

**UNIVERSITY OF BAHRAIN**

**College of Engineering**

**Department of Mechanical Engineering**



# **Root Causes of Cost Deviation in Highway Construction Projects in Bahrain**

A Thesis submitted in partial fulfilment of the requirements for the  
Master's Degree in Engineering Management

**Prepared by:**

**Ahmed Ghazi Al Kooheji**

20054779

**Supervised by**

**Dr. Saad Suliman**

(Professor)

University of Bahrain

**Kingdom of Bahrain**

**January, 2017**

# **Root Causes of Cost Deviation in Highway Construction Projects in Bahrain**

A Thesis submitted in partial fulfilment of the requirements for the  
Master's Degree in Engineering Management

**Prepared by:**

**Ahmed Ghazi Al Kooheji**

20054779

**Supervised by**

**Dr. Saad Suliman**

(Professor)

University of Bahrain

**Kingdom of Bahrain**

**January, 2017**

## DEFENSE COMMITTEE'S APPROVAL

University of Bahrain

College of Engineering

Department of Mechanical Engineering

Master in Engineering Management

Student Ahmed Ghazi AL Kooheji ID Number 20054779 defended his thesis by which he fulfilled the requirement for the degree of Master's in (Engineering Management) entitled (Root Causes of Cost Overrun in Highway Construction Projects in Bahrain) on this day of (\_\_\_\_\_).

The committee recommends awarding of M.A. Degree with the grade of: \_\_\_\_\_.

### (Defense Committee)

| Name  |                          | Signature |
|-------|--------------------------|-----------|
| _____ | <b>Supervisor</b>        | _____     |
| _____ | <b>External Examiner</b> | _____     |
| _____ | <b>Internal Examiner</b> | _____     |

\_\_\_\_\_  
Academic department's stamp

# **ABSTRACT**

In this research the cost overrun in highway construction projects in Bahrain was investigated. Fifty-two causes were identified from the literature and from interviews with highway construction engineers working at contractors, consultants, and at Ministry of Works (MoW). The causes were classified into six groups. A field survey was conducted through a questionnaire including thirty-six contractors, twenty-four consultants and eighty-four engineers working at MoW to study the frequency and severity of the causes of overrun.

For the model that was developed for this study, the data were gathered from interviews with project managers working at MoW, who managed 38 highway construction projects in Bahrain between years 2005 to 2016. They were asked to rank the severity and the frequency of occurrence of the six groups that were identified earlier, which had caused cost overruns to their projects. Based on the interviews' data, an ANN model was developed to identify which group had more effect on cost overrun, and the results were compared to the ones from the questionnaire.

It was concluded that there are many causes of cost overrun related primarily to owner group, consultants group and contractors group such as frequent change orders, lack of experience of project manager, and lack of communication with suppliers, respectively. However, factors related to project characteristics, estimation, and environment were not as significant to the above groups.

Finally, recommendations were suggested in order to minimize the cost overrun in highway construction projects in Bahrain. Furthermore, recommendations for future research were suggested.

## **DEDICATION**

I dedicate this thesis to my parents, sister, and my loved one and to everyone who supported my graduate study.

## **ACKNOWLEDGEMENT**

Special thanks are to be expressed to Prof. Saad Suliman, Thesis Supervisor, for his continuous advice and support throughout the preparation of this thesis.

Thanks are also to be extended to all those who participated in the survey and meetings, especially Eng. Mohammed Hayat, Head roads improvement and new highways group at Ministry of Works (MoW).

# TABLE OF CONTENTS

| Subject                                                                     | Page Number |
|-----------------------------------------------------------------------------|-------------|
| Defense Committee's Approval                                                | C           |
| Abstract                                                                    | D           |
| Dedication                                                                  | E           |
| Acknowledgement                                                             | F           |
| Table of Contents                                                           | G           |
| List of Tables                                                              | I           |
| List of Figures                                                             | J           |
| Abbreviations                                                               | K           |
| Appendices                                                                  | M           |
| Chapter One<br>Introduction                                                 |             |
| 1.1 Introduction                                                            | 2           |
| 1.2 Statement of Problem                                                    | 3           |
| 1.3 Objectives of Research                                                  | 4           |
| 1.4 Research Questions                                                      | 5           |
| 1.5 Research Methodology                                                    | 5           |
| 1.6 Research Limitations                                                    | 6           |
| 1.7 Thesis Organization                                                     | 7           |
| Chapter Two<br>Literature Review                                            |             |
| 2.1 Introduction                                                            | 10          |
| 2.2 Previous Studies                                                        | 11          |
| 2.2.1 Studies related to building construction                              | 11          |
| 2.2.2 Studies related to railway/transportation                             | 16          |
| 2.2.3 Studies related to highway construction                               | 19          |
| 2.3 Summary                                                                 | 27          |
| Chapter Three<br>Research Methodology and Data Collection                   |             |
| 3.1 Introduction                                                            | 31          |
| 3.2 Research Framework                                                      | 31          |
| 3.3 Data Collection                                                         | 33          |
| 3.3.1 Data for Frequency and Severity Analysis                              | 35          |
| a) Sample size determination                                                | 35          |
| b) Questionnaire design and development                                     | 37          |
| 3.3.2 Data for NN Model                                                     | 38          |
| Chapter Four<br>Results and Analysis of Cost Overrun Frequency and Severity |             |
| 4.1 Introduction                                                            | 46          |

| Subject                                                       | Page Number |
|---------------------------------------------------------------|-------------|
| 4.2 Cost Overrun Frequency and Severity Results               | 46          |
| 4.2.1 Ranking of factors                                      | 46          |
| Chapter Five<br>Neural Network Theoretical Background         |             |
| 5.1 Introduction                                              | 61          |
| 5.2 Types of ANNs                                             | 65          |
| 5.2.1 Single-layer feed forward networks                      | 65          |
| 5.2.2 Feed forward networks                                   | 66          |
| 5.3 Training of NN                                            | 68          |
| 5.4 Cross-Validation of NN                                    | 70          |
| 5.5 Testing of NN                                             | 71          |
| 5.6 Performance Measures of ANN Model                         | 72          |
| 5.6.1 Mean absolute error (MAE)                               | 72          |
| 5.6.2 Mean absolute percentage error (MAPE)                   | 72          |
| 5.6.3 Correlation coefficient                                 | 73          |
| 5.7 NNs Properties                                            | 74          |
| 5.8 Problems and Challenges                                   | 75          |
| 5.9 Application of ANN in Cost Estimation                     | 77          |
| 5.10 SimBrain Application                                     | 80          |
| Chapter Six<br>Neural Network Model Development               |             |
| 6.1 Introduction                                              | 82          |
| 6.2 Data Standardization and Organization                     | 83          |
| 6.3 Model Building                                            | 88          |
| 6.3.1 Network structure                                       | 89          |
| 6.3.2 Data entry                                              | 90          |
| 6.3.3 Model training and validation                           | 92          |
| 6.4 Discussion of ANN Model Results                           | 93          |
| Chapter Seven<br>Comparison of Results                        |             |
| 7.1 Introduction                                              | 100         |
| 7.2 Comparison of Results                                     | 100         |
| Chapter Eight<br>Conclusions, Recommendations and Future Work |             |
| 8.1 Conclusions                                               | 104         |
| 8.1.1 Most frequent and severest factors of cost overrun      | 104         |
| 8.2 Recommendations                                           | 106         |
| 8.3 Future Work                                               | 107         |
| References                                                    | 108         |
| الخلاصة                                                       | ١           |

## LIST OF TABLES

| No. | Subject                                                                                           | Page |
|-----|---------------------------------------------------------------------------------------------------|------|
| 3-1 | Causes of Cost Overrun Identified from Literature Review and Interviews with MoW Project Managers | 33   |
| 3-2 | Questionnaire Distribution and Response Rates                                                     | 38   |
| 3-3 | Sample Weight Calculation for Project 1 Based on Interview with the Project Manager               | 40   |
| 3-4 | Summary of the Interviews Results                                                                 | 41   |
| 4-1 | Frequency and Severity Results                                                                    | 48   |
| 4-2 | Importance Index and Ranking of Each Factor under the Consultant Group                            | 52   |
| 4-3 | Importance Index and Ranking of Each Factor under the Contractor Group                            | 53   |
| 4-4 | Importance Index and Ranking of Each Factor under the Estimation Group                            | 55   |
| 4-5 | Importance Index and Ranking of Each Factor under the Project Characteristics Group               | 56   |
| 4-6 | Importance Index and Ranking of Each Factor under the Owner Group                                 | 57   |
| 4-7 | Importance Index and Ranking of Each Factor under the Environment Group                           | 58   |
| 4-8 | Importance Indices and Ranking of Each Group                                                      | 59   |
| 6-1 | Available Range of Input Data in ANN Model for Each Group                                         | 83   |
| 6-2 | Normalized Indices (Weight) of Each Cost Overrun Group Based on Interview Results                 | 85   |
| 6-3 | Results Summary of Loading to Each Factor's Group                                                 | 94   |
| 6-4 | 0.75m Hidden Layer NN Results                                                                     | 95   |
| 6-5 | m Hidden Layer NN Results                                                                         | 96   |
| 6-6 | 2m+1 Hidden Layer NN Results                                                                      | 96   |
| 6-7 | Main Factors Influencing Cost Overrun in Highway Construction Projects in Bahrain                 | 98   |
| 7-1 | Comparison of Results Using Statistical and NN Analyses                                           | 102  |

## LIST OF FIGURES

| No. | Subject                                                                 | Page |
|-----|-------------------------------------------------------------------------|------|
| 3-1 | Research Framework                                                      | 33   |
| 5-1 | Artificial Neural Network Structure                                     | 63   |
| 5-2 | Three Most Commonly Used Activation Functions                           | 64   |
| 5-3 | Single Layer Feed Forward Network (AlNajjar, 2005)                      | 65   |
| 5-4 | Multilayer Perceptron (Christian et al., 2000)                          | 67   |
| 5-5 | General Feed Forward Networks Structure (Principe et al., 2010)         | 68   |
| 6-1 | Number of Layers and Neurons Selection for ANN Model (0.75m)            | 89   |
| 6-2 | ANN Model for MLP Network Using 0.75m Nodes in Hidden Layer             | 90   |
| 6-3 | ANN Model Data Entry for Input Layer Using 0.75m Nodes in Hidden Layer  | 91   |
| 6-4 | ANN Model Data Entry for Output Layer Using 0.75m Nodes in Hidden Layer | 91   |
| 6-5 | Workflow of Training Process                                            | 92   |
| 6-6 | Screenshot of NN Training Process                                       | 93   |

## **ABBREVIATIONS**

|        |                                                  |
|--------|--------------------------------------------------|
| AI     | Artificial Intelligence                          |
| ANN    | Artificial Neural Network                        |
| ANNs   | Artificial Neural Networks                       |
| ANFIS  | Artificial Neuro-Fuzzy Inference System          |
| EFNIM  | Evolutionary Fuzzy Neural Inference Model        |
| EWCCCE | Evolutionary Web-Based Conceptual Cost Estimator |
| ESP    | Estimate Score Program                           |
| GFF    | General Feed Forward                             |
| GA     | Genetic Algorithm                                |
| GCC    | Gulf Corporation Council                         |
| GoF    | Goodness of Fit                                  |
| IMP.I  | Importance Index                                 |
| MLP    | Multi-Layer Perceptron                           |
| MSE    | Mean Square Error                                |
| MAE    | Mean Absolute Error                              |
| MAPE   | Mean Absolute Percentage Error                   |
| MoW    | Ministry of Works                                |
| NN     | Neural Network                                   |
| NNs    | Neural Networks                                  |
| PIREM  | Principal Item Ratio Estimating Method           |

|     |                                |
|-----|--------------------------------|
| R   | Correlation Coefficient        |
| RFB | Radial Basis Function Networks |
| SOM | Self-Organizing Map            |

## APPENDICES

| Appendix | Title                                    | Page |
|----------|------------------------------------------|------|
| A        | Questionnaire form and statistical table | 121  |
|          | A1. Survey questionnaire                 | 122  |
|          | A2. Required sample size table           | 135  |
| B        | Collected projects data                  | 136  |

# **CHAPTER ONE**

## **INTRODUCTION**

# **CHAPTER ONE**

## **INTRODUCTION**

### **1.1 Introduction**

The success of every construction project can be defined as meeting the goals and objectives of the client/owner as specified in the project plan. A project is therefore said to be successful when it has accomplished the technical performance and been completed within schedule and budgeted cost.

To ensure the success of projects, proper management techniques and tools should be effectively utilized; such as managing the resources, workers, money, equipment and machines, materials and methods to ensure projects success. Projects that are not managed effectively experience many cost deviations.

Cost overrun is common in infrastructure projects. Researches on highway construction projects in some developing countries indicate that by the time a project is completed, the actual cost exceeds the original contract price by about 30% (Al-Momani, 1996). Cost overruns in highway projects have a serious impact on program budgeting from the view of the owner (Government). The planning and programming of future highway construction projects are vitally important tasks in highway organizations. A construction program outlines how highway funds are to be spent over time and any deviation from the stated program often brings a quick response from the public, the press, and politicians. When this occurs, the government

(MoW), loses creditability and will take time defending deviation from the published program.

For instance, Sitra Link Bridge and Um-Alhassam interchange upgrade (2006-2010), which is connecting Sh. Isa bin Salman Highway with Sh. Jaber Al Ahmed AlSobah Highway, had +3.3% cost deviation. The project was budgeted for BD 64 Million however, the government ended up paying over BD 66 Million. Moreover, King Faisal Highway widening project to 6 lanes (2012) was budgeted for BD 5.01 Million however the government ended up paying BD 6.71 Million, which is 33.8% increase in cost.

This thesis discusses and investigates cost overrun causes in highway construction projects in the Kingdom of Bahrain. A model is developed to identify the critical causes. It also suggests recommendations to overcome this issue in future highway construction projects in Bahrain.

## **1.2 Statement of Problem**

It is well known that the recent drop in oil price had a significant negative effect on the government's budget in Bahrain. As a result, infrastructure projects and more specifically highway construction projects were highly affected negatively, since the government does not have sufficient budget for these projects. Although, Gulf Corporation Council (GCC) countries offered to finance some of the major highway upgrades projects in Bahrain, nevertheless, these GCC funds will not be utilized efficiently, if highway construction projects in Bahrain continue to exceed the estimated cost. When projects

become more and more expensive and still involve cost overruns, the financial consequences can become so large that it even may destabilize the finances of a whole country.

Oil prices might increase in future, however cost overrun will still affect the budget for other projects, particularly as the total budget for government infrastructure investments is often fixed for a given period. Moreover, cost overruns can lead to delays and further cost overruns. When confronted with cost overruns, attempts must be made to secure additional funding, and projects must often be renegotiated or reapproved. This definitely takes time and will cause an increase in cost overruns.

Yet, there is a lack of studies relating the occurrence of highway projects size to the cost overruns of actual completed projects. Thus, it is necessary that reasons for cost overruns of highway construction projects in Bahrain be investigated and analyzed, as this will help focusing on problematic areas and also control and reduce cost deviations while developing more realistic highway project budget estimates.

### **1.3 Objectives of Research**

The purpose of this research is to:

1. Identify the internal and external factors that cause cost overrun in highway construction projects in Bahrain.
2. Establish the relationship between the cost overrun and the identified factors.
3. Recommend solutions to avoid or reduce cost deviation in future

road construction projects in Bahrain.

## **1.4 Research Questions**

The cost deviation in highway construction projects can address several questions concerning the frequency and severity of both causes and effects. These questions are:

1. What are the factors causing cost deviations in highway construction projects in Bahrain?
2. What is the relationship between these factors and cost deviation in highway construction projects in Bahrain?
3. How can cost overrun be avoided in future highway projects?

## **1.5 Research Methodology**

In order to identify the causes of cost overruns in previously constructed highway projects in the Kingdom of Bahrain, this research is based on field interviews with the owner (MoW), the consultants' engineers and the contractors' engineers who are prequalified on working on highway construction projects. The extensive literature review will help identifying the internal and external causes of cost deviation, and the interviews will therefore provide a clearer approach to relate those causes to highway construction projects in Bahrain.

The research framework includes the following steps:

1. Perform a comprehensive literature review by reading several articles in scientific journals that are related to the topic of this study.

2. Identify the key factors responsible for cost overrun in highway construction projects from literature review.
3. Perform interviews with expert highway engineers in MoW to identify the general factors of cost overrun in Bahrain.
4. Gather historical data from MoW of highway construction projects undertaken by the ministry from years 2005 to 2016, including estimated cost, actual cost upon completion of the project, and factors that lead to cost overrun of each project.
5. Distribute a questionnaire to determine and analyze the frequency and severity of the identified factors that lead to cost overrun.
6. Develop a model using data gathered from point number three above to describe the relationship between the cost overrun and the identified factors, and verify its validity. The ANN modeling approach will be used.

Report, discuss and compare results and major findings to introduce conclusions and recommendations.

## **1.6 Research Limitations**

This research focuses on direct causes affecting cost overrun. It does not consider the non-direct factors. The research is questionnaire based; therefore results may change if sample size increased or if participants changed their opinion.

Model limitations: In spite of the acceptable accuracy of using ANN in cost estimation, it has a considerable defect, as it depends mainly on historical data; this dependency has several disadvantages as the following;

- Diversity of variables for effective factors is limited to what available in collected data.
- Data should contain sufficient projects for each variable.
- New variables that were not included in adopted model will not be handled.

## **1.7 Thesis Organization**

This thesis will determine and analyze the internal and external factors that affect highway projects' cost estimation in Bahrain, that leads to cost deviations upon completion of projects. The thesis will develop a model that describes the relationship between cost overrun and these factors. Also, this thesis will recommend solutions to avoid or reduce cost deviation in future highway construction projects.

