



Ain Shams University
Faculty of Engineering
Department of Structural Engineering

Risk Assessment in the Construction of Potable Water Treatment Plants in Egypt

A Thesis submitted in partial fulfilment of the requirements of the degree
of

Master of Science In Civil Engineering
(Structural Engineering)

By

Ahmed Mostafa Awad

Bachelor of Science In Civil Engineering
(Structural Engineering)

Faculty of Engineering, El Shorouk Academy, 2008

Supervised By

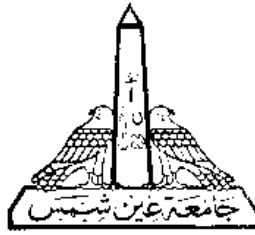
Prof. Dr. Ibrahim Abd El Rashid

Professor of Construction Projects Management
Department of Structural Engineering
Faculty of Engineering
Ain Shams University

Dr. Mohamed Tantawy

Assistant Professor of Project Management
Department of Civil Engineering
Faculty of Engineering
Helwan University

Cairo (2019)



Ain Shams University
Faculty of Engineering
Department of Structural Engineering

Risk Assessment in the Construction of Potable Water Treatment Plants in Egypt

A Thesis submitted in partial fulfillment of the requirements of the degree
of Master of Science in Civil Engineering
(Structural Engineering)

By

Ahmed Mostafa Awad

Bachelor of Science In Civil Engineering
(Structural Engineering)

Faculty of Engineering, El Shorouk Academy, 2008

Examiners' Committee

Name and Affiliation

Signature

Prof. Dr. Ibrahim Abd El Rashid

.....

Professor of Project Management, Structural
Engineering Department, Faculty of
Engineering, Ain Shams University
(Advisor)

Prof. Dr. Ali Sherif Abdel Fayyad

.....

Professor of Concrete and Construction
Management, Structural Engineering
Department, Faculty of Engineering, Ain Shams
University
(Examiner)

Prof. Hossam El Dien Hosny

.....

Professor of Project Management, Structural
Engineering Department, Faculty of
Engineering, Zagazig University
(Examiner)

Cairo (2019)

CONTENTS

Title	Page No.
List of Fig.s	
List of Tables	
Acknowledgment	
Abstract	
<u>1-Chapter (1) Introduction</u>	
1.1 General	1
1.2 Problem Statement	2
1.3 Research Objectives	2
1.4 Scope of Research	3
1.5 Methodology	3
<u>2 Chapter (2) Literature review</u>	
2.1 Introduction	4
2.2 Risk	4
2.2.1 Risk Definitions	4
2.3 Causes of Risks as Threats	6
2.4 Sources of Risks	8
2.5 The Process of Risk Management	9
2.5.1 The Risk Management Life Cycle	11
2.5.2 Project Risk Management Process	12
2.5.2.1 Establishing Risk Context	12
2.5.2.2 Risk Identification	13
2.5.2.3 Analysis of Risk	16
2.5.2.3.1 Analysis of Risk Qualitatively	17
2.5.2.3.1.1 Risk Qualitative Analysis (Tools and Techniques)	18
2.5.2.3.2 Analysis of Risk Quantitatively	20
2.5.2.3.2.1 Quantitative Risk Analysis and Modeling Techniques	21
2.5.2.4 Risk Evaluation	23
2.5.2.5 Risk Response	24
2.6 Previous Studies in Risk Management	28
2.6.1 International Studies	28
2.6.2 Middle East Studies	30
2.6.3 Egyptian Studies	31
<u>3 Chapter (3) Research Approach and Methodology</u>	
3.1 Introduction	33
3.2 Research Methodology	33
3.3 The Risk Management Process	34
3.4 Risk Identification and Initial Assessment	35
3.5 Questionnaire Content	39
3.6 Risk Response	40
3.6.1 Risk Response Strategies	41
3.6.2 Methodology of Achieving Risk Mitigation and Response	41
3.7 Statistical Sampling	42
3.7.1 Sample Selection	42
3.7.2 Sample Size	42
<u>4 Chapter (4) Risk Identification and Assessment for Potable Water Treatment Plant Projects Data Collection, Analysis, and Results</u>	
4.1 Introduction	44
4.2 Expert Background	44

