks influence =16.02
VI. RESULT OF RESEARCH

The tables shows the final research result

| No. | Significant risk factors                                                                 | Qualitative analysis | Cost contingency |
|-----|-----------------------------------------------------------------------------------------|----------------------|-----------------|
| 1   | Geotechnical issues and soil - analysis troubles                                         | 20                   |                 |
| 2   | Variation in the cost of equipment                                                        | 20                   |                 |
| 3   | Labor productivity lower than required                                                    | 16                   |                 |
| 4   | Variation in the cost of materials                                                        | 16                   |                 |
| 5   | Restructuring in financial agreements                                                    | 15                   |                 |
| 6   | Not following safety regulation and Environmental incompatibility                       | 15                   |                 |

VII. CONCLUSION

✔ The risk management process showed in the research should be adopted with the same methodology shown, and to be applied all over the project life cycle for the construction of water control structure projects in Egypt, as taken into consideration the risk factors shown subsidiary from each risk categories, mutually helps in optimizing the cost and the duration of these type of projects, leading to a successful project targets, as not implementing risk management process concerning hazard factors only.

✔ The cost contingency needed to account for the different risk factors defined in this research is to increase the estimated cost by 12.35% on the total estimated budget of the project. The time contingency needed to consider the different risk factors affecting on the project time is to increase the scheduled time by 11.25% over the total originally scheduled of the project.

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