The thesis is divided into the following seven chapters:

Chapter (1) will present an introduction that provides an overview of the cost deviation problem in highway construction projects, and also includes the statement of the problem, research questions and objectives.

Chapter (2) will include the literature review and previous studies to identify the key factors causing cost overrun in highway construction projects.

Chapter (3) will discuss the research methodology and data collection, which includes data collection for frequency and severity analysis, and data collection for the model.

Chapter (4) will discuss results and analysis of cost overrun frequency and severity.

Chapter (5) will discuss NN theoretical background.

Chapter (6) will discuss NN model development, which includes data standardization and organization, and discussion of model results.

Chapter (7) will include comparison of results, conclusions, and future work.

## **CHAPTER TWO**

### **LITERATURE REVIEW**

# **CHAPTER TWO**

## **LITERATURE REVIEW**

### **2.1 Introduction**

The success of every construction project can be defined as meeting the goals and objectives of the owner as specified in the project plan. A project is therefore said to be successful when it has accomplished the technical performance, and been completed within schedule and budgeted cost.

Cost and time overruns are common in infrastructure and building construction projects. Researches on highway construction projects in some developing countries indicate that by the time a project is completed, the actual cost exceeds the original contract price by about 30 % (Al-Momani, 1996).

To ensure the success of projects, proper management techniques and tools should be effectively utilized such as: managing the resources; workers; money, equipment and machines; materials and methods to ensure projects success. Projects that are not managed effectively experience many cost deviations (Nicholas, 2010). This chapter will discuss previous related studies in cost deviation of highway construction projects.

## **2.2 Previous Studies**

Several articles in scientific journals that are related to cost deviation in construction projects have been reviewed along with those related to highway construction projects in particular, which present the cost overrun in construction projects and its causes and effects. Among these studies, the most relevant to this research will be presented briefly in the following sections.

### **2.2.1 Studies related to building construction**

In general, time-delays and cost overruns increases are among the most common phenomena in the construction industry – from simple to complex projects. Morris and Hugh (1980) examined the records of more than 4000 construction projects and found that projects were rarely finished on time, or within the allocated budget. Tah et al. (1993) also observed that time and cost overruns were commonplace in the construction industry worldwide.

Studies have shown that the size of a construction project (contract amount) influences the rate of cost deviation. Rowland (1981), in a study of Southern United States construction contracts, found that cost overrun rates increased with increase in the contract amount of construction projects. While Randolph et al. (1987) found that cost overrun rates decreased as the contract amount increased based on their study for contract costs in Lansing, Michigan.

Jahren et al. (1990) conducted research on predictors of cost overrun rates. The analysis included one thousand, five hundred and seventy six building construction projects that were in progress from 1984 to 1987. It was found that the shape of the frequency distribution

for the cost overrun rates changed with the size of the project. Cost overruns occurred more frequently for larger projects.

Watson et al. (1992) examined the application of an expert system for the estimating of costs of residential projects. The paper describes the implementation and objective-oriented architecture of the expert system. The main advantage of the artificial intelligence (AI) technology – reduction in the quantity of data requirements – is also discussed. The result of the model application provides strategic estimates of costs before plans have been drawn up. In addition, the model can use its knowledge to explain its conclusions, resulting in greater confidence in the AI system's results. Also presented in the paper are the model's implementation, specific features, its benefits, and the potential for further development.

Several studies have also classified the main causes of cost overrun as materials-related, labor-related, and equipment-related. A comprehensive grouping of the main causes of construction cost overrun, however, was recommended by Hensey (1993). These included: materials; labor; equipment; and financial factors. Also counted among the causes of postponements were improper planning; lack of control; subcontractor delays; poor co-ordination; inadequate supervision; improper construction methods; technical personnel shortages; and poor communication.

Al-Hammad (1993) conducted a study of the relationship between contractors and subcontractors in Saudi Arabia. It was found that a number of factors significantly affected these relationships. Based on the result of a questionnaire survey of sixteen general contractors and seventeen subcontractors, the following conclusions were made. Delay in

contract progress payment; lack of construction quality; errors and delays in shop drawings; and approval of sample materials were ranked highest as contractor-subcontractor interface problems. Ranking lowest among these factors were legal disputes; scheduling conflicts among subcontractors; geological problems; and weather conditions.

In the United Kingdom, Skitmore and Wilcock (1994) surveyed nine small builders involved in all types of building projects to ascertain the pricing mechanism in preparing a bill of quantities for competitive tender. The bulk of the items were priced by experience, except a small percentage of specialized items, which were priced by the prescribed detailed methods. However, the research asserted that the combination of both the subjective and prescribed methods is the most efficient manner in which achieving accurate tender prices for estimators in a time-constrained environment can be achieved.

Mansfield et al. (1994) revealed that poor project management during the construction phase produces not only the deficiencies in the projects' plan and cost control, but also jeopardizes the target outcomes expected by clients, contractors, and consultants in the overall development process. Although the technical ability of project managers is an important element to the project's success, the contribution of contractors and consultants in the process of cost monitoring and controlling is equally important in achieving overall success in projects (Iyer and Jha 2005).

Ogunlana et al. (1996) studied the causes of construction cost overrun in a developing economy. The study involved a survey of cost overrun experienced in the construction of high-rise building projects in Bangkok, Thailand. It was found that resource supply problems were by

far the most acute problems of the Thai construction industry. The results also supported the view that construction problems in developing economies could be classified into three major groups: inadequacy of resource supplies, owner and consultant shortcomings, and contractor incompetence/ inadequacy.

Chan and Kumaraswamy (1997) reported five principal causes of cost overruns perceived among clients, contractors, and consultants in Hong Kong construction projects. A questionnaire survey was designed comprising 83 cost overrun factors across eight categories and distributed to 400 local firms involved in construction activities. Based on a 37% response, the five most significant sources of overrun were poor site management and supervision, unforeseen ground conditions, low speed in decision-making, client-initiated variations, and design change. However, the findings failed to establish any insights into the roles and responsibilities of the three groups and their underlying impacts on the overall cost performance of the project.

Based on data collected from 84 contractors firms in the United Kingdom, Akintoye (2000) reported the primary factors relevant to cost estimating practice are:

- Project complexity
- Scale and scope of construction
- Market conditions
- Methods of construction
- Site constraints
- Client's financial position
- Build-ability
- Location of the project

However, an investigation on how such factors would be perceived by clients and consultants, and their potential impacts on overall cost performance of projects, was not performed.

Based on the case study data on completed projects in Ghana, Frimpong et al. (2000) identified five key factors that impact project cost performance. These factors are monthly payment difficulties from agencies, poor contractor management, material procurement, poor technical performance, and escalation of materials prices.

Al-Momani (2000) investigated the causes of cost overrun in Saudi Arabia on public projects residential, office and administration buildings, school buildings, medical centers, and communication facilities and found that the cost overrun were related to designers, user changes, weather, site conditions, late deliveries, economic conditions, and increase in quantity.

Al-Zarooni et al. (2000) conducted a survey to investigate variations in UAE public projects' estimates. They found that the variations (positive or negative) between feasibility and contract cost, ranging between -28.5% and +36%. They stated that these variations could be explained by the fact that feasibility estimates in the government agencies are usually budgeted using a single unit estimating (cost per square foot) basis, regardless of the nature of projects and their associated risks or the construction complexity of each building type. And it may also be because feasibility studies are normally done before any details are settled.

Shehu et al. (2014) conducted a study in Malaysia to explore the construction cost performance of projects in terms of public and private sectors based on procurement methods, tendering methods, nature of

project and project size. A questionnaire survey of Malaysian quantity-surveying consultants was performed. They found that 55% of Malaysian construction projects experienced cost overruns and that public sector projects performed better than private sector projects. Based on procurement and tendering methods, they found that design and build delivery method was associated with reduced cost overrun, followed by traditional then project management.

Chimwaso (2016) evaluated ten projects to assess their cost performance. The results have shown that seven out of ten projects had reported cost overruns. The factors that influence cost overruns have been identified and ranked in order of significance. These factors have further been classified under categories according to the format of final account reports. The four categories were: variations; measurement of provisional works; contractual claims; and fluctuations in the cost of labor and materials, with variations being the most significant.

### **2.2.2 Studies related to railway/transportation**

A study by Skamris et al. (1996) compared the accuracy of traffic forecasts and cost estimates on large transport projects in Denmark. The main conclusion from this study is that cost overruns of 50–100% are common for larger transport infrastructure projects and that overruns above 100% are not unusual.

Al-Juwairah (1997) identified the top five ranked factors affecting transportation construction cost in Saudi Arabia from contractors' view are: previous experience of contract; payments; availability of financial management and plans; type and size of contract and its content; and project location. On the other hand, the top five rank factors from consultants view are: previous experience of contract; type and size of

contract and its content; payments; project location; and contract period.

Flyvbjerg et al. (2002) conducted a study of 258 transportation infrastructure projects. The distribution of the projects was as follows: rail: 58, fixed link (bridges and tunnels): 33, and road: 167 projects. The projects were located in 20 nations on 5 continents, including both developed and developing nations. The geographical distribution of projects was: Europe: 181, North America: 61, and others: 16 projects. The main findings from the study were as follows: 9 out of 10 transport infrastructure projects experienced cost deviation; for rail, the average cost deviation was 45%; for roads the average cost deviation was 20%; for all project types the average cost deviation was 28%; cost deviation exists across 20 nations and 5 continents, it appears to be a global phenomenon; cost deviation appears to be more pronounced in developing nations than in North America and Europe; for fixed links (tunnels and bridges) the average cost deviation was 34%; and cost deviation has not decreased over the past 70 years.

Oberlender and Trost (2002) conducted a study of 67 railway construction projects around the world. They identified 45 factors contributing to the accuracy of early stage estimates. The five most important factors include: process design; team's experience; cost information; time allowed to prepare estimates; and site requirements.

Odusami and Onukwube (2003) studied the factors that influence the accuracy of consultant pretender cost estimate in Nigeria. Data were collected, through the administration of questionnaire, from 50 randomly selected quantity surveyors in consulting firms. They concluded that the main affecting factors are: expertise of consultants; quality of

information and flow requirements; project team's experience of the construction type; tender period and market condition; complexity of design and construction; and availability/supplies of labor and materials.

Okpala et al. (2003) studied the causes of high costs of construction in Nigeria, the results indicated that: high costs can be minimized by minimizing lapses in the management of human and material resources; despite some slight differences, the professionals agreed that shortage of materials, method of financing and payments for completed works, and poor contract management, are the three major reasons for high construction costs; and price fluctuation was identified as the most important factor responsible for the escalation of project costs.

Iyer and Jha (2004) stated that the factors most adversely affecting the cost performances of rail construction projects in India are: conflict among project participants; ignorance and lack of knowledge; presence of poor project specific attributes and non-existence of cooperation; hostile socio-economic and climatic conditions; reluctance in timely decision; aggressive competition at tender stage; and short bid preparation time.

Morris (2016) studied the factors influencing cost overruns in transportation projects, he found that escalation in costs is attributable partly to the fact that the original estimates were prepared at the then current prices, and partly to delays which enhance the effect of inflation and to direct escalation in costs arising out of change in scope, errors etc. Based on certain assumptions with regard to the pace of expenditure on projects Morris have roughly computed that for the 133 projects which were studied only about 25 to 30% of the cost increase can be attributed to inflation. The remaining 70 to 75% has to be explained in

terms of delays, inefficiencies; scope changes; changes in statutory levies; variations in exchange rates; and to the combined effect of these factors with inflation.

### **2.2.3 Studies related to highway construction**

Virginia's Joint Legislative Audit and Review Committee found that underestimation of construction costs were common and typically led to serious consequences such as postponement or cancellation of other projects. In a study by Florida's Office of Program Policy Analysis and Government Accountability (1996), it was determined that the state suffered from an average of 9% cost overrun.

Akinci and Fischer (1998) stated that risk factors in highway construction projects are associated with the project design, construction, and project environment. They also analyzed cost overruns associated with Washington State highway projects and found that the cost overruns, expressed as a percentage of the contract amount, tended to increase with project size.

In an economic and efficiency audit study for the state of Delaware, Wagner (1998) found that state's department of highways and transportation had experienced cost overruns averaging 13.9% between 1994 and 1996, largely due to changes in the work scope and incorrect estimates of work quantities in the original bid specifications.

Cost estimation in highway project planning stages has long been a major concern of construction management studies. Sonmez and Ontepeli (2009) developed cost estimation models for the pre-design stage for highways projects. These studies used regression and NN techniques that were useful for estimating cost ranges. Wu (2009) integrated the

parametric estimation method, ratio estimation methods, and a cost significance model to develop a new conceptual construction cost estimation method called the principal item ratio estimating method (PIREM). He also combined the PIREM with an adaptive neuro-fuzzy inference system (ANFIS) to overcome the difficulties of traditional experience and knowledge-based cost estimation approaches. Similarly, Cheng et al. (2009) integrated a genetic algorithm, fuzzy logic, and NNs to develop an evolutionary fuzzy neural inference model (EFNIM) for estimating highway construction projects. This model proved to be highly accurate for pre-design cost estimation and was incorporated with both internet and historical data to provide a Web-accessible platform, named the Evolutionary Web-based Conceptual Cost Estimator (EWCCE).

Other previous studies have considered the practical application of early cost estimation. Instead of estimating the actual cost, Oberlender and Trost (2001) and Trost and Oberlender (2003) developed the estimate score program (ESP) to predict the accuracy of early cost estimates. This program measures the impact of the participants, the process, and known information, while considering such factors as determinants of cost estimate accuracy. They also have discovered critical factors for effective cost estimation based on organization control theory, and asserted that project information, cost information and team experience are critical factors in the cost estimation at the conceptual stage. Kinney and Soubiran (2004) presented six steps for conceptual cost estimation, in the form of an interactive roadmap for cost engineers, to make more accurate estimations and to share information more effectively. They have also proposed a fuzzy model to assess the quality of an infrastructure project cost that assumes ideal relationships between the project size, quantities, and the costs of each cost element.

Although these studies contributed to the accurate estimation of highway construction costs of various structures, they rarely gave consideration to the front-end phase of project planning. Rather, most of the research was focused on cost estimating during the preliminary feasibility study or the feasibility study stage, not for the conceptual policy planning stage.

The problem of cost overruns is generally acknowledged, however the causes and explanations are subject to more debate. The literature has identified various causes of cost overruns including poor project design and implementation; the inadequate funding of projects; bureaucracy in decision making process; the lack of coordination between enterprises; inflation; incompleteness of estimates; adjustments to projects; project size; project type; region; and construction and implementation period.

Odeck (2004) found rather surprisingly as no other study has noted it previously, that smaller projects have relatively larger cost overruns compared to larger ones. The study by Flyvbjerg et al. (2004) concludes conversely that cost overruns are large for all project sizes. As a consequence, the causes of possible cost overruns in the Bahrain could also be diverse, and if ecological fallacy plays a role, it is impossible to draw any conclusions regarding the causes of cost overruns in individual countries from aggregate results.

In line with the definition in Flyvbjerg et al. (2002), what is meant by ‘cause’ is ‘to result in’; the cause is not the explanation of the result. Causes refer to the variables or factors that influence the cost overruns, such as the implementation period or the size of the project. Explanations are more general and might comprise several causes. Flyvbjerg et al. (2004) gave the following types of explanations for forecasting

inaccuracy:

- *Technical explanations*: these are ‘forecasting errors’ in technical terms e.g. imperfect forecasting techniques, inadequate data and lack of experience;
- *Economic explanations*: these explain cost overruns either in terms of economic self-interest or in terms of public interest, but both depict underestimation as deliberate and economically rational;
- *Psychological explanations*: these include the concepts of planning fallacy and optimism bias (a systematic tendency for project appraisers to be overly optimistic)
- *Political explanations*: strategic misrepresentation; deliberately and strategically overestimating benefits and underestimating costs when forecasting the outcomes of projects.

Despite these explanations, cost overruns continue to be a problem in large-scale highway projects. This asks for a different approach in studying cost overruns, namely from a theoretical perspective. A sound theoretical basis is particularly important as it substantiates the explanation and provides opportunities to define appropriate cures. Insight into the theories underlying the explanations for cost overruns has been the subject of only a few studies. A systematic overview of the theories that are used or can be used to explain cost overruns is however lacking. Moreover, an application of a specific theory to show how cost overruns can occur has not been conducted (Flyvbjerg et al., (2007))

Flyvbjerg et al. (2007) stressed on the need for less deception and more honesty in the estimation of costs if projects are to be implemented. They thereby distinguish two situations. In the first situation, planners consider it important to get forecasts right and better forecasting methods

are proposed as a cure for forecasting inaccuracy. To be more specific, Flyvbjerg et al. (2007) recommended the use of reference class forecasting, taking an ‘outside view’ next to the usual ‘inside view’. In the second situation, planners do not consider it important to get forecasts right because optimistic forecasts are seen as a necessary means to get a project started. In this latter situation, improved incentive structures are proposed as a cure.

Other research studies have focused on uncovering the specific factors that affect cost overruns. For example, Rowland (1981) ascertained that the likelihood of cost overrun increased with: The contract size; complexity; length of communication channels; and distortion of information associated with larger projects.

Jahren and Ashe (1990) found that a cost overrun rate of 1% to 11% is more likely to occur on larger projects compared to overruns on smaller projects, but mentioned that managers on large projects typically make special efforts to keep cost overrun rates low. They also determined that the risk of high cost overrun rates is greater when the winning bid amount is less than the engineer’s estimate and further identified some cost-overrun factors such:

- The contract document quality
- Nature of interpersonal relations on the project
- Contractor policies.