4.2.1 Respondents' Companies	45
4.2.2 Respondents Company Ownership type	46
4.2.3 Respondents Company Representative role	47
4.2.4 Respondents' Technical Background	48
4.2.5 Respondents' Years of Experience	49
4.2.6 Company Years of Experience	50
4.3 Data Analysis	51
4.3.1 Statistical Techniques	51
4.3.2 Qualitative Risk Analysis	52
4.3.2.1 Risk Score	53
4.3.2.2 Importance Index	54
4.4 Survey Results	55
4.4.1 Identification of Significant Risk Factors	55
4.4.2 Result of Statistical Analysis for Probability of Occurrence	56
4.4.3 Result of Statistical Analysis for Probability of Consequence	62
4.4.4 The Result of the Survey	70
4.4.5 Risk Factor for Each Risk Group	77
5 <u>Chapter (5) System Development</u>	
5.1 Introduction	116
5.2 Suitable Problems for Expert System Application	116
5.3 Main Steps for development of A.R.M.S.	116
5.3.1 Data Collection Required for Developing of A.R.M.S.	117
5.3.2 Programming of A.R.M.S.	117
5.4 Running A.R.M.S.	118
5.4.1 The Input Screens for A.R.M.S.	119
5.4.2 The Output Screens for A.R.M.S.	120
5.5 A.R.M.S. Automation and Testing	120
5.5.1 Project Data	120
5.5.2 Interface Input Screens	121
5.5.3 Interface Output Screen	126
6 <u>Chapter (6) Conclusions and Recommendations</u>	
6.1 Introduction	128
6.2 Conclusions	128
6.2.1 Risk Identification and Qualitative Assessment	128
6.2.2 Risk Response Methods and Techniques	128
6.3 Research Contributions	130
6.4 Recommendations for Future Work	130
<u>References</u>	131
<u>Appendix A</u>	
<u>Appendix B</u>	

LIST OF FIG.S

Title	Page No
Fig. 2-1 Causes of Risk as Threats by, (Rwelamila, P. and Lobelo, 1997).	7
Fig. 2-2 Sources of Risks, (Estate Management Manual: Court Service, 2001)	8
Fig 2-3: Straightforward Risk Management Process	9
Fig 2-4 A Five Phases Methodology Risk Management	10
Fig. 2-5 Risk Management Process (Raz & Michael, 2001)	10
Fig 2-6 The Risk Management Related Actions	11
Fig. 2-7 The Risk Management Life Cycle (Ragab, 2003).	11
Fig. 2-8 Project Risk Management Process (Hassan 2004),	12
Fig. 2-9 Combined Method of Risk Identification (Ragab (2003)	15
Fig. 2-10 Source of Information (Kerzener, 1998).	15
Fig .2-10 Life Cycle Risk Analysis (Kerzener, 1998).	16
Fig. 2-12 Components of Risk Analysis (Kindinger, 2000).	17
Fig. 2-13 Probability and Impact Matrix	19
Fig. 2-14 The Quantitative Analysis Approach (Render, 2003)	21
Fig. 2-15 Decision Tree Diagram	22
Fig. 2-16 Risk Response Strategies	25
Fig. 3-1 Research Steps and Outputs	34
Fig. 3-2 The Schematic Diagram of the Methodology (Powell 1996).	35
Fig 3-3 The R.B.S. Potable Water Treatment Plants Construction Projects	37
Fig. 4-1(a) Frequency Histogram for the Respondents' Companies.	45
Fig.4-1(b) Percentage of Frequency for the Respondents' Companies	45
Fig. 4-2(a) Frequency Histogram for the Respondents' Companies Ownership.	46
Fig.4-2(b) Percentage of Frequency for the Respondents' Companies Ownership.	46
Fig. 4-3(a) Frequency Histogram for the Respondents' Companies Role.	47
Fig.4-3(b) Percentage of Frequency for the Respondents' Companies Role.	47
Fig. 4-4(a) Frequency Histogram for the Respondents' Technical Background	48
Fig.4-4(b) Percentage of Frequency for the Respondents' Technical Background	48
Fig. 4-5(a) Frequency Histogram for the Respondents' Years of Experience.	49
Fig.4-5(b) Percentage of Frequency for the Respondents' Years of Experience.	49
Fig. 4-6(a) Frequency Histogram for the Company Years of Experience.	50
Fig.4-6(b) Percentage of Frequency for the Company Years of Experience.	50
Fig.4-7 The Average Risk Factor According to Risk Nature	77
Fig.4-8 The Average Risk Factor According to Risk Groups.	77
Fig.4-9 Risk Score for Each Risk in Contractor Risk Group.	78
Fig. 4-10 Frequency of Risk Response Strategy in Contractor Risk Group	82
Fig. 4-11 Percentage of Frequency of Risk Response Strategy in Contractor Risk Group	82
Fig. 4-12 Risk Score for Each Risk in Design Risk Group	83
Fig. 4-13 Frequency of Risk Response Strategy in Design Risk Group	85
Fig. 4-14 Percentage of Frequency of Risk Response Strategy in Design Risk Group	85