Al-Khaldi (1990) conducted a study aims at identifying factors affecting construction cost in Saudi Arabia from contractors and consultants’ view. He found that project size is one of the top five affecting factors from both contractors and consultants’ view.

In Indonesia, Kaming et al. (1997) identified variables that have an

impact on construction time and cost overruns using factor analysis techniques. In their work, time and cost overrun variables were grouped into factors, and their relationships were analyzed. It was found that the main causes for cost overruns were the complexity of the project; inflationary increases in material costs; and inaccurate material estimates. They stated that the main causes of cost overrun were related to inadequate planning; design changes; and poor labor productivity.

The study by Odeyinka and Yusuf (1997) revealed that seven out of ten projects surveyed in Nigeria suffered cost overruns in their execution.

In other studies, the reasons for cost overruns have been found to include rising costs of labor and materials; inadequate analysis poor costing methods; poor control and scheduling; and inadequate information (Akpan and Igwe, 2001). Also, Chang (2002) categorized the reasons for cost and time increases in engineering design projects as follows:

- Those within the owner's control for which the owner is responsible
- Those within the consultant's control for which the consultant is responsible and;
- Those beyond the control of the owner or the consultant, such as increased work scope, changes in legislation, changes in standards, and archeological discoveries.

Flyvbjerg et al. (2002) determined that cost escalation is a pervasive phenomenon in transport infrastructure projects irrespective of project type, geographical location and historical period. However, Flyvbjerg et al. (2004) found that cost escalation is strongly influenced by the implementation phase length and project type, and suggested that

decision makers and planners should be duly concerned about long implementation phases.

Attalla and Hegazy (2003) presented an interesting study that pioneered the comparison of the performance of different techniques by considering ANN and regression in predicting cost deviation in highway construction projects. In a similar subsequent study, Williams (2003) compared the performance of NNs and regression in explaining highway project cost deviations in Texas on the basis of bidding information such as bidding ratio, mean bid, and second lowest bid.

Nassar et al. (2005) used the Weibull statistical method, commonly used in failure analysis and reliability engineering, to evaluate cost and schedule performance of highway construction projects.

Battaineh (2007) evaluated the progress reports of 164 building and 28 highway projects constructed during the period 1997-2007 in Jordan. He found that cost overruns were extensive: the average overrun of actual cost to the estimated cost was 160% for road construction projects and 120% for building projects.

Hassanein and Afify (2007) identified that lack of appreciation and execution of risk by contractors can lead to project cost overruns. Moreover, Azhar et al. (2008) conducted a study to identify the major factors affecting cost estimating accuracy in the construction sector of Pakistan. 42 factors were short-listed and made part of the survey questionnaire and the survey was conducted with representatives from local general contracting firms. They found that the top ten affecting factors are:

- Fluctuation in prices of raw materials

- Unstable cost of manufactured materials
- High cost of machineries
- Lowest bidding procurement procedures
- Poor project management or poor cost control
- Delays between design and procurement phases
- Incorrect or inappropriate methods of cost estimation
- Additional work
- Improper planning, and unsupportive government policies

Aje et al. (2009) identified that contractors' management capability had significant impact on cost and time of building projects. Also, Koushki et al. (2009) conducted a study in Kuwait to study the factors affecting cost estimating in construction projects. An interview survey of 450 randomly selected private residential project owners and developers have been done. They found that the main factors affecting are: contractor related problems; material related problems; and owners' financial constraints.

Mahamid (2013) conducted a study to identify the factors affecting cost estimating accuracy in highway construction projects in Palestine. He concluded that the top five affecting factors are: fluctuation in currency exchange rate; project financing; contract management; level of competitors; and cost of materials.

Koleola et al. (2015) concluded that six important factors affecting the accuracy of a pre-tender cost estimate in highway construction projects. The six factors are: expertise of consultants; quality of information and information flow requirements; the project team's experience of the construction type; the tender period and market condition; extent of completion of pre-contract design; and the

complexity of design and construction.

Al- Khalil and Al-Ghafly (2015) assessed the frequency of highway projects' overrun, and the extent of the overrun. They found that a large number of projects experience cost overrun, especially in medium- and large size projects.

Aibinu and Jagboro (2016) examined the effects of cost overrun on the delivery of construction projects in Nigeria. Utilizing a questionnaire survey of 61 construction projects they have identified and assessed the impact of cost overrun on the delivery of construction projects. Time and cost overruns were found to be frequent. Acceleration of site activities coupled with improved owners' project management procedures and the inclusion of an appropriate contingency allowance in the pre-contract estimate were recommended as a means of minimizing the adverse effect of construction cost overrun in Nigeria.

Duran (2016) found that cost overrun is attributed to problems in finance and payment arrangements; poor contract management; material shortages; changes in site conditions; design changes; mistakes and discrepancies in contract documents; mistakes during constructions; price fluctuations; inaccurate estimating; delays; additional work; shortening of contract periods; and fraudulent practices and kickbacks.

## **2.3 Summary**

After reviewing regional and international cases of cost deviation studies related to highway construction projects, the studies showed that almost all approached are statistical ones, in which the causes of cost overrun are identified from literature and grouped. Then the causes are

ranked based on questionnaire responses of stakeholders. Other studies however have focused on using a model to establish the relationship between the causes of cost overrun and the overrun itself. The model was then also used to rank the causes of cost overrun, yet there is a lack of studies that have combined the two approaches (model and statistical) and compare the results. This research aims to identify the root causes of cost overrun in highway construction projects using both approaches in order to address the gap found in the literature.

Upon thorough review of literature and previous studies related to the topic of this research, the main causes of cost deviation in highway construction projects are summarized below:

1. Fluctuation in prices of raw materials
2. Project complexity
3. Location of Project
4. Cost estimation methods
5. Poor project management/poor cost control
6. Design errors and omissions
7. Estimator's experience
8. Extent of completion of pre-contract design
9. Slowness in inspection and testing of completed works
10. Lack of communication
11. Lack of qualified project manager
12. Availability of data of similar projects
13. Procedure for updating cost information
14. Time allowed for preparing the cost estimate
15. Unexpected geological conditions
16. Tender period and market condition
17. Cultural heritage issues

18. Escalation of material prices
19. Frequent breakdown of construction equipment
20. Government interference
21. Inflation
22. Lead times for delivery of materials
23. Monopoly of material suppliers
24. Weather
25. Specifications change
26. Delays in work approval waiting for information
27. Cash flow during construction
28. Low speed at decision-making
29. Disputes
30. Form of procurement and contractual arrangements
31. Frequent change orders/variation by client
32. Payment delay

## **CHAPTER THREE**

### **RESEARCH METHODOLOGY AND DATA COLLECTION**

## **CHAPTER THREE**

### **RESEARCH METHODOLOGY AND DATA COLLECTION**

#### **3.1 Introduction**

In order to identify the causes of cost overruns in previously constructed highway projects in the Kingdom of Bahrain, this research is based on field interviews with the owner (MoW), the consultants' engineers and the contractors' engineers who are prequalified on working on highway construction projects. The extensive literature review will help identifying the internal and external causes of cost deviation, and the interviews will therefore provide a clearer approach to relate those causes to highway construction projects in Bahrain.

This chapter will introduce the research framework and the data collection methods.

#### **3.2 Research Framework**

The research framework includes the steps shown in Figure (3-1), which can be summarized in the following points:

7. Perform a comprehensive literature review by reading several articles in scientific journals that are related to the topic of this study.
8. Identify the key factors responsible for cost overrun in highway

construction projects from literature review.

9. Perform interviews with expert highway engineers in MoW to identify the general factors of cost overrun in Bahrain.

10. Gather historical data from MoW of highway construction projects undertaken by the ministry from years 2005 to 2016, including estimated cost, actual cost upon completion of the project, and factors that lead to cost overrun of each project.

11. Distribute a questionnaire to determine and analyze the frequency and severity of the identified factors that lead to cost overrun.

12. Develop a model using data gathered from point number three above to describe the relationship between the cost overrun and the identified factors, and verify its validity. The ANN modeling approach will be used.

13. Report, discuss and compare results and major findings to introduce conclusions and recommendations.

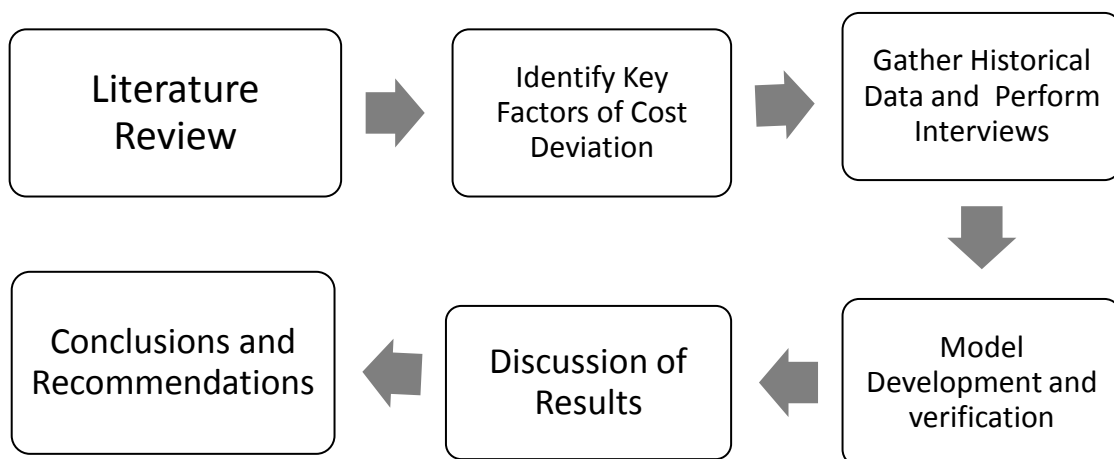


**Figure (3-1)**  
**Research Framework**

### 3.3 Data Collection

The first type of data was gathered through a review of literature on cost deviation in highway construction projects. The second type of data was obtained by interviewing consultant firms, contractors and engineers from Roads Affairs in MoW to have their opinions on the general factors of cost overrun in highway construction projects in Bahrain. The identified factors will be used in the questionnaire for frequency and severity analysis.

A third type of data was collected from project managers of thirty eight highway construction projects in Bahrain awarded over the years 2005-2016. The data comprise specific groups of cost overrun factors for each project. These data will be used in the NN model.

The identified cost overrun factors from literature and interviews were grouped into 6 groups as shown in Table (3-1).

**Table (3- 1)**  
**Causes of Cost Overrun Identified from Literature Review and Interviews with MoW Project Managers**

| Group                            | Description of Factors                                                                                                                                                                                                                  |
|----------------------------------|-----------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| 1. Factors related to consultant | 1.Design errors and omissions<br>2.Estimator's experience<br>3.Extent of completion of pre-contract design<br>4.Slowness in inspection and testing of completed works<br>5.Lack of communication<br>6.Lack of qualified project manager |

|                                                      |                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                |
|------------------------------------------------------|------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
| <p>2. Factors related to contractor</p>              | <ol style="list-style-type: none"> <li>1. Contractor's deficiencies in planning and scheduling at tender stage</li> <li>2. Effective monitoring and feedback process</li> <li>3. Communication with suppliers</li> <li>4. Poor procurement programming of materials</li> <li>5. Low speed at decision-making</li> <li>6. Staff training in the skill areas relevant to project</li> <li>7. Availability and supplies of labor and materials</li> <li>8. Contractor's financial difficulties</li> <li>9. Inadequate contractors experience</li> <li>10. Lack of project knowledge</li> <li>11. Lack of qualified project manager</li> <li>12. Methods/techniques of construction</li> <li>13. Planning and scheduling deficiencies</li> <li>14. Poor site management and supervision</li> <li>15. Rework from poor materials quality</li> </ol> |
| <p>3. Factors related to estimation</p>              | <ol style="list-style-type: none"> <li>1. Estimator's experience</li> <li>2. Cost estimation methods</li> <li>3. Deficiencies in cost estimates prepared</li> <li>4. Procedure for updating cost information</li> <li>5. Time allowed for preparing the cost estimate</li> <li>6. Availability of data of similar projects</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                          |
| <p>4. Factors related to project characteristics</p> | <ol style="list-style-type: none"> <li>1. Project duration</li> <li>2. Build-ability (including on-site prefabrication)</li> <li>3. Complexity of design and construction</li> <li>4. Location of project</li> <li>5. Services relocation costs</li> <li>6. Project size</li> <li>7. Construction techniques required</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                               |
| <p>5. Factors related to owner</p>                   | <ol style="list-style-type: none"> <li>1. Delays in work approval waiting for information</li> <li>2. Cash flow during construction</li> <li>3. Low speed at decision-making</li> <li>4. Disputes</li> <li>5. Form of procurement and contractual</li> </ol>                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                                   |

|                                   |                                                                                                                                                                                                                                                                                                                                       |
|-----------------------------------|---------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------------|
|                                   | arrangements<br>6.Frequent Change orders/Variation by owner<br>7.Payment delay<br>8.Specifications Change                                                                                                                                                                                                                             |
| 6. Factors related to environment | 1.Tender period and market condition<br>2.Cultural heritage issues<br>3.Escalation of material prices<br>4.Frequent breakdown of construction equipment<br>5.Government interference<br>6.Inflation<br>7.Lead times for delivery of materials<br>8.Monopoly of material suppliers<br>9.Weather<br>10.Unexpected geological conditions |

### 3.3.1 Data for frequency and severity analysis

#### a) Sample size determination

In this research there are three populations of respondents, namely MoW, contractors, and consultants working in road projects in Bahrain. For sample size determination, Krejcie and Morgan (1970) developed the following formula:

$$s = X^2 * N * P(1 - P) \div \{d^2(N - 1) + X^2 * P(1 - P)\} \quad (1)$$

Where:

s = Sample size.

$X^2$  = The tabulated value of chi-square for 1 degree of freedom at a confidence level of 95% is (3.841) (Appendix B).

N = Population size.

P = Population proportion (assumed to be 0.50 since this would provide the maximum sample size).

d = Degree of accuracy expressed as a proportion (0.05).

Specification of the samples from the three populations will be as follows:

**i. The owner:** Number of engineers working at Roads Section at MoW is 209 engineers as stated in the records of MoW. This section consists of two directorates which are Roads Planning and Design and Road Projects and Maintenance Directorates.

The following is application of Equation (1) with N= 209:

$$s = \{3.841 * 209 * 0.5^2\} / \{((0.05)^2 * 208) + (3.841 * 0.5^2)\}$$

$$s = 200.69225 / (0.52 + 0.96025) = 135.58 \approx 136$$

**ii. The contractors:** According to MoW, there is a list of prequalified contractors that the ministry usually deals with in road projects. This study will target type AA and type A contractors, where type AA contractors are qualified by the Ministry to award over BD 2.5 million contracts, and type A contractors are qualified to win up to BD 2.5 million tenders.

To determine the population of contractors, types AA and A contracting offices are phoned to ask about the number of their road engineers. It has been found that population of contractors is 69 engineers.

The following is application of Equation (1) with N= 69:

$$s = \{3.841 * 69 * 0.5^2\} / \{((0.05)^2 * 68) + (3.841 * 0.5^2)\}$$

$$s = 66.25725 / (0.17 + 0.96025) = 58.62 \approx 59$$

**iii. The consultants:** According to MoW there are very few consultant engineering offices experienced in road projects, and all of them are

foreign. These offices are phoned to determine the number of road engineers working at.

The population of consultant engineering offices is 34 engineers. Thus, Equation (1) is used with  $N=34$  to establish the sample size:

$$s = \{3.841 * 34 * 0.5^2\} / \{((0.05)^2 * 33) + (3.841 * 0.5^2)\}$$

$$s = 32.6485 / (0.0825 + 0.96025) = 31.31 \approx 32$$

Refer to Appendix B for  $X^2$  Values

## **b) Questionnaire design and development**

From the literature review and meetings with road engineers from the contractors, the consultants and MoW, a list of cost overrun factors has been developed and grouped into six groups. The questionnaire consisted of an introduction and two parts, (A) and (B) a copy of the questionnaire is shown in Appendix (A). The introduction gives a description of the survey, its purpose and objectives, and provides some basic definitions. Part (A) is related to general information about the respondents. The respondents were requested to answer general questions pertaining to their experience and educational level.

Part (B) includes a list of cost overrun factors based on literature review and actual historical data in Bahrain, for which it is required to choose the frequency of occurrence and severity based on likert-scale ranging from 1 to 5 which was categorized as follows: not severe; slightly severe; moderately severe; strongly severe; and extremely severe.

The questionnaire was distributed by hand and sent by e-mail to 169 road engineers working at MoW, 63 engineers working with contractors and 34 engineers working at consultant engineering offices. In approximately one month and a half, after distributing and sending

the questionnaire for a second time to most of those being contacted in the first time, and with daily following up by telephone, a total of 84 engineers working with owner have responded. In addition, 36 engineers working with contractors have replied and the number of consultants that have replied is 24. Table (3-2) shows the details of questionnaire distribution and response rates.

**Table (3- 2)**  
**Questionnaire Distribution and Response Rates**

| <b>Participating Group</b> | <b>Population</b> | <b>Sample Size</b> | <b>No. distributed</b> | <b>No. Responses</b> | <b>% Responses</b> |
|----------------------------|-------------------|--------------------|------------------------|----------------------|--------------------|
| <b>Owner</b>               | 209               | 136                | 169                    | 84                   | 61.8               |
| <b>Contractors</b>         | 69                | 59                 | 63                     | 36                   | 61.0               |
| <b>Consultants</b>         | 34                | 32                 | 34                     | 24                   | 75.0               |

It can be observed from Table (3-2) that number of distributed questionnaires is greater than the sample size of the 3 populations in order to increase the response rates, however, the response rate for MoW was 61.8%, for the contractors was 61% and for consultants was 75%.