Title	Page No
Fig.4-15 Risk Score for Each Risk in Equipment & Labor Risk Group	86
Fig. 4-16 Frequency of Risk Response Strategy in Equipment & Labor Risk Group	88
Fig.4-17 Percentage of Frequency of Risk Response Strategy in Equipment and Labor Risk Group	89
Fig. 4-18 Risk Score for Each Risk in Owner Risk Group	89
Fig. 4-19 Frequency of Risk Response Strategy in Owner Risk Group	93
Fig. 4-20 Percentage of Frequency of Risk Response Strategy in Owner Risk Group	94
Fig.4-21 Risk Score for Each Risk in Site Risk Group	94
Fig. 4-22 Frequency of Risk Response Strategy in Site Risk Group	97
Fig. 4-23 Percentage of Frequency of Risk Response Strategy in Site Risk Group	97
Fig. 4-24 Risk Score for Each Risk in Supplier & Material Risk Group	98
Fig. 4-25 Frequency of Risk Response Strategy in Supplier (Material) Risk Group	99
Fig. 4-26 Percentage of Frequency of Risk Response Strategy in Supplier (Material) Risk Group	100
Fig. 4-27 Risk Score for Each Risk in Technical Risk Group	101
Fig.4-28 Frequency of Risk Response Strategy in Technical Risk Group	104
Fig. 4-29 Percentage of Frequency of Risk Response Strategy in Technical Risk Group	104
Fig. 4-30 Risk Score for Each Risk in Commissioning and Maintenance Risk Group	105
Fig. 4-31 Frequency of Risk Response Strategy in Commissioning and Maintenance Risk Group	106
Fig. 4-32 Percentage of Frequency of Risk Response Strategy in Commissioning and Maintenance Risk Group	106
Fig. 4-33 Risk Score for Each Risk in Economic Risk Group	107
Fig. 4-34 Frequency of Risk Response Strategy in Economic Risk Group	110
Fig. 4-35 Percentage of Frequency of Risk Response Strategy in Economic Risk Group	110
Fig. 4-36 Risk Score for Each Risk in Environmental Risk Group	111
Fig. 4-37 Frequency of Risk Response Strategy in Environmental Risk Group	112
Fig. 4-38 Percentage of Frequency of Risk Response Strategy in Environmental Risk Group	112
Fig. 4-39 Risk Score for Each Risk in Political Risk Group	113
Fig. 4-40 Frequency of Risk Response Strategy in Political Risk Group	115
Fig. 4-41 Percentage of Frequency of Risk Response Strategy in Environmental Risk Group	115
Fig. 5-1 Fig. 5-1 the Main Screen of A.R.A.R.D	118
Fig. 5-2 Page No.1 in Add New Project Path	121
Fig. 5-3 Page No.2 in Add New Project Path	122
Fig. 5-4 Page No.3 in Add New Project Path	122
Fig. 5-5 Page No.1 in Edit an Existing Project Path	123
Fig. 5-6 Page No.2 in Edit an Existing Project Path	124

Title	Page No
Fig. 5-7 Page No.3 in Edit an Existing Project Path	124
Fig. 5-8 Page No.4,5 in Edit an Existing Project Path	125
Fig. 5-9 Part No.1 in the Output Screens	126
Fig. 5-10 Part No.2 in the Output Screens	127
Fig. 5-11 Part No.3 in the Output Screens	127

LIST OF TABLES

Title	Page No.
Table 2.1 Definitions of Expression Related to Risk:(Shortreed, j., Hicks, J., Craig, 2003)	6
Table 2-2 Risk response strategies -Source: (Khodier et al., 2015)	25
Table 4.1 Respondents' Companies	45
Table 4.2 Respondents' Companies Ownership	46
Table 4.3 Respondents' Companies Role.	47
Table 4.4 Respondents' Technical Background.	48
Table 4.5 Respondents' Years of Experience.	49
Table 4.6 Company Years of Experience.	50
Table 4-7 Numerical Values for Likelihood and Impact Rating-Source: (Cooper 2005).	53
Table 4-8 The Result of Frequency of Risk Probability of Occurrence	56
Table 4-9 The Result of Statistical Analysis for Probability of Occurrence	59
Table 4-10 The Result of Frequency of Risk Consequence	62
Table 4-11 The Result of Statistical Analysis for Risk Consequence	66
Table 4-12 The Result of Statistical Analysis of Overall Risk Significant	70
Table 4-13 Twenty Most Significant Risks in Egypt Construction Industry	74
Table 4-14 Risk Score for Each Risk in Contractor Risk Group	78
Table 4-15 Risk Response Strategies for Contractor Risk Group	82
Table 4-16 Risk Score for Each Risk in Design Risk Group	83
Table 4-17 Risk Response Strategies for Design Risk Group	84
Table 4-18 Risk Score for Each Risk in Design Risk Group	86
Table 4-19 Risk Response Strategies for Equipment & Labor Risk Group	88
Table 4-20 Risk Score for Each Risk in Owner Risk Group	89
Table 4-21 Risk Response Strategies for Owner Risk Group	93
Table 4-22 Risk Score for Each Risk in Site Risk Group	95
Table 4-23 Risk Response Strategies for Site Risk Group	97

Table 4-24 Risk Score for Each Risk in Site Supplier & Material Risk Group	98
Table 4-25 Risk Response Strategies for Supplier (Material) Risk Group	99
Table 4-26 Risk Score for Each Risk in Technical Risk Group.	100
Table 4-27 Risk Response Strategies for Technical Risk Group	104
Table 4-28 Risk Score for Each Risk in Commissioning and Maintenance Risk Group.	105
Table 4-29 Risk Response Strategies for Commissioning and Maintenance Risk Group	106
Table 4-30 Risk Score for Each Risk in Economic Risk Group.	106
Table 4-31 Risk Response Strategies for Economic Risk Group	109
Table. 4-32 Risk Score for Each Risk in Environmental Risk Group.	111
Table 4-33 Risk Response Strategies for Environmental Risk Group	112
Table 4-34 Risk Score for Each Risk in Political Risk Group.	113
Table 4-35 Risk Response Strategies for Political Risk Group	114

Acknowledgment

I would like to express my deepest gratitude to my supervisor **Prof. Dr. Ibrahim Abd El Rashid** not only for providing the chance for this research but also for his directive supervision and continuous support and advice without his effective contribution this study would not have been successfully completed.

I would like also to express my deep thankfulness to my advisor, my mentor **Dr. Mohamed Tantawy** for his support during all the phases of the research and for his continuous guidance and support throughout preparing this thesis.

Also, thanks are given to **all participants** in potable water treatment projects who participated in the survey for their participation in the survey and their comments. Their knowledge provided valuable insights into the research.

I am fully indebted to **Mohamed Abas** for his contribution and for sparing no effort in developing the expert system (A.R.M.S. Web application) model for my research so special thanks to him.

I would finally like to express my deepest thanks to my family especially my dad, mother & my wife for their continuous encouragement, support, and endless prayers through day and night keep lighting me the way.