### **3.3.2 Data for NN model**

Interviews were made with project managers of 38 highway construction projects from MoW. Each project manager was asked to rank the frequency and severity of cost overrun factors' groups, which had resulted into cost overrun of his project. For instance, the project manager of the first project ranked the frequency and severity of the

“consultant related factors” as two and three respectively as in Table (3-3). Therefore, the weight of this group for the first project is six. Table (3-4) summarizes the interviews’ results; the data were then used in NN model to determine the most influential factors’ groups on cost overrun.

**Table (3-3)**

**Sample Weight Calculation for Project 1 Based on Interview with the Project Manager**

| Group                   | Project 1 |   |   |   |   |          |   |   |   |   | Weight |
|-------------------------|-----------|---|---|---|---|----------|---|---|---|---|--------|
|                         | Frequency |   |   |   |   | Severity |   |   |   |   |        |
|                         | 1         | 2 | 3 | 4 | 5 | 1        | 2 | 3 | 4 | 5 |        |
| Consultant              |           |   |   |   |   |          |   |   |   |   | 6      |
| Contractor              |           |   |   |   |   |          |   |   |   |   | 8      |
| Estimation              |           |   |   |   |   |          |   |   |   |   | 12     |
| Project Characteristics |           |   |   |   |   |          |   |   |   |   | 6      |
| Owner                   |           |   |   |   |   |          |   |   |   |   | 12     |
| Environment             |           |   |   |   |   |          |   |   |   |   | 10     |
| Cost overrun = BD 9,823 |           |   |   |   |   |          |   |   |   |   |        |

**Table (3-4)****Summary of the Interviews Results**

| Factors Groups | Weight of cost overrun groups |            |            |                         |       |             | Overrun<br>BD |
|----------------|-------------------------------|------------|------------|-------------------------|-------|-------------|---------------|
|                | Consultant                    | Contractor | Estimation | Project Characteristics | Owner | Environment |               |
| Project 1      | 6                             | 8          | 12         | 6                       | 12    | 10          | 9,823         |
| Project 2      | 10                            | 12         | 6          | 8                       | 9     | 9           | 16,749        |
| Project 3      | 6                             | 12         | 14         | 6                       | 8     | 9           | 7,271         |
| Project 4      | 9                             | 12         | 4          | 6                       | 8     | 9           | 68,521        |
| Project 5      | 14                            | 10         | 6          | 5                       | 8     | 5           | 42,060        |
| Project 6      | 9                             | 9          | 4          | 12                      | 9     | 8           | 23,220        |
| Project 7      | 10                            | 8          | 5          | 5                       | 6     | 12          | 5,401         |
| Project 8      | 8                             | 12         | 5          | 8                       | 12    | 9           | 329,492       |
| Project 9      | 9                             | 6          | 12         | 8                       | 8     | 12          | 8,001         |
| Project 10     | 12                            | 9          | 8          | 5                       | 5     | 10          | 5,891         |
| Project 11     | 9                             | 12         | 6          | 6                       | 14    | 9           | 123,111       |

| Factors Groups | Weight of cost overrun groups |            |            |                         |       |             | Overrun BD |
|----------------|-------------------------------|------------|------------|-------------------------|-------|-------------|------------|
|                | Consultant                    | Contractor | Estimation | Project Characteristics | Owner | Environment |            |
| Project 12     | 12                            | 12         | 8          | 9                       | 14    | 8           | 252,748    |
| Project 13     | 14                            | 14         | 6          | 8                       | 12    | 9           | 25,996     |
| Project 14     | 10                            | 10         | 8          | 6                       | 12    | 8           | 278,008    |
| Project 15     | 12                            | 12         | 9          | 8                       | 14    | 9           | 170,000    |
| Project 16     | 12                            | 12         | 8          | 9                       | 8     | 9           | 4,482      |
| Project 17     | 10                            | 12         | 8          | 8                       | 12    | 5           | 31,180     |
| Project 18     | 10                            | 8          | 6          | 12                      | 9     | 12          | 114,565    |
| Project 19     | 10                            | 12         | 6          | 8                       | 12    | 8           | 168,412    |
| Project 20     | 12                            | 10         | 6          | 8                       | 12    | 9           | 242,533    |
| Project 21     | 12                            | 12         | 9          | 8                       | 12    | 8           | 23,223     |
| Project 22     | 10                            | 12         | 8          | 9                       | 12    | 5           | 151,651    |
| Project 23     | 12                            | 12         | 8          | 9                       | 10    | 9           | 607,596    |
| Project 24     | 9                             | 12         | 9          | 8                       | 9     | 8           | 407,553    |

| Factors Groups | Weight of cost overrun groups |            |            |                         |       |             | Overrun BD |
|----------------|-------------------------------|------------|------------|-------------------------|-------|-------------|------------|
|                | Consultant                    | Contractor | Estimation | Project Characteristics | Owner | Environment |            |
| Project 25     | 12                            | 12         | 8          | 9                       | 8     | 9           | 21,709     |
| Project 26     | 10                            | 12         | 8          | 8                       | 12    | 5           | 110,362    |
| Project 27     | 12                            | 14         | 14         | 9                       | 12    | 12          | 1,440,645  |
| Project 28     | 14                            | 14         | 14         | 8                       | 12    | 12          | 728,521    |
| Project 29     | 12                            | 12         | 12         | 9                       | 9     | 12          | 820,159    |
| Project 30     | 12                            | 10         | 9          | 8                       | 12    | 8           | 201,982    |
| Project 31     | 14                            | 14         | 10         | 10                      | 12    | 8           | 60,221     |
| Project 32     | 10                            | 12         | 12         | 10                      | 12    | 8           | 407,832    |
| Project 33     | 12                            | 8          | 10         | 9                       | 10    | 8           | 1,386,212  |
| Project 34     | 12                            | 12         | 8          | 9                       | 14    | 8           | 110,760    |
| Project 35     | 14                            | 14         | 6          | 8                       | 12    | 9           | 110,226    |
| Project 36     | 12                            | 8          | 9          | 4                       | 9     | 12          | 403,591    |
| Project 37     | 9                             | 10         | 4          | 3                       | 8     | 10          | 292,201    |

| Factors<br>Groups | Weight of cost overrun groups |            |            |                         |       |             | Overrun<br>BD |
|-------------------|-------------------------------|------------|------------|-------------------------|-------|-------------|---------------|
|                   | Consultant                    | Contractor | Estimation | Project Characteristics | Owner | Environment |               |
| Project 38        | 12                            | 6          | 10         | 9                       | 11    | 8           | 507,394       |

**CHAPTER FOUR**

**RESULTS AND ANALYSIS OF COST  
OVERRUN FREQUENCY AND SEVERITY**

## **CHAPTER FOUR**

### **RESULTS AND ANALYSIS OF COST OVERRUN FREQUENCY AND SEVERITY**

#### **4.1 Introduction**

This chapter discusses the results obtained from the questionnaire. It discusses major factors leading to cost overrun in highway construction projects in Bahrain based on frequency and severity analysis of questionnaire results. The identified fifty-two factors of cost overrun in highway construction projects in Bahrain Table (3-1) were ranked based on their importance indices.

#### **4.2 Cost Overrun Frequency and Severity Results**

The analysis is based on the questionnaire participants' response to severity and frequency.

##### **4.2.1 Ranking of factors**

The factors under each group were ranked by the measurement of importance index according to the following equation.

$$\text{IMPI}(i) = \text{FI}(i) \times \text{SI}(i) \quad (2)$$

Where IMPI(i), FI(i), and SI(i) are the importance, frequency, and severity indices of factor (i), respectively.

The frequency index is given by:

$$FI(i) = \frac{\sum_{j=1}^5 (w_j \times f_{ij})}{5 \times N} \quad (3)$$

And the severity index is given by:

$$SI(i) = \frac{\sum_{j=1}^5 (w_j \times s_{ij})}{5 \times N} \quad (4)$$

Where;  $w_j$  ( $j=1,2,\dots,5$ ) is the weight given to each factor  $i$  (ranges from  $w_1 = 1$  for very low up to  $w_5 = 5$  for very high),  $f_{ij}/s_{ij}$  are the frequency/severity of the responses for each factor  $i$  associated with weight  $w_j$ , and  $N$  is the total number of responses.

The total number of responses received for the distributed questionnaire is 144. The response results for ranking the frequency and severity of the identified causes of cost overrun are summarized in Table (4-1). Moreover, the table also summarizes the calculated frequency, severity, and importance indices for all factors within each group based on ranking responses.

Based on Table (4-1), factors were then ranked in ascending order of their importance indices. Tables (4-2) to (4-7) show the ranking of the different groups' factors.

**Table (4-1)**  
**Frequency and Severity Results**

| Group      | Factor                                                                  | Frequency (weight) |    |    |    |    |       | Severity (weight) |    |    |    |    |       | IMPI% |
|------------|-------------------------------------------------------------------------|--------------------|----|----|----|----|-------|-------------------|----|----|----|----|-------|-------|
|            |                                                                         | 1                  | 2  | 3  | 4  | 5  | FI    | 1                 | 2  | 3  | 4  | 5  | SI    |       |
| Consultant | 1. Design errors and omissions                                          | 5                  | 15 | 20 | 60 | 44 | 0.785 | 11                | 10 | 10 | 30 | 83 | 0.832 | 65.35 |
|            | 2. Estimator's experience                                               | 5                  | 9  | 30 | 40 | 60 | 0.817 | 1                 | 10 | 27 | 16 | 90 | 0.863 | 70.55 |
|            | 3. Extent of completion of pre-contract design                          | 1                  | 10 | 27 | 16 | 90 | 0.858 | 10                | 5  | 29 | 40 | 60 | 0.790 | 67.79 |
|            | 4. Slowness in inspection and testing of completed works                | 10                 | 5  | 29 | 38 | 62 | 0.797 | 6                 | 9  | 19 | 30 | 80 | 0.830 | 66.13 |
|            | 5. Lack of communication                                                | 2                  | 3  | 19 | 26 | 94 | 0.897 | 5                 | 19 | 17 | 44 | 59 | 0.780 | 69.98 |
|            | 6. Lack of qualified project manager                                    | 0                  | 3  | 20 | 24 | 97 | 0.903 | 7                 | 15 | 26 | 46 | 50 | 0.760 | 68.62 |
| Contractor | 1. Contractor's deficiencies in planning and scheduling at tender stage | 2                  | 6  | 20 | 30 | 86 | 0.878 | 17                | 9  | 27 | 35 | 56 | 0.740 | 64.96 |
|            | 2. Effective monitoring and feedback process                            | 1                  | 10 | 27 | 14 | 92 | 0.869 | 4                 | 20 | 70 | 30 | 20 | 0.660 | 57.38 |
|            | 3. Communication with Suppliers                                         | 4                  | 10 | 28 | 39 | 63 | 0.802 | 2                 | 6  | 20 | 30 | 86 | 0.870 | 69.75 |
|            | 4. Poor procurement programming of materials                            | 5                  | 15 | 33 | 43 | 48 | 0.765 | 5                 | 19 | 17 | 44 | 59 | 0.782 | 59.80 |
|            | 5. Low speed at decision-making                                         | 2                  | 10 | 26 | 40 | 66 | 0.823 | 7                 | 15 | 26 | 46 | 50 | 0.765 | 62.93 |
|            | 6. Staff training in the skill areas relevant to project                | 6                  | 13 | 33 | 40 | 52 | 0.769 | 6                 | 9  | 19 | 30 | 80 | 0.837 | 64.40 |
|            | 7. Availability and supplies of labor and materials                     | 7                  | 17 | 17 | 42 | 61 | 0.786 | 5                 | 5  | 28 | 40 | 66 | 0.811 | 63.74 |

| Group      | Factor                                      | Frequency (weight) |    |    |    |     |       | Severity (weight) |    |    |    |    |       | IMPI% |
|------------|---------------------------------------------|--------------------|----|----|----|-----|-------|-------------------|----|----|----|----|-------|-------|
|            |                                             | 1                  | 2  | 3  | 4  | 5   | FI    | 1                 | 2  | 3  | 4  | 5  | SI    |       |
| Contractor | 8. Contractor's financial difficulties      | 2                  | 18 | 70 | 15 | 39  | 0.701 | 5                 | 19 | 17 | 44 | 59 | 0.780 | 54.69 |
|            | 9. Inadequate contractors experience        | 8                  | 20 | 70 | 30 | 16  | 0.637 | 2                 | 6  | 20 | 30 | 86 | 0.870 | 55.46 |
|            | 10.Lack of project knowledge                | 0                  | 0  | 3  | 22 | 119 | 0.974 | 2                 | 18 | 70 | 15 | 39 | 0.690 | 67.2  |
|            | 11.Lack of qualified project manager        | 6                  | 9  | 17 | 30 | 82  | 0.845 | 5                 | 5  | 28 | 40 | 66 | 0.814 | 68.77 |
|            | 12.Methods/techniques of construction       | 6                  | 9  | 21 | 28 | 80  | 0.838 | 2                 | 18 | 70 | 15 | 39 | 0.694 | 58.18 |
|            | 13.Planning and scheduling deficiencies     | 7                  | 15 | 23 | 46 | 53  | 0.779 | 5                 | 19 | 17 | 44 | 59 | 0.785 | 61.17 |
|            | 14.Poor site management and supervision     | 7                  | 17 | 21 | 39 | 60  | 0.794 | 6                 | 9  | 19 | 30 | 80 | 0.830 | 65.89 |
|            | 15. Rework from poor materials quality      | 3                  | 4  | 3  | 3  | 131 | 0.945 | 9                 | 33 | 77 | 15 | 10 | 0.598 | 56.52 |
| Estimation | 1. Estimator's Experience                   | 3                  | 6  | 3  | 3  | 129 | 0.959 | 7                 | 15 | 26 | 46 | 50 | 0.769 | 73.74 |
|            | 2. Cost Estimation Methods                  | 14                 | 2  | 2  | 4  | 122 | 0.919 | 7                 | 17 | 17 | 42 | 61 | 0.789 | 72.48 |
|            | 3. Availability of data of similar projects | 6                  | 10 | 18 | 27 | 83  | 0.848 | 6                 | 9  | 19 | 30 | 80 | 0.830 | 70.38 |
|            | 4. Deficiencies in cost estimates prepared  | 2                  | 6  | 20 | 30 | 86  | 0.870 | 3                 | 13 | 28 | 40 | 60 | 0.802 | 69.75 |
|            | 5. Procedure for updating cost information  | 6                  | 7  | 18 | 30 | 83  | 0.849 | 10                | 5  | 29 | 40 | 60 | 0.808 | 68.63 |

| Group                   | Factor                                              | Frequency (weight) |    |    |    |     |       | Severity (weight) |    |    |    |     |       | IMPI% |
|-------------------------|-----------------------------------------------------|--------------------|----|----|----|-----|-------|-------------------|----|----|----|-----|-------|-------|
|                         |                                                     | 1                  | 2  | 3  | 4  | 5   | FI    | 1                 | 2  | 3  | 4  | 5   | SI    |       |
| Estimation              | 6. Time allowed for preparing the cost estimate     | 0                  | 0  | 4  | 13 | 127 | 0.985 | 2                 | 6  | 80 | 17 | 39  | 0.723 | 71.2  |
| Project Characteristics | 1. Project duration                                 | 0                  | 3  | 20 | 23 | 98  | 0.902 | 2                 | 18 | 70 | 15 | 39  | 0.695 | 62.7  |
|                         | 2. Build-ability (including on-site prefabrication) | 8                  | 14 | 58 | 12 | 52  | 0.722 | 7                 | 15 | 26 | 46 | 50  | 0.774 | 55.91 |
|                         | 3. Complexity of design and construction            | 2                  | 18 | 70 | 15 | 39  | 0.715 | 7                 | 17 | 17 | 42 | 61  | 0.780 | 55.74 |
|                         | 4. Location of project                              | 4                  | 20 | 68 | 31 | 21  | 0.672 | 2                 | 3  | 19 | 30 | 90  | 0.890 | 59.8  |
|                         | 5. Services relocation costs                        | 2                  | 3  | 19 | 26 | 94  | 0.891 | 4                 | 20 | 70 | 30 | 20  | 0.660 | 58.78 |
|                         | 6. Project size                                     | 2                  | 8  | 19 | 30 | 85  | 0.864 | 9                 | 15 | 26 | 48 | 46  | 0.750 | 64.78 |
|                         | 7. Construction techniques required                 | 4                  | 18 | 70 | 15 | 37  | 0.688 | 5                 | 5  | 28 | 40 | 66  | 0.823 | 56.63 |
| Owner                   | 1. Delays in work approval waiting for information  | 9                  | 4  | 16 | 29 | 86  | 0.860 | 2                 | 6  | 20 | 30 | 86  | 0.869 | 74.76 |
|                         | 2. Cash flow during construction                    | 0                  | 4  | 20 | 30 | 90  | 0.896 | 10                | 5  | 29 | 40 | 60  | 0.795 | 71.27 |
|                         | 3. Low speed at decision-making                     | 0                  | 0  | 4  | 4  | 136 | 0.998 | 7                 | 15 | 26 | 46 | 50  | 0.775 | 77.36 |
|                         | 4. Disputes                                         | 10                 | 5  | 29 | 40 | 60  | 0.811 | 2                 | 3  | 19 | 28 | 92  | 0.886 | 71.89 |
|                         | 5. Form of procurement and contractual arrangements | 9                  | 15 | 26 | 46 | 48  | 0.748 | 0                 | 1  | 7  | 7  | 129 | 0.984 | 73.56 |
|                         | 6. Frequent Change orders/Variation by owner        | 0                  | 3  | 15 | 16 | 110 | 0.920 | 1                 | 10 | 27 | 16 | 90  | 0.854 | 78.55 |

| Group       | Factor                                          | Frequency (weight) |    |    |    |     |       | Severity (weight) |    |    |    |    |       | IMPI% |
|-------------|-------------------------------------------------|--------------------|----|----|----|-----|-------|-------------------|----|----|----|----|-------|-------|
|             |                                                 | 1                  | 2  | 3  | 4  | 5   | FI    | 1                 | 2  | 3  | 4  | 5  | SI    |       |
| Owner       | 7. Payment delay                                | 0                  | 3  | 15 | 14 | 112 | 0.931 | 7                 | 15 | 26 | 48 | 48 | 0.764 | 71.13 |
|             | 8. Specifications Change                        | 6                  | 6  | 18 | 30 | 84  | 0.846 | 2                 | 3  | 20 | 24 | 95 | 0.890 | 75.25 |
| Environment | 1. Tender period and market condition           | 8                  | 4  | 20 | 31 | 81  | 0.848 | 7                 | 15 | 26 | 45 | 49 | 0.752 | 63.75 |
|             | 2. Cultural heritage issues                     | 4                  | 17 | 68 | 15 | 40  | 0.718 | 2                 | 6  | 20 | 30 | 86 | 0.873 | 62.68 |
|             | 3. Escalation of material prices                | 2                  | 14 | 69 | 16 | 43  | 0.716 | 3                 | 13 | 28 | 40 | 60 | 0.803 | 57.47 |
|             | 4. Frequent breakdown of construction equipment | 3                  | 18 | 70 | 15 | 38  | 0.693 | 5                 | 9  | 30 | 40 | 60 | 0.806 | 55.89 |
|             | 5. Government interference                      | 0                  | 6  | 80 | 17 | 41  | 0.732 | 4                 | 3  | 17 | 27 | 93 | 0.886 | 64.85 |
|             | 6. Inflation                                    | 14                 | 20 | 80 | 15 | 15  | 0.594 | 2                 | 7  | 13 | 23 | 99 | 0.893 | 53.01 |
|             | 7. Lead times for delivery of materials         | 10                 | 14 | 27 | 45 | 48  | 0.754 | 7                 | 15 | 26 | 44 | 52 | 0.779 | 58.75 |
|             | 8. Monopoly of material suppliers               | 0                  | 8  | 30 | 39 | 67  | 0.830 | 5                 | 20 | 70 | 30 | 19 | 0.654 | 54.26 |
|             | 9. Weather                                      | 0                  | 4  | 82 | 17 | 41  | 0.731 | 2                 | 12 | 28 | 40 | 62 | 0.813 | 59.39 |
|             | 10.Unexpected geological conditions             | 0                  | 8  | 30 | 39 | 67  | 0.839 | 2                 | 6  | 81 | 17 | 38 | 0.725 | 60.82 |