ABSTRACT

Life is connected through drinking water as it the most essential aspect of life, even though it though it also represent one of the highest risk for humankind (Water, 2019). Egypt is a part of the world and its population increases every day therefore it is also subject to that risk. According to the Central Agency for Public Mobilization and Statistics, drinking water in Egypt per capita fell from 88.9 m³ in 2013 to 76.9 m³ in 2014 representing 13.5% making drinking water one of Egypt's problems in the coming period. Which prompted the Egyptian government to allocate 35% from the total Egyptian government plan to develop potable and wastewater systems in 2015 (4.44 billion Egyptian pounds), equivalent to 1.5 billion Egyptian pounds. Because of the dedication of the Egyptian government represented in the ministry of housing to solve that problem, the result is the rate per capita increased by 45% from 76.9 m³/year 2014 to 112.1 m³/year 2018. The total production also increased by 38% from 7.8 billion m³/year in 2014 to 10.8 billion m³/year in 2018 (CAPMAS, n.d.). The Egyptian government represented in the ministry of housing still invest in the construction of many potable water plants to eradicate of the potable water problems. This type of projects has significant importance due to the strategic impact, big budget, tight schedules, and a lot more obstacles. As the potable water treatment plant, bear a large number of risks, which make this project one of the riskiest projects in the construction business. Two techniques were utilized literature review and meeting with professionals in the construction of this type of projects to identify and verify 56 risk factors. A questionnaire was developed to obtain a professional opinion of the impact and probability of the previously identified risk and its proper response plan. The Risk factor of each risk is calculated using $(P+C-(P \times C))$ formula. A priority list developed to identify the most significant risks. The most significant risks include Fluctuation in the currency exchange rate, delay in contractor payments to sub-contractors, tight schedule and crowding, late delivery of materials, delay in progress payments, inflation, change in energy cost. Internal project risks are slightly more important than external risks. A recommended risk strategy is presented to help contractors in selecting the appropriate approach to respond to any risk of the identified risks in this research, all of this based on the collected data. This research directed to the concerned parties of this type of projects (project manager, sponsors, etc.) to help to better prepare a proper risk plan and their mitigation strategy plan at the start of the project.

Keywords Project Management, Risk Management, Potable Water Treatment Plants, Planning & Control, and Infrastructure.

Chapter (1)

Introduction

1.1 Introduction

The construction sector is counted as one of the most active sectors affecting the Egyptian economy to the extent that about 45% of the funds allocated for the national development plans in Egypt since 1981 were allocated to the construction sector (Ahmed, 2003)[6]. Many projects constructed annually to meet the needs of Egyptian society such as bridges, tunnels, highways, roads, sewer systems, and water supply facilities (Ismail, 1999)[33]. Water treatment plants are classified as infrastructure projects that are usually administrated by public authorities. Such class of projects is critical and has different components including buildings, underground piping, and equipment. In recent decades, Egypt witnessed the construction of many water treatment plants (Mohamed Marzouk, 2015)[46].

The primary goal of every construction project is to meet stakeholder's functional requirements. It has been noted that quite often, construction projects fail to achieve their objectives (time and budget). This is frequently because of the failure of the contractor to analyze and assess seen and unforeseen risks.

Currently, many construction firms are seeking to identify and develop techniques for measuring the risks associated with construction projects, due to the increasingly competitive market. All construction projects are related to different levels of risk, regarding cost and duration depending on project complexity, resources, market prices, location, and many other challenging factors (Hassan, 2004)[30].

In the practice of construction risk management, (Perry, J.G. and Hayes, 1985)[50] stated characteristics of construction risk as risks and uncertainties are associated with specific events or activities that can be individually identified. A wide range of results materializes when a risk event happens each result has its likelihood of happening.

- Some risks offer only the prospect of adverse consequence (loss) as bankruptcy, war, sea or flood damage; these may be of low or high probability but high impact.
- Many common construction risks offer the prospect of either loss or gain as productivity of labor and plant; these are typical of high probability and may be of low or high impact.
- Subjective judgment is usually required to calculate the probability of occurrence of specific outcomes of the risk event.