#### **a. Factors related to consultant**

Table (4-2) shows the importance index and ranking of each factor under the consultant group. Six factors are considered under this group. The table shows that the respondents pointed out “estimator’s experience” factor as the top affecting factor under this group with an importance index value of 70.55%. This result is supported by Azhar et al. (2008), who confirmed that estimator’s experience affects accuracy of cost estimating. “Lack of communication” is ranked in position number two with importance index value of 69.98%. “Lack of qualified project manager” is ranked in third position with importance index value of 68.62%. It can be noticed that all factors under this group have importance indices higher than 60%, indicating that all of them are highly affecting the accuracy of cost estimate.

**Table (4- 2)**

#### **Importance Index and Ranking of Each Factor under the Consultant Group**

| Factor                                                | IMPI% | Rank |
|-------------------------------------------------------|-------|------|
| Estimator’s experience                                | 70.55 | 1    |
| Lack of communication                                 | 69.98 | 2    |
| Lack of qualified project manager                     | 68.62 | 3    |
| Extent of completion of pre-contract design           | 67.79 | 4    |
| Slowness in inspection and testing of completed works | 66.13 | 5    |
| Design errors and omissions                           | 65.35 | 6    |

## **b. Factors related to contractor**

Table (4-3) illustrates the ranking of the 15 factors in the group related to contractor. The results show that the most important factor affecting the pre-tender cost estimate is “communication with suppliers” as the top contributing factor to cost overrun with importance index value of 69.75%. This can be related to the fact that when the contractor communicates with the suppliers he will know the latest rates based on which he can prepare the cost estimate. “Lack of qualified project manager” with importance index value of 68.77% is ranked as second in this group. “Lack of project knowledge” is ranked at third position with importance index value of 67.20%. The factor ranked at the bottom of the list is “contractor’s financial difficulties” with importance index value of 54.69%. This low value is related to the fact that highway construction contractors in Bahrain have good financial status, and therefore it is very rarely that they will have financial difficulties. Also, the second to last factor in the list is “inadequate contractors’ experience” with importance index value of 55.46%. This can be related to the fact that MoW go through a thorough process for contractor pre-qualification and selection. All contractors who bid for a highway construction project are evaluated financially and technically, and those who don’t pass the evaluation are disqualified.

**Table (4-3)**

### **Importance Index and Ranking of Each Factor under the Contractor Group**

| Factor                       | IMPI% | Rank |
|------------------------------|-------|------|
| Communication with suppliers | 69.75 | 1    |

|                                                                      |       |    |
|----------------------------------------------------------------------|-------|----|
| Lack of qualified project manager                                    | 68.77 | 2  |
| Lack of project knowledge                                            | 67.20 | 3  |
| Poor site management and supervision                                 | 65.89 | 4  |
| Staff training in the skill areas relevant to project                | 64.40 | 5  |
| Availability and supplies of labor and materials                     | 63.74 | 6  |
| Low speed at decision-making                                         | 62.93 | 7  |
| Planning and scheduling deficiencies                                 | 61.17 | 8  |
| Contractor's deficiencies in planning and scheduling at tender stage | 60.65 | 9  |
| Poor procurement programming of materials                            | 59.80 | 10 |
| Methods/techniques of construction                                   | 58.18 | 11 |
| Effective monitoring and feedback process                            | 57.38 | 12 |
| Rework from poor materials quality                                   | 56.52 | 13 |
| Inadequate contractors' experience                                   | 55.46 | 14 |
| Contractor's financial difficulties                                  | 54.69 | 15 |

### **c. Factors related to estimation**

Table (4-4) indicates the ranking of 6 factors under the group related to cost estimating. These factors are placed in descending order according to their importance: In first place with importance index value of 73.74% is the factor “estimator’s experience”, followed by “cost estimation methods” with importance index value of 72.48%. The top third factor in this group is “time allowed for preparing cost estimates” with importance index value of 71.20%. The factor ranked at

the bottom of the list is “procedure for updating cost information” which has an importance value of 68.63%.

**Table (4- 4)**  
**Importance Index and Ranking of Each Factor under the Estimation Group**

| Factor                                       | IMPI% | Rank |
|----------------------------------------------|-------|------|
| Estimator’s experience                       | 73.74 | 1    |
| Cost estimation methods                      | 72.48 | 2    |
| Time allowed for preparing the cost estimate | 71.20 | 3    |
| Availability of data of similar projects     | 70.38 | 4    |
| Accuracy and reliability of cost information | 69.75 | 5    |
| Procedure for updating cost information      | 68.63 | 6    |

#### **d. Factors related to project characteristics**

Table (4-5) shows the seven factors in the group related to project characteristics; these are ranked according to their importance in affecting accuracy of cost estimate as follows: In first place with importance index value of 64.78% is the factor “project size”, followed by “project duration” with importance index value of 62.70%. The top third factor in this group is “location of project” with importance index value of 59.80%. It should be mentioned that only two factors of this group have importance index values of more than 60%. The factors “build-ability” comes at the bottom of the list with importance index value of 55.91%.

**Table (4- 5)**  
**Importance Index and Ranking of Each Factor under the Project Characteristics Group**

| Factor                                           | IMPI% | Rank |
|--------------------------------------------------|-------|------|
| Project size                                     | 64.78 | 1    |
| Project duration                                 | 62.70 | 2    |
| Location of project                              | 59.80 | 3    |
| Services relocation costs                        | 58.78 | 4    |
| Construction techniques required                 | 56.63 | 5    |
| Complexity of design and construction            | 55.74 | 6    |
| Build-ability (including on-site prefabrication) | 55.91 | 7    |

**e. Factors related to owner**

Table (4-6) shows the importance index and ranking of each factor under the owner group. Eight factors are considered under this group. The top ranked factor is “frequent change orders/variations by owner” with importance index value of 78.55%. The second top factor in this group is “low speed in decision-making” with an importance index value of 77.36%. “Specification change” is ranked as the third top factor in this group with importance index value of 75.25%. All the factors of this group have shown importance index value of more than 71%.

**Table (4- 6)****Importance Index and Ranking of Each Factor under the Owner Group**

| Factor                                           | IMPI% | Rank |
|--------------------------------------------------|-------|------|
| Frequent Change orders/Variation by owner        | 78.55 | 1    |
| Low speed at decision-making                     | 77.36 | 2    |
| Specifications Change                            | 75.25 | 3    |
| Delays in work approval waiting for information  | 74.76 | 4    |
| Form of procurement and contractual arrangements | 73.56 | 5    |
| Disputes                                         | 71.89 | 6    |
| Cash flow during construction                    | 71.27 | 7    |
| Payment delay                                    | 71.13 | 8    |

**f. Factors related to environment**

Table (4-7) shows the 10 factors in the group related to environment; these are ranked according to their importance in affecting accuracy of cost estimate as follows: In first place with importance index value of 64.85% is the factor “government interference. This factor is somehow similar to the factor “frequent changes made by the owner” in factors’ group related to owner, which is intentionally added to ensure the results are accurate, i.e. for cross checking. However, it is considered here as an environmental factor. The second most ranked factor is “tender period and market condition” with importance value of 63.75%. “Cultural heritage issue” is the third

top ranked factor with importance index value of 62.68%. Four factors have importance values of more than 60%, whereas, the remaining six have values of less than 60%.

**Table (4- 7)**  
**Importance Index and Ranking of Each Factor under the Environment Group**

| Factor                                       | IMPI% | Rank |
|----------------------------------------------|-------|------|
| Government interference                      | 64.85 | 1    |
| Tender period and market condition           | 63.75 | 2    |
| Cultural heritage issues                     | 62.68 | 3    |
| Unexpected geological conditions             | 60.82 | 4    |
| Weather                                      | 59.39 | 5    |
| Lead times for delivery of materials         | 58.75 | 6    |
| Escalation of material prices                | 57.47 | 7    |
| Frequent breakdown of construction equipment | 55.89 | 8    |
| Monopoly of material suppliers               | 54.26 | 9    |
| Inflation                                    | 53.01 | 10   |

### **g. Groups ranking**

The six groups of the identified fifty-two factors causing cost overruns in highway construction projects in Bahrain are ranked based on average IMPI, and are presented in Table (4-8). The results show that the top-affecting group is the owner related group (IMPI = 74.22%), followed by estimation related group (IMPI = 71.03%) and

consultant related group (IMPI = 68.07%). The table also shows that the groups' importance indices are ranging from 59% to 74%, and the environment group is the one with the lowest importance index.

**Table (4- 8)**  
**Importance Indices and Ranking of Each Group**

| Group                                   | IMPI% | Rank |
|-----------------------------------------|-------|------|
| Owner related factors                   | 74.22 | 1    |
| Estimation related factors              | 71.03 | 2    |
| Consultant related factors              | 68.07 | 3    |
| Contractor related factors              | 61.76 | 4    |
| Project characteristics related factors | 59.20 | 5    |
| Environment related factors             | 59.10 | 6    |

**CHAPTER FIVE**

**NEURAL NETWORK THEORETICAL  
BACKGROUND**

## **CHAPTER FIVE**

# **NEURAL NETWORK THEORETICAL BACKGROUND**

### **5.1 Introduction**

The applications of Artificial Neural Networks (ANN) in construction management go back to the early 1980's. These applications of ANN cover a very wide area of construction issues (ElSawy et al., 2011). The early attempts to use ANN techniques for cost estimation were conducted by Sonmez (1993) who developed models for estimating the cost of assembly systems. Bouabaz and Hamami (2008) developed cost models using curve-fitting multi-layer networks, but they did not undertake performance evaluation and systematic comparison through their work.

Internationally, NN models have been developed to assist the construction managers or contractors in many crucial construction decisions. Some of these models were designed for cost estimation, decision making, predicting the percentage of mark up, predicting production rate,.. etc. (ElSawy et al., 2011).

NN structure plays a significant role in model accuracy (Dindar, 2004). However, there are no applicable rules for the optimal setting of control variables and topologies (Caputo and Pelagagge, 2008). Otherwise, generalization and over fitting is directly related to the

architecture used in the NN to model the data, since training iterations and the number of hidden units are key elements during the training of the network, and adjusting these elements could lead to great improvements in the networks modeling capability (Dindar, 2004). Bouabaz and Hamami (2008) demonstrated that there are a number of factors for selecting the NN structure and rules, such as the nature of the problem, data characteristics, complexity of data and the number of sample data.

The network architecture refers to the number of hidden layers and the number of nodes within each hidden layer. As a matter of fact, there are two questions in designing a NN that have no specific answers because they are mainly depend on the application; the first is the required data to train a network, and the best number of hidden layers and nodes to be used. Generally, the more data and the fewer hidden layers and hidden nodes that can be used, is the better. There is a subtle relationship between the number of data and the number of hidden layers/nodes. Having too few data or too many hidden layers/nodes can cause the network to "Memorize". When this happens, it performs well during training but tests poorly (ElSawy et al., 2011).

As a rule of thumb, determining the number of hidden layers/nodes is one of the main drawbacks of NNs, because there is no specific rule and it requires many trial and error processes while considerable time must be spent (Kim et al., 2004). Hegazy and Moselhi (1994) stated that one hidden layer with a number of hidden nodes as  $0.75m$ ,  $m$ , or  $2m+1$ , where  $m$  is the number of input nodes, is suitable for most applications.

The main building elements of ANNs are nodes or nodes and the links connecting between them. Each link has a weight parameter associated with it. These nodes are assorted into three categories, which

are input, output, and hidden nodes. Each neuron receives stimulus from the neighboring nodes connected to it, processes the information and produces an output. Nodes that receive stimuli from outside the network (i.e., not from nodes of the network) are called input nodes. Nodes whose outputs are used externally are called output nodes. Nodes that receive stimuli from other nodes and whose output is a stimulus for other nodes in the NN are known as hidden nodes. There are different ways in which information can be processed by a node, and different ways of connecting the nodes to one another. In general, different NN structures can be constructed by using different nodes and by the specific manner in which they are connected (Cengiz et al., 2005).

Figure (5-1) displays the above structure of ANN, which consists of three basic layers, input, hidden and output layer. Each one contains several nodes except output layer; it contains one neuron that represents the output of training process.

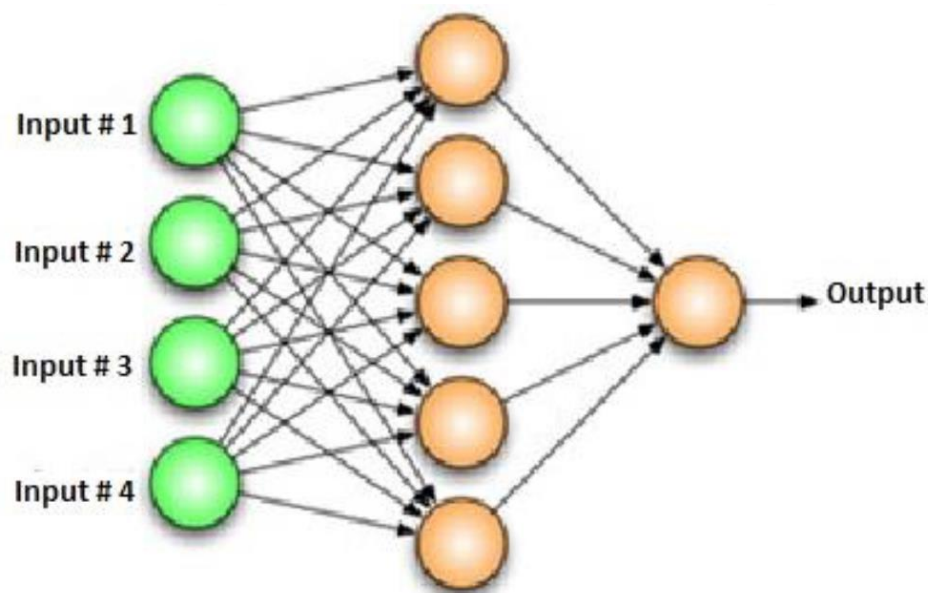
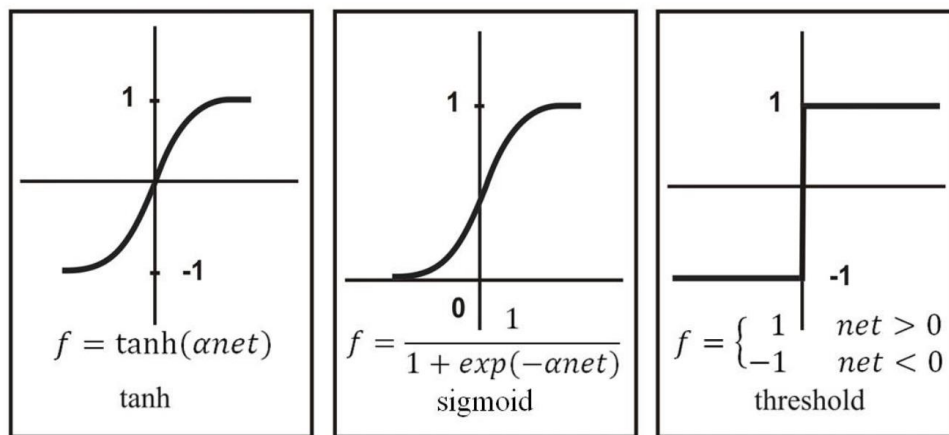


**Figure (5- 1)**  
**Artificial Neural Network Structure (Principe et al., 2010)**

Activation functions experimentally change based on the placed independent variables in the model and expected outputs (Attal, 2010). The activation function performs a mathematical operation on the signal output, depending upon the type of input data and the output required (Kriesel, 2005). Over the years, the researchers tried several functions to convert the input into output, various mathematical functions have been used as activation functions, These functions can take many forms: Linear, Logistic, and tangent, etc. Most commonly used are threshold function (Hard limit), sigmoid function, tanh function, and bias function as shown in Figure (5-2) (Principe et al., 2010).



“net” is the NN and “ $\alpha net$ ” is the angle of the NN

**Figure (5- 2)**  
**Three Most Commonly Used Activation Functions (Principe et al., 2010)**

Before starting the training phase, it is usually necessary to scale the data, or normalize it to the network's paradigm. Kshirsagar and Rathod (2012) and Gunaydin and Dogan (2004) stated that data is generally normalized for the purpose of confidentiality and for effective training of the model being developed. Thus, the input data must be normalized between an upper and lower bounds (Principe et al., 2010).

The normalization of training data is recognized to improve the performance of trained networks.

## 5.2 Types of ANNs

There are several types of ANNs which can be classified according to their connection geometries or by the algorithms used in the training process, such as feed forward network, radial basis function networks (RFB), self-organizing map (SOM),.. etc. (Cengiz et al., 2005). The following paragraphs classify the most common ANN types.

### 5.2.1 Single-layer feed forward networks

It is the simplest form of a layered network, which consists of a single layer of weights, where the inputs are directly connected to the outputs by series of weights as shown in Figure (5-3). Such a network is called a single-layer network, with the designation "single layer" referring to the output layer of computation nodes. The input layer of source nodes is not counted because no computation is performed there (Al-Najjar, 2005).

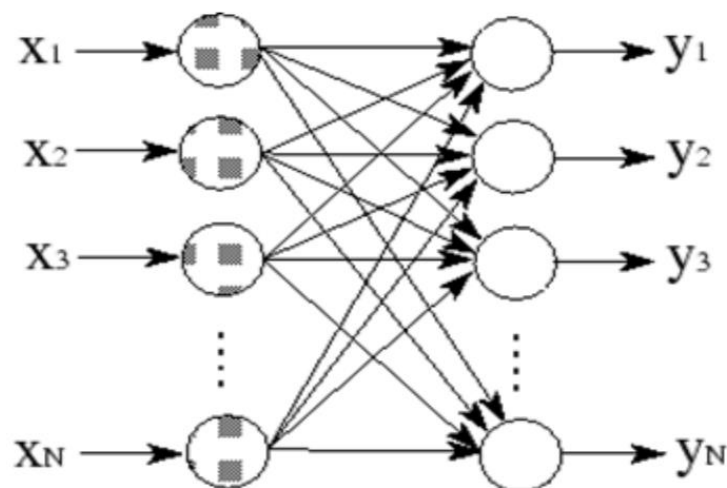


Figure (5- 3)

Single Layer Feed Forward Network (AlNajjar, 2005)

## **5.2.2 Feed forward network**

In this network, the information moves just in one direction, forward, from the input nodes, through the hidden nodes and to the output nodes. There are no cycles or loops in the network (Kshirsagar and Rathod, 2012). Feed forward networks can be classified into several types, the most common ones are multi-layer perceptron (MLP) and general feed forward (GFF) (Pawar, 2007).

### **a) Multi-layer perceptron (MLP)**

The most popular type of NN in use currently is MLP, which is commonly used in regression and classification problems. They are capable of modeling many functions but require a large amount of time, epochs, and nodes (Weckman et al., 2010).

In MLP, nodes are organized in several layers: the first is the input layer (fed by a pattern of data), while the last is the output layer (which provides the answer to the presented pattern). Between input and output layers there is one or more hidden layers, which are comprised of the nodes chosen in the design phases shown in Figure (5-4) (Christian et al., 2000).

Each node of these takes the input values, associated weights, and runs them through the chosen function. The chosen function affects how and how well the network is able to learn. The node then uses a transfer function to produce a weight- associated output. The hidden node values and weights are run through the output node (layer) algorithm, and a final output value is calculated (Dowler, 2008).

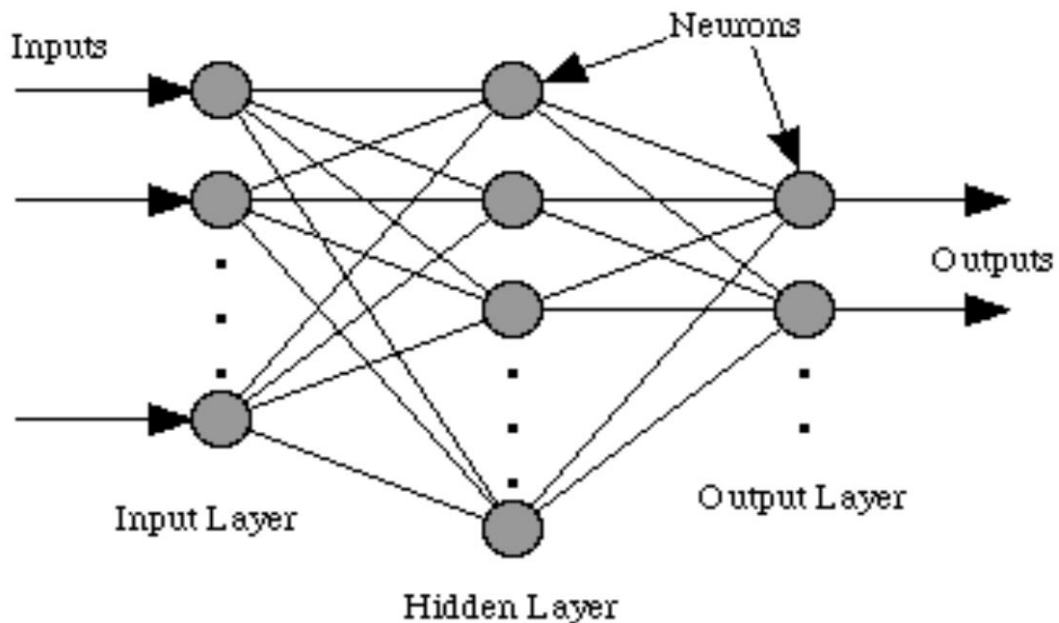


**Figure (5-4)**  
**Multilayer Perceptron (Christian et al., 2000)**

b) General feed forward (GFF)

GFF networks are a special case of MLP such that connections can jump over one or more layers as shown in Figure (5-5). The GFF networks often solve the problem much more efficiently. A classic example of this is the two-spiral problem. Without describing the problem, it suffices to say that a standard MLP requires hundreds of times more epochs of training than the generalized feed forward (for the same size network) (Principe et al., 2010).

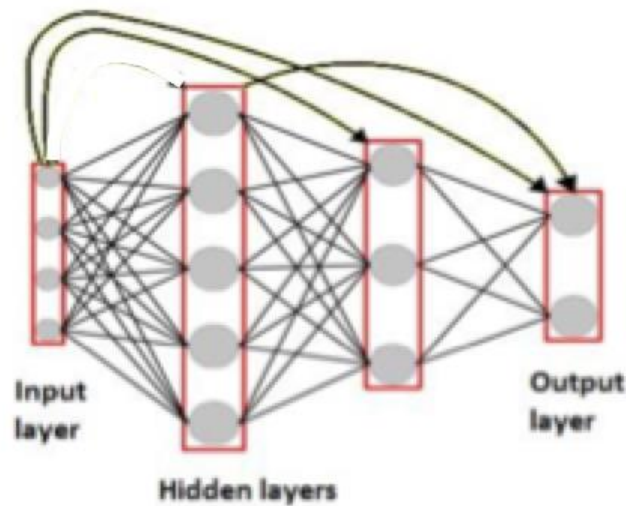


**Figure (5- 5)**

**General Feed Forward Networks Structure (Principe et al., 2010)**

## **5.3 Training of NN**

The objective of training a NN is to adjust the network's weights to bring its output closer to the desired output, where the weights after training contain meaningful information, whereas before training, they are random and have no meaning. This process of changing or adapting the connection weights in some orderly fashion using a suitable learning method is referred to as the learning rule of the network (Doğan, 2005).

The first step in the training process is to initialize the weight of parameters that randomly assigned to the links between nodes. The output of the NN is compared with desired values, and an error is calculated by learning algorithm then the weights associated with each link are adjusted in an attempt to minimize the network's mean square error. The input values are run through the network with the adjusted

weights and the process restarts from the beginning. The process is repeated for the predetermined number of epochs. An epoch represents one cycle of the training process (Dowler, 2008). When the training reaches a satisfactory level, the network holds the weights constant and uses the trained network to make decisions, or define associations in new input data sets not used to train it (Doğan, 2005).

As mentioned earlier, there are several training algorithms to be chosen for training process, one of the most common and powerful algorithm that is adopted in this study is back propagation algorithm, which belongs to the realm of supervised learning (Gunaydın and Dogan, 2004). Back propagation was introduced in 1969 to learn a multilayer network for a given set of input patterns with known classifications. It tries to improve the performance of the NN by reducing the total error through changing the weights along its gradient (Jitendra et al., 2011). The error can be expressed by the mean-square error (MSE), which is calculated by:

$$MSE = \frac{\sqrt{\sum_{i=1}^n (x_i - E_i)^2}}{n} \quad (5)$$

Where  $n$  is the number of examples to be evaluated in the training set;  $x_i$  is the network output (target) related to the example ( $i=1, 2, \dots, n$ ); and  $E_i$  is the desired output.

As the error converges to zero, the output patterns computed by the ANN perfectly match the expected values, and the network is well trained (Dogan, 2005). The algorithm involves two phases, forward phase to compute the output and the backward phase to perform modifications in the backward direction (Jitendra et al., 2011).

These two phases compose one cycle, where each training cycle is

called an epoch, and the weights are updated in each cycle. Training process stops when one of the following three conditions is met (Weckman et al., 2010):

- 1) The maximum number of epochs is reached,
- 2) The cross validation error starts to increase, or
- 3) Very large number of epochs without improvement in error is reached.

Eventually, the network's weights are continuously adjusted until the error in the calculated outputs converges to an acceptable level or stopping the training process if one of previous condition is reached.

## **5.4 Cross-Validation of NN**

A simple method to compare the performance of NNs is to test the errors of the networks using a separate validation/test data set. Basically, the available data is always divided into three parts prior to the training including: training data; cross-validation data; and testing data. The cross-validation data is used during the training but for monitoring not to train the network, to check the learning of the network during the training; and the testing data is used to validate the training network after finishing training process (Edara, 2003).

Cross validation uses its own data set to monitor the NN's ability to produce generalized cost estimates; this is done by training many networks on a training set and comparing the errors of the networks on the validation set. The networks that performed best on the validation data set are then selected (Dindar, 2004). The network continues to

learn as the error for the cross validation and the training data set continue to decrease.

Once the error for the cross validation data set starts to increase, the training stops and the weight values that provided the lowest error for the cross validation data set are considered the best. If cross validation is not used, then a testing data set is critical to prove that memorization and over-fitting is not occurring (Weckman et al., 2010 and Dowler, 2008).

## **5.5 Testing of NN**

Testing the network is essentially the same as training (ElSawy et al., 2011). The testing set is critical to confirm that the network has not simply memorized a given set of data but has learned the general patterns involved within an application (Kshirsagar and Rathod, 2012).

The testing data is totally a different set of data that the network is unaware of; after finishing the training process testing data is used for validation and generalization of the trained network. If the network is able to generalize rather precisely the output for this testing data, then it means that the NN is able to predict the output correctly for new data and hence the network is validated. Moreover, the amount of data that is to be used for training and testing purposes is depending on the availability of the data, but in general the training data is 2/3rd of the full data and the remaining is used for testing purposes. The cross-validation data can be 1/10th of the training data (Edara, 2003).

## 5.6 Performance Measures of ANN Model

The most common approaches that have been utilized to determine the estimation accuracy in the testing phase are:

- Mean absolute error (MAE)
- Mean absolute percentage error (MAPE)
- Correlation coefficient (R)

### 5.6.1 Mean absolute error (MAE)

It is one of many ways to quantify the difference between an estimated and the actual value of the projects being estimated. According to Willmott and Matsuura (2005) the MAE is relatively simple, it involves summing the magnitudes (absolute values) of the errors to obtain the “total error” and then dividing the total error by n, it can be defined by the following formula:

$$MAE = \frac{\sum_{j=0}^P \sum_{i=0}^N |dy_{ij} - dd_{ij}|}{NP} \quad (6)$$

Where P is the number of outputs; N is the number of exemplars in the data set;  $dy_{ij}$  is the denormalized network output for exemplar i; and  $dd_{ij}$  is the denormalized desired output for exemplar i.

### 5.6.2 Mean absolute percentage error (MAPE)

The mean absolute percentage error is a quantity used to measure how close forecasts or predictions are to the eventual outcomes. According to Principe et al. (2010), the MAPE is defined by the following formula:

$$MAPE = \frac{100}{NP} \sum_{j=0}^P \sum_{i=0}^N \frac{|dy_{ij} - dd_{ij}|}{dd_{ij}} \quad (7)$$

Where the definitions of the parameters are as given for the MAE measure.

### 5.6.3 Correlation coefficient (R)

According to Principe et al. (2010), the size of the mean square error (MSE) can be used to determine how well the network output fits the desired output, but it doesn't necessarily reflect whether the two sets of data move in the same direction. For instance, by simply scaling the network output, we can change the MSE without changing the directionality of the data. The correlation coefficient (r) solves this problem.

By definition, the correlation coefficient between a network output  $x$  and a desired output  $d$  is given by:

$$r = \frac{\frac{\sum_i (x_i - \bar{x})(d_i - \bar{d})}{N}}{\sqrt{\frac{\sum_i (d_i - \bar{d})^2}{N}} \sqrt{\frac{\sum_i (x_i - \bar{x})^2}{N}}} \quad (8)$$

Where  $x_i$  is input of exemplar  $i$ ;  $\bar{x}$  is the average value of exemplar inputs;  $d_i$  is the denormalized network output for exemplar  $i$ ;  $\bar{d}$  is the average value of the denormalized network outputs for all exemplars.

The correlation coefficient is confined to the range  $[-1,1]$ . When  $r = 1$  there is a perfect positive linear correlation between  $x$  and  $d$ . When  $r = -1$ , there is a perfectly linear negative correlation between  $x$  and  $d$ . When  $r = 0$  there is no correlation between  $x$  and  $d$ , i.e. the variables are uncorrelated. Intermediate values describe partial correlations. For example a correlation coefficient of 0.88 means that the fit of the model to the data is reasonably good (Principe et al., 2010).

## 5.7 NNs Properties

An important property of NNs is their ability to detect hidden relationships among case data, and to apply these relationships to new data. They can be used to classify data (clustering), to approximate functions (curve), and to extract orthogonal factors (principle components) from interdependent data. Moreover, NNs are robust; they are able, within limits, to deal with inexact or missing data. However, the suitability of the result depends on the type of application and the architecture of the network. Another property is the robustness of NNs against physical failure of a single component. The low level of complexity and the small number of training samples allow NNs to run on a single microcomputer (Bode, 1998).

According to these properties of the NNs; it achieves many pros in the area of cost estimation including accuracy, time, and the ability for a person with very little knowledge about NNs to produce a good cost estimate once the network has been trained (Dowler, 2008). NNs can deal more readily with multivariate non-linear relationships problems. More significantly, these relationships are determined implicitly by the model, and do not therefore require them to be specified (Harding et al., 1999).

Al-Najjar (2005) summarized some advantages of ANNs from several researches as the following:

- 1- ANNs are well suited to model complex problems where the relationship between the model variables is unknown.
- 2- ANNs have the capability of producing correct or nearly correct outputs when presented with partially incorrect or incomplete inputs.

3- ANNs do not need any prior knowledge about the nature of the relationship between the input/output variables, which is one of the benefits that ANNs have compared with most empirical and statistical methods.

4- ANNs can always be updated to obtain better results by presenting new training examples as new data become available.

5- ANNs have the advantage that it gives you the output without the need to perform any manual work such as using tables, charts, or equations.

6- It is often faster to use NNs than a conventional approach.

7- Engineers often deal with incomplete and noisy data, which is one area where ANNs are most applicable.

8- ANNs can learn and generalize from examples to produce meaningful solutions to problems.

9- Data presented for training ANNs can be theoretical data, experimental data, empirical data based on good and reliable experience or a combination of these.

Eventually, ANNs can solve problems that are too complex for conventional techniques, and create its own organization or representation of the information that it receives during the learning time by automated transformation of variables in the network.

## **5.8 Problems and Challenges**

Despite the good performance of NNs in the previous studies essentially in cost estimation, the process of developing and

implementing NNs to parametric cost estimation has a number of problems associated with it. One of the main problems is the black box nature of NNs and their inability to duplicate results. That is because the initial weights being randomly assigned, by another word, it is hard to persuade individuals who do not have a broad understanding of the technique that the NN is producing a reliable cost estimate because it is very difficult to recreate a network (Dowler, 2008).

These problems usually highlighted in previous researches, Kim et al. (2004) stated that NN approach is a black box technique and its knowledge acquisition process is very time consuming. In addition, Islam et al. (2009) declared that the most problem of NN is its hidden internal structure and it is very difficult to duplicate even using the same input variables.