1.2 Problem Statement

The construction industry faces a lot of obstacles those are multiplied in the past few years due to the circumstances of the state and because most of the contractors in the industry were not ready to face those risks. The risk management technique was not hugely adopted with the majority of the participants in the industry, which lead to a catastrophic effect on the contractors against these huge no number of unforeseen risks, which was raised in the past few years.

According to the central agency for public mobilization and statistics, the Egyptian government spends approximately 4.44 billion Egyptian pounds in the water systems and sewer systems [financial year of 2014/2015] 35% (1.5 billion Egyptian pounds) of this sum is spent on the water treatment plants. The potable water treatment plants have a significant importance due to the strategic importance, big budget, tight schedules, and a lot more obstacles, As the potable water treatment plant bear large number of risks which make it one of the riskiest project in the construction business and for a contractor to enter that kind of projects without a proper risk and risk response plan will only lead the contractor to an inevitable loss.

Therefore, a thorough study must focus on the risks and the risk responses in the potable water treatment construction project and try to come out with a framework for managing risks in the potable water treatment plant construction project to help contractors in selecting the appropriate strategy to manage the risks and uncertainties and devolve a risk response plan to counter these risks.

1.3 Research Main Objective.

These research main goals are to:

- 1- Specify the most significant risk factors related to the construction of the potable water treatment plant projects in Egypt and perform a qualitative risk assessment for such factors.
- 2- Identify the risk response strategies during the project life cycle.
- 3- Develop risk expert application (automated risk management system [A.R.M.S.]) using WordPress as web-based software to generate a web application to help contractors in selecting the appropriate strategy to respond to any risk all of this based the collected data.

1.4 Scope of Research

The range of this research includes a complete project risk management cycle (negative risks) for potable water treatment plant projects in Egypt whether constructing new plant or rehabilitation and enhancing existing plant and their associated response methods in the project life cycle. In addition, an expert web application model is developed to help contractors in this field.

1.5 Methodology

- 1- A Literature review will be carried out to identify a list of risk factors, which could affect the potable water treatment plant construction projects.
- 2- Several meetings with professionals in these types of projects will be done to verify the aforementioned list.
- 3- Based on this literature review a survey will be conducted with experts in the construction of potable water treatment plant projects to evaluate the list of the significant risk regarding (probability & impact).
- 4- Following data collection, the data will be analyzed statistically to determine the most critical factors in potable water treatment plant construction projects.
- 5- Identify the response actions and strategies that could be employed to mitigate the effect of the identified risks.
- 6- Develop a risk expert application model [A.R.M.S.]

Chapter (2)

Literature Review

2.1 Introduction

A huge number of risks faces the construction industry as the construction projects contain a great number of risks in its process because of the involvement of a considerable number of participants such as (owner-contractor etc.) (El-Sayegh, 2008)[22]. The success parameter of any project is to accomplish the project with proper (scope, time, budget and quality) that can be achieved through decision-making process which depends on two important parameters analysis and management of risk. Construction projects frequently fail to meet their time, quality and budget goals. One of the main reasons behind this is the failure of the contractor to analyze and assess project risks. The divergence in the environment of the project is considered the primary obstacle in the success of the project to meet its objectives.

The problem increases with the magnitude and nature of the construction project. The amount of risks in the internal and external environments of a project is a critical factor in deciding whether there will be scheduled and cost overruns. Thus, The frequency of increase in budget and schedule of construction project made the risk in construction a primary subject of interest. Risk management is the key tool in construction project management as it defines the needs for every aspect in project management technique example (schedule is done to avoid time overruns, etc.) Therefore, the most important process in project management is managing the risk

2.2 RISK

2.2.1 Risk Definitions

Defining the terms "Risk" and "Uncertainty."

Risk can be defined in different ways. (Project Management Institute (PMI)., 2013)[53]. Defined risk as when one or more objective of the projects such as scope budget schedule and quality is subjected to a negative or positive divergence due to the defined or undefined event. (Creedy, G., Skitmore, M., and Wong, 2010)[18] Defined risk as an external factor if happens to a pre-planned (situation or circumstances) change a certain progression of planned events resulting in impacts