Otherwise, designing the network architecture and setting its parameters is not a straight-forward approach; it actually requires some trial and error process, and there is no explicit set of rules to determine whether a given learning algorithm is suitable for a particular application or not. However, some problems related to back-propagation algorithm are the speed of convergence, the possibility of ending up in a local minimum of the error function and requiring optimization of the network training in order to achieve adequate generalization. In addition, the sample size of data has to be large, so a large amount of time must be spent in determining the best network architecture and the network parameters that best fit the application under consideration.

Finally, NNs do not perform well with applications where precise numerical computations are required, like detailed estimating and cost

control (Ayed, 1997).

## **5.9 Application of ANN in Cost Estimation**

In general, applications of ANN in construction management go back to the early 1980's. These applications cover a very wide area of construction issues. NN models have been developed internationally to assist the managers or contractors in many crucial construction decisions. Some of these models were designed for cost estimation, decision making, predicting the percentage of mark up, predicting production rate ... etc. (ElSawy et al., 2011).

However, despite the large number of researchers who applied NN approach in various fields of engineering, but the studies and researches on utilizing NNs to estimate the cost of construction projects at various stages of the work are very limited (Arafa and Alqedra, 2011). The early attempts to embed ANN technique within the cost estimation area was by Bouabaz and Hamami (2008) who developed models for estimating the cost of assembly systems.

Locally, there is a lack of cost estimation researches based on ANN. According to Al-Shanti (2003) the most of contracting companies are still estimating the cost of projects manually, and a little user friendly estimating software packages due to a lack of available qualified personnel in using computer-based estimating systems. Therefore, AlShanti tried to develop a powerful and user friendly cost estimating system which runs within Microsoft Excel sheets.

Arafa and Alqedra (2011) developed an ANN model to estimate

the cost of highway construction projects at early stages. A database of 71 projects as collected from the construction industry of the Gaza Strip was used in developing ANN model that had one hidden layer with seven nodes. The results obtained from the trained models indicated that NNs reasonably succeeded in predicting the early stage cost estimation of highways using basic information of the projects.

Regionally, Elsayy et al. (2011) developed a NN model to assess the percentage of site overhead costs for building projects in Egypt, which can assist the decision makers during the tender analysis process. Fifty-two actual real-life cases of building projects constructed in Egypt during the seven year period 2002-2009 were used as training data. The NN architecture was presented for the estimation of the site overhead costs as a percentage from the total project price. The results of the testing model indicated an accuracy of (80%), as the model wrongly predicted the percentage of site overhead costs for only one project out of 5 tested samples.

Internationally, Kim et al. (2005) applied hybrid models of ANN and Genetic Algorithm (GA) to estimate the preliminary cost of residential buildings. Data used for training and performance evaluation were for residential buildings constructed from 1997 to 2000 in Seoul, Korea. They first optimized parameters of the back-propagation algorithm using genetic algorithms and then obtained a set of trained weights for the ANN model using GA. The results of the research revealed that optimizing each parameter of back-propagation networks using GA is most effective in estimating the preliminary costs of residential buildings.

Gunaydin and Dogan (2004) developed an ANN model to estimate

the cost of a square meter of the structural system of buildings in early phases of design processes. They collected cost and design data from thirty projects of four to eight storey residential buildings in Turkey. The input layer of the trained ANN model comprised eight parameters available at the early design stage. The trained ANN model was capable of providing accurate estimates of at least 93% of buildings cost per square meter.

Sonmez (2004) developed conceptual cost models for continuing care retirement community projects with regression analysis and NNs. The results obtained from the models were compared for closeness of fit and prediction performance. He indicated that while regression analysis requires a decision about the class of relations to be used in modeling, NN was able to identify the relations between variables and the project cost. It was also shown that by using regression analysis and NN techniques simultaneously, a satisfactory conceptual cost model (which fits the data adequately and has a reasonable prediction performance) can be achieved.

Emsley et al. (2002) trained NN cost models using a database of nearly 300 building projects. They used linear regression techniques as a benchmark for evaluation of the NN models. The results showed the ability of NN to model the nonlinearity in the data, where the model was capable of evaluating the total cost of the construction, and the trained ANN model obtained a mean absolute percentage error of 16.6%.

The above researches indicated that the application of artificial NNs to estimate the early cost of construction projects is a promising area and more studies should be carried out in this field.

## 5.10 SimBrain Application

Several applications support the establishment of NNs like SPSS, MATLAB, etc. In this research, SimBrain application was selected, where SimBrain is the premier NN simulation environment. As mentioned in SimBrain Inc. (2012), SimBrain combines a modular, icon-based network design interface with advanced learning procedures and genetic optimization. It can perform cluster analysis, sales forecasting, sports predictions, medical classification, and much more. Among the features of SimBrain are the following:

Powerful and flexible: NN software is the perfect tool for solving data modeling problems, so it's flexible to build fully customizable NNs or choose from numerous pre-built NN architectures; modify hidden layers, number of processing elements and the learning algorithm (SimBrain Inc., 2012).

Easy to use: SimBrain is an intuitive and easy-to-use NN development tool for Microsoft Windows and MAC, it does not require any prior knowledge of NNs and is seamlessly integrated with Microsoft Excel and MATLAB. SimBrain also includes neural wizards to ensure both beginners and advanced users can easily get started. (SimBrain Inc., 2012).

**CHAPTER SIX**

**NEURAL NETWORK MODEL  
DEVELOPMENT**

## **CHAPTER SIX**

# **NEURAL NETWORK MODEL DEVELOPMENT**

### **6.1 Introduction**

A NNs training program, SimBrain, was used as a standalone environment for NNs development and training. Moreover, for verifying this work, a plentiful trial and error process was performed to obtain the best model architecture. .

Model limitations: In spite of the acceptable accuracy of using ANN in cost estimation, it has a considerable defect, as it depends mainly on historical data; this dependency has several disadvantages as the following;

- Diversity of variables for effective factors is limited to what available in collected data.
- Data should contain sufficient projects for each variable.
- New variables that were not included in adopted model will not be handled.

The following sections present the steps performed to design the ANN model.

## 6.2 Data Standardization and Organization

Having collected the interviews results related to frequency and severity of cost overrun groups' causes for the thirty-eight projects, importance indices were then calculated using Equation (2) as was shown in Table (3-4) in Chapter 3.

Table (6-1) illustrates the available range of input data for each group (variable) in the intended ANN model for cost estimation of highway construction projects based on Table (3-4) in Chapter 3. Weights are importance indices based on frequency and severity results of the groups causing cost overrun in 38 highway projects from years 2005 to 2016. The results were based on interviews with expert engineers in highway construction in MoW.

**Table (6- 1)**  
**Available Range of Input Data in ANN Model for Each Group**  
**(Based on Table (3-4))**

| Group (Variable)                              | Minimum Value<br>(Weight) | Maximum<br>Value (Weight) |
|-----------------------------------------------|---------------------------|---------------------------|
| Factors related to consultant                 | 6                         | 14                        |
| Factors related to contractor                 | 6                         | 14                        |
| Factors related to estimation                 | 4                         | 14                        |
| Factors related to project<br>characteristics | 3                         | 12                        |
| Factors related to<br>Environment             | 5                         | 14                        |
| Factors related to owner                      | 5                         | 12                        |

Ranges in Table (6-1) represent a limitation to the model, as the range should be minimum of 1 and maximum of 25 (likert based scale). However, the table illustrates that the range is between 4 and 14.

Furthermore, input data were normalized for effective model training. Tests have proven that normalized data performed better for the prediction of the total construction cost (Emsley et al., 2002). Data were normalized in the range from 0 to 1 as shown in Table (6-2) using the following formula:

$$\text{Group normalized value for project (i)} = \frac{\text{Group original value for project (i)}}{\text{Group maximum value over all projects}} \quad (9)$$

The normalized data of Table (6-2) will be used in the NN model.

**Table (6-2)****Normalized Indices (Weight) of Each Cost Overrun Group Based on Interviews Results**

|            | Factors Group |            |            |                         |       |             |         |
|------------|---------------|------------|------------|-------------------------|-------|-------------|---------|
|            | Consultant    | Contractor | Estimation | Project Characteristics | Owner | Environment | Overrun |
| Project 1  | 0.43          | 0.57       | 0.86       | 0.50                    | 0.86  | 0.83        | 0.007   |
| Project 2  | 0.71          | 0.86       | 0.43       | 0.67                    | 0.64  | 0.75        | 0.012   |
| Project 3  | 0.43          | 0.86       | 1.00       | 0.50                    | 0.57  | 0.75        | 0.005   |
| Project 4  | 0.64          | 0.86       | 0.29       | 0.50                    | 0.57  | 0.75        | 0.048   |
| Project 5  | 1.00          | 0.71       | 0.43       | 0.42                    | 0.57  | 0.42        | 0.029   |
| Project 6  | 0.64          | 0.64       | 0.29       | 1.00                    | 0.64  | 0.67        | 0.016   |
| Project 7  | 0.71          | 0.57       | 0.36       | 0.42                    | 0.43  | 1.00        | 0.004   |
| Project 8  | 0.57          | 0.86       | 0.36       | 0.67                    | 0.86  | 0.75        | 0.229   |
| Project 9  | 0.64          | 0.43       | 0.86       | 0.67                    | 0.57  | 1.00        | 0.006   |
| Project 10 | 0.86          | 0.64       | 0.57       | 0.42                    | 0.36  | 0.83        | 0.004   |
| Project 11 | 0.64          | 0.86       | 0.43       | 0.50                    | 1.00  | 0.75        | 0.085   |
| Project 12 | 0.86          | 0.86       | 0.57       | 0.75                    | 1.00  | 0.67        | 0.175   |
| Project 13 | 1.00          | 1.00       | 0.43       | 0.67                    | 0.86  | 0.75        | 0.018   |
| Project 14 | 0.71          | 0.71       | 0.57       | 0.50                    | 0.86  | 0.67        | 0.193   |

|            | Factors Group |            |            |                         |       |             |         |
|------------|---------------|------------|------------|-------------------------|-------|-------------|---------|
|            | Consultant    | Contractor | Estimation | Project Characteristics | Owner | Environment | Overrun |
| Project 15 | 0.86          | 0.86       | 0.64       | 0.67                    | 1.00  | 0.75        | 0.118   |
| Project 16 | 0.86          | 0.86       | 0.57       | 0.75                    | 0.57  | 0.75        | 0.003   |
| Project 17 | 0.71          | 0.86       | 0.57       | 0.67                    | 0.86  | 0.42        | 0.022   |
| Project 18 | 0.71          | 0.57       | 0.43       | 1.00                    | 0.64  | 1.00        | 0.080   |
| Project 19 | 0.71          | 0.86       | 0.43       | 0.67                    | 0.86  | 0.67        | 0.117   |
| Project 20 | 0.86          | 0.71       | 0.43       | 0.67                    | 0.86  | 0.75        | 0.168   |
| Project 21 | 0.86          | 0.86       | 0.64       | 0.67                    | 0.86  | 0.67        | 0.016   |
| Project 22 | 0.71          | 0.86       | 0.57       | 0.75                    | 0.86  | 0.42        | 0.105   |
| Project 23 | 0.86          | 0.86       | 0.57       | 0.75                    | 0.71  | 0.75        | 0.422   |
| Project 24 | 0.64          | 0.86       | 0.64       | 0.67                    | 0.64  | 0.67        | 0.283   |
| Project 25 | 0.86          | 0.86       | 0.57       | 0.75                    | 0.57  | 0.75        | 0.015   |
| Project 26 | 0.71          | 0.86       | 0.57       | 0.67                    | 0.86  | 0.42        | 0.077   |
| Project 27 | 0.86          | 1.00       | 1.00       | 0.75                    | 0.86  | 1.00        | 1.000   |
| Project 28 | 1.00          | 1.00       | 1.00       | 0.67                    | 0.86  | 1.00        | 0.506   |
| Project 29 | 0.86          | 0.86       | 0.86       | 0.75                    | 0.64  | 1.00        | 0.569   |
| Project 30 | 0.86          | 0.71       | 0.64       | 0.67                    | 0.86  | 0.67        | 0.140   |

|            | Factors Group |            |            |                         |       |             |         |
|------------|---------------|------------|------------|-------------------------|-------|-------------|---------|
|            | Consultant    | Contractor | Estimation | Project Characteristics | Owner | Environment | Overrun |
| Project 31 | 1.00          | 1.00       | 0.71       | 0.83                    | 0.86  | 0.67        | 0.042   |
| Project 32 | 0.71          | 0.86       | 0.86       | 0.83                    | 0.86  | 0.67        | 0.283   |
| Project 33 | 0.86          | 0.57       | 0.71       | 0.75                    | 0.71  | 0.67        | 0.962   |
| Project 34 | 0.86          | 0.86       | 0.57       | 0.75                    | 1.00  | 0.67        | 0.077   |
| Project 35 | 1.00          | 1.00       | 0.43       | 0.67                    | 0.86  | 0.75        | 0.077   |
| Project 36 | 0.86          | 0.57       | 0.64       | 0.33                    | 0.64  | 1.00        | 0.280   |
| Project 37 | 0.64          | 0.71       | 0.29       | 0.25                    | 0.57  | 0.83        | 0.203   |
| Project 38 | 0.86          | 0.43       | 0.71       | 0.75                    | 0.79  | 0.67        | 0.352   |

## 6.3 Model Building

Several types of ANNs softwares exist that are used to predict the future values based on the past data like SPSS, MATLAB, SimBrain ... etc. Many researchers used SimBrain application in building their NNs that achieved good performance, among these are Edara (2009); Gunaydin and Dogan (2010); Dowler (2012); Attal (2012); Wang et al. (2012).

The developed model in this research is based on SimBrain for Excel program. It is selected for its ease of use, speed of training, flexibility of building and executing the NN model. In addition, the modeler has the flexibility to specify his own NN type, learning rate, momentum, activation functions, number of hidden layers/nodes, and graphical interpretation of the results. Finally, it has multiple criteria for training and testing the model.

The available data were divided into three sets: training set, cross-validation set and test set. Training and cross-validation sets were used in learning the model through utilizing training set in modifying the network weights to minimize the network error, and monitoring this error by cross-validation set during the training process. However, test set did not enter in the training process and it hasn't got any effect on the training process, where it is used for measuring the generalization ability of the network, and evaluating network performance (Arafa and Alqedra, 2011). In this study, the total available data of 38 exemplars (projects/indices) were divided using the following ratio:

- Training set (includes 20 exemplars  $\approx 52\%$ ).
- Cross validation set (includes 8 exemplars  $\approx 21\%$ ).
- Test set (includes 10 exemplars  $\approx 27\%$ ).

Once all data were prepared, then the subsequent step is represented in creating the initial network by selecting the network type, number of hidden layer/nodes, transfer function, learning rule, and number of epochs and runs.

### 6.3.1 Network structure

As mentioned in Section 5.1, the number of hidden layer's nodes was selected using  $0.75m$ ,  $m$  and  $2m+1$ . Figures (6-1) and (6-2) show a sample of the layers and nodes selection, and network configuration respectively.

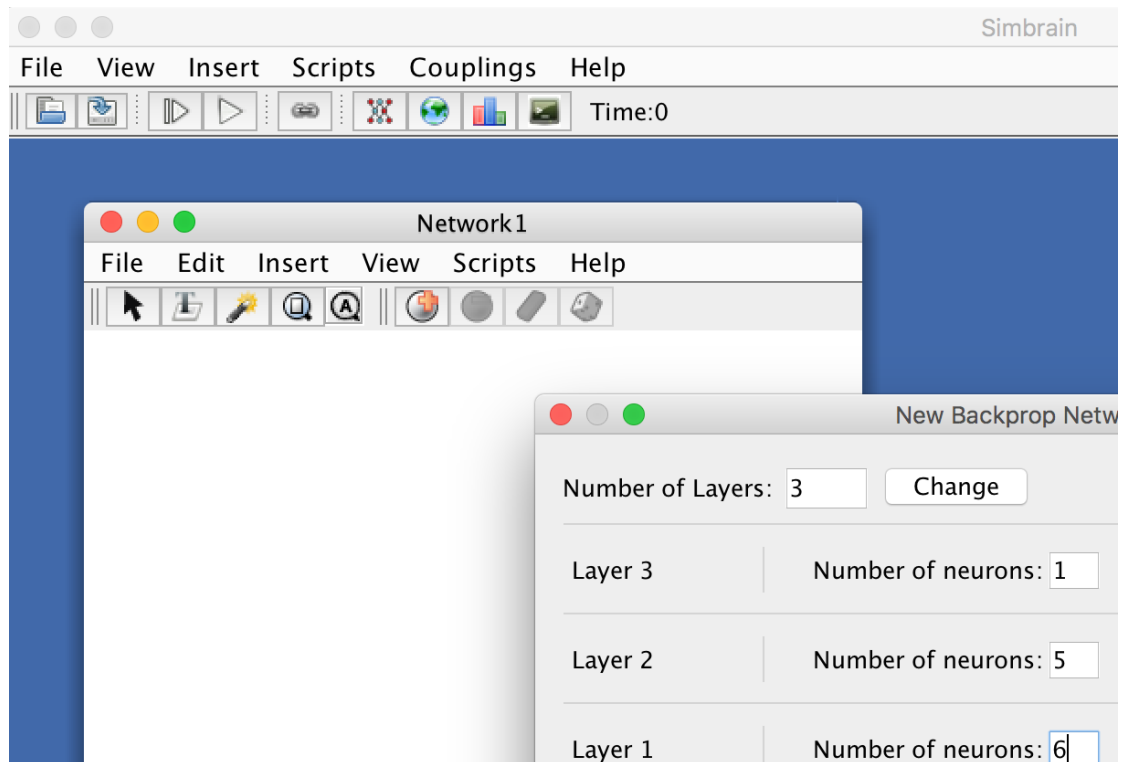


**Figure (6-1)**  
**Number of Layers and Neurons Selection for ANN Model (0.75m)**

As a result of Figure (6-1), we will obtain Figure (6-2)

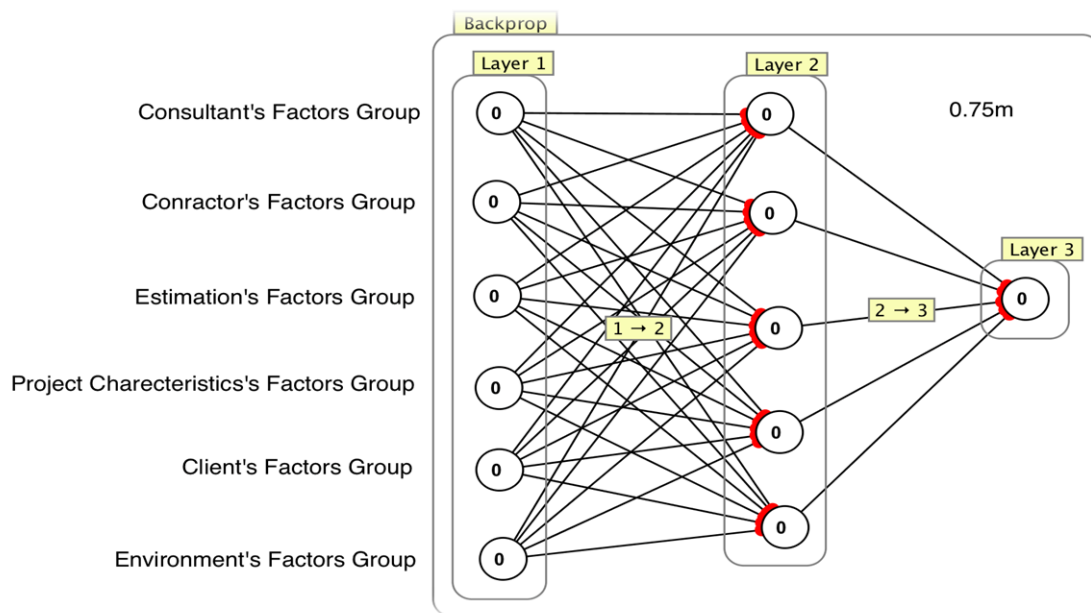


**Figure (6-2)**

### **ANN Model for MLP Network Using 0.75m Nodes in Hidden Layer**

In Figure (6-2), layer one is the input layer (six nodes), layer two is the hidden layer (five nodes), and layer three is the output layer (one node). Similarly the steps were repeated for the rest of the ANN models configuration.

### **6.3.2 Data entry**

Figures (6-3) and (6-4) show the data entry in the input layer and the output layer respectively using SimBrain application.

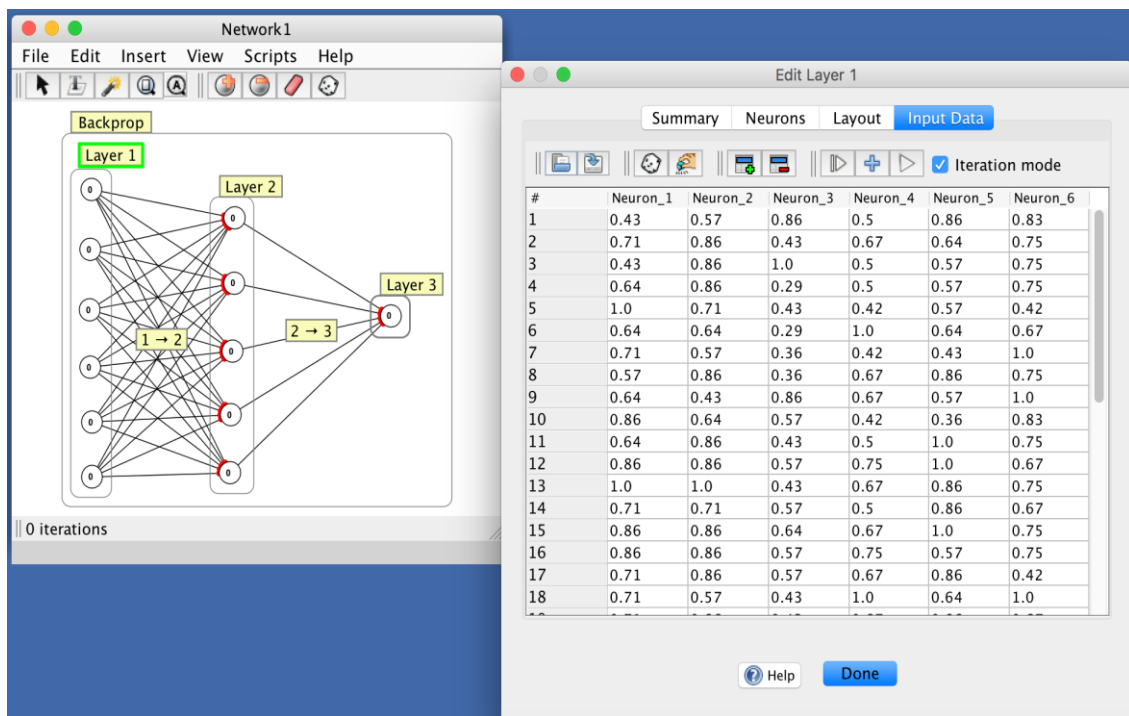


Figure (6-3)

**ANN Model Data Entry for Input Layer Using 0.75m Nodes in Hidden Layer**

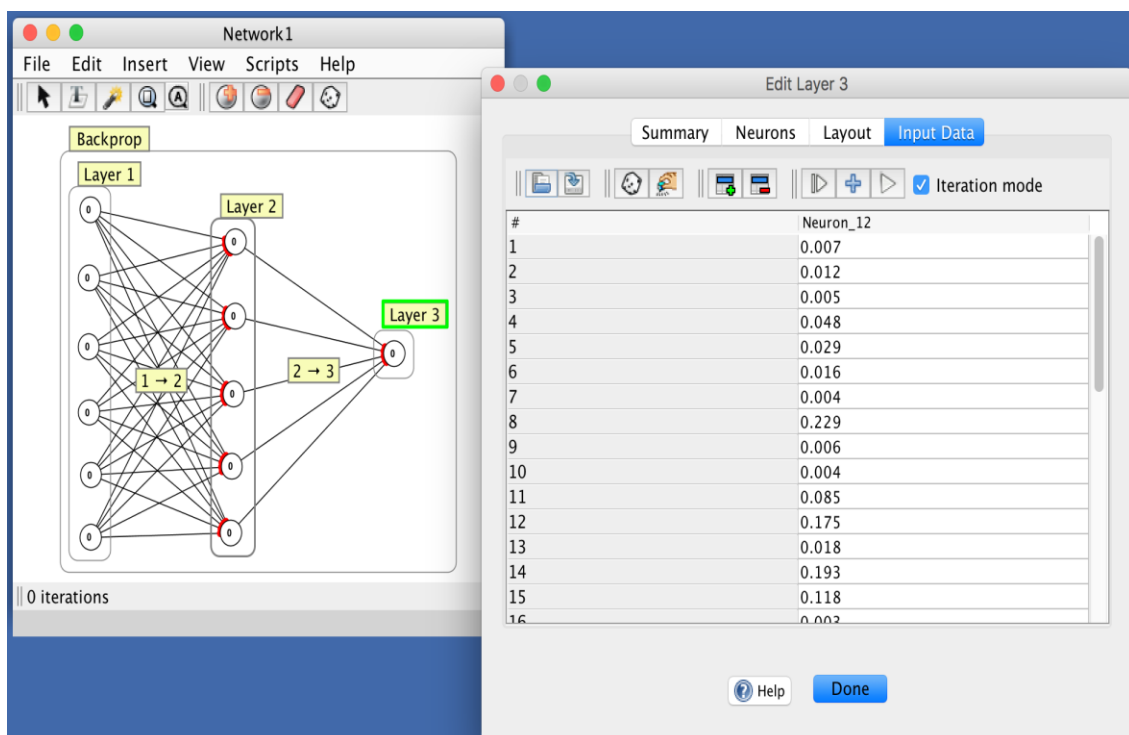


Figure (6-4)

**ANN Model Data Entry for Output Layer Using 0.75m Nodes in Hidden Layer**

### 6.3.3 Model training and validation

The objective of training NN is to get a network that performs best on unseen data through training many networks on a training set and comparing the errors of the networks on the cross-validation set (Dindar, 2004). Therefore, several network parameters such as number of hidden nodes, transfer functions and learning rules were trained multiple times to produce the best weights for the model.

Two types of NNs were chosen (MLP and GFF) to be focused in following training process due to their good initial results. Figure (6-5) summarizes the workflow of the NNs training process.

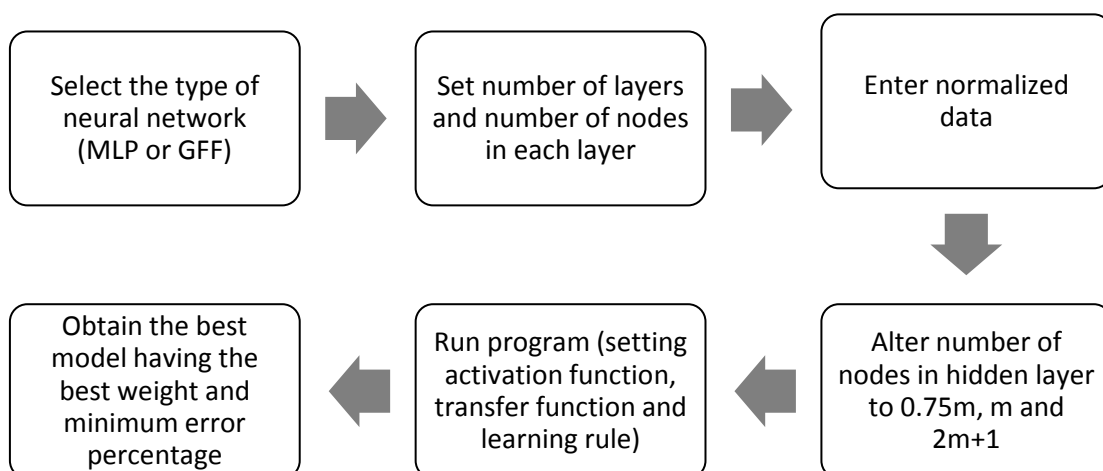


**Figure (6-5)**  
**Workflow of Training Process**

Ten runs with 3000 iterations for each run were applied. However, in each run, new weights were applied in the first layer, and then the weights were adjusted to minimize the percentage of error in other nodes (Dindar, 2004).

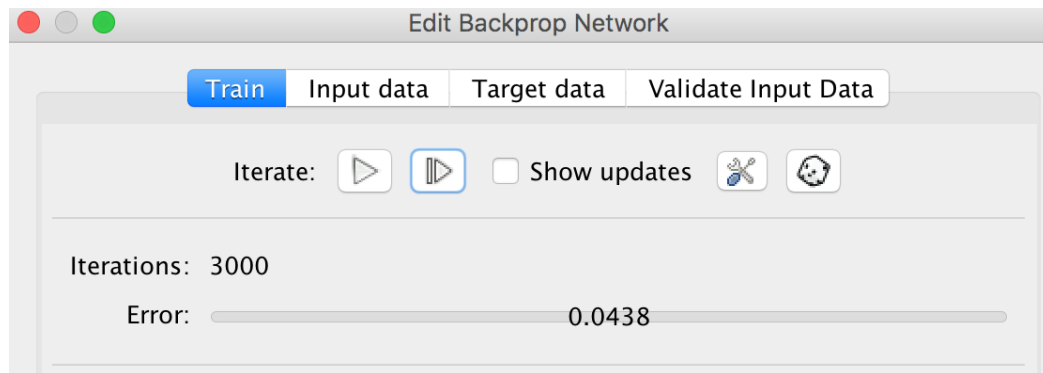


**Figure (6-6)**

### **Screenshot of NN Training Process**

Compared to normal training processes, that trains the network and then calculates the error, cross-validation option was selected, which simultaneously computes the error while the network is being trained to avoid overtraining of the network Figure (6-6). Letting the network to learn too much may eventually make it perform worse (Arafa and Alqedra, 2011).

In order to begin the model with simple model architecture, each of the MLP and GFF models was started with one hidden layer and five hidden nodes (0.75m). Then the number of hidden nodes was increased to six (m), and then to sixteen (2m+1). After training, the best model was selected in terms of the associated values of MAE, MAPE, and R.

## **6.4 Discussion of ANN Model Results**

As mentioned earlier, the purpose of the testing phase of ANN model is to ensure that the developed model was successfully trained, and generalization is adequately achieved. Through a system of trial and error, the best model that provided more accurate results was structured of MLP,

which includes one input layer with 6 input nodes (factor groups) and one hidden layer with (5 hidden nodes), and finally one output layer with one output node (cost overrun).

**Table (6-3)**

**Results Summary of Loading to Each Factor's Group**

| Group (Variable)                           | Loading |
|--------------------------------------------|---------|
| Factors related to consultant              | 0.773   |
| Factors related to contractor              | 0.747   |
| Factors related to estimation              | 0.631   |
| Factors related to project characteristics | 0.642   |
| Factors related to Environment             | 0.653   |
| Factors related to owner                   | 0.784   |

After entering the data in the model, random initial loadings are set to start the model process. The loadings of the connection between nodes get updated as the network learns. As mentioned earlier 3000 iterations were made and the training was stopped when the error became minimal. Table (6-3) summarizes the final loading of the group nodes.

Final loadings are the standardized path loadings connecting the factors to the indicator variables; the loadings vary from 0 to 1. The loadings should be significant. In general, the larger the loadings, the stronger and more reliable the measurement model. Indicator reliability may be interpreted as the square of the measurement loading. The closer the loadings are to 1.0, the more reliable the variable is. By convention, for a well-fitting reflective model, loadings should be above 0.70 and not below 0.4 (Attalla and Hegazy, 2003).

From Table (6-3) it can be seen that all variables have loading values that are much larger than the minimum acceptable level of 0.4 and close to the preferred level of 0.7. However, “factors related to owner”, “factors related to consultant”, and “factors related to contractor” groups are the top ranked variables with loading values of 0.784, 0.773, and 0.747 respectively. However, the loading of “factors related to estimation” group is the lowest with value of 0.631.

Tables (6-4), (6-5) and (6-6) show that both models (MLP and GFF) gave relatively similar results, however MLP model with 6-5-1 configuration had less error and gave an accuracy of 95.2% compared to 93.7% of GFF model. Also the coefficient of determination,  $R^2$  for MLP model was 0.893, which is higher than that of GFF model. This means that the 6 groups in MLP model moderately explain 89.3% of the variance in cost overrun. This proves that the developed model has substantial explaining power to represent the relationship of construction groups of cost overrun towards cost overrun.

**Table (6-4)**

**0.75m Hidden Layer NN Results**

| Model type | Network architecture | MAE   | MAPE (Accuracy) | R     | $R^2$ |
|------------|----------------------|-------|-----------------|-------|-------|
| MLP        | 6-5-1                | 0.048 | 4.8% (95.2%)    | 0.945 | 0.893 |
| GFF        | 6-5-1                | 0.063 | 6.3% (93.7%)    | 0.928 | 0.861 |

**Table (6-5)**  
**m Hidden Layer NN Results**

| Model type | Network architecture | MAE   | MAPE (Accuracy) | R     | R <sup>2</sup> |
|------------|----------------------|-------|-----------------|-------|----------------|
| MLP        | 6-6-1                | 0.168 | 16.8% (83.2%)   | 0.826 | 0.682          |
| GFF        | 6-6-1                | 0.193 | 19.3% (80.7%)   | 0.803 | 0.644          |

**Table (6-6)**  
**2m+1 Hidden Layer NN Results**

| Model type | Network architecture | MAE   | MAPE (Accuracy) | R     | R <sup>2</sup> |
|------------|----------------------|-------|-----------------|-------|----------------|
| MLP        | 6-13-1               | 0.184 | 18.4% (81.6%)   | 0.874 | 0.763          |
| GFF        | 6-13-1               | 0.233 | 23.3% (76.7%)   | 0.831 | 0.690          |

In terms of Goodness of Fit (GoF), it was employed to judge the overall fit of the model; it is the geometric mean of the average communality and the average R<sup>2</sup>. It represents an index for validating the NN model globally, by looking for a compromise between the performance of the measurement and the structural model, respectively. Thus, GoF is given by:

$$GoF = \sqrt{\overline{AVE} \times \bar{R}^2} \quad (10)$$

The GoF calculations for MLP model are as follows:

$$\overline{AVE} (0.784+0.773+0.747+0.653+0.642+0.631)/6= 0.705$$

$$\bar{R}^2 = 0.893$$

$$\text{GoF} = \sqrt{(0.705 \times 0.893)} = 0.793$$

Whereas, the calculations of GoF for GFF model are:

$$\overline{AVE} (0.714+0.735+0.751+0.729+0.649+0.683)/6 = 0.710$$

$$\bar{R}^2 = 0.861$$

$$\text{GoF} = \sqrt{(0.710 \times 0.861)} = 0.781$$

For the MLP and GFF models mentioned above with six nodes in the input layer, five nodes in the hidden layer, and one node in the output layer, the GoF indices are 0.793 and 0.781, respectively. These values exceed all the cut-off values in comparison of baseline values of  $\text{GoF}_{\text{small}} = 0.1$ ,  $\text{GoF}_{\text{medium}} = 0.25$ , and  $\text{GoF}_{\text{large}} = 0.36$ . This shows that the models have substantial explaining power, however, MLP model gave better results.

Based on loading results from NN model using MLP network, with six nodes in the input layer, five nodes in the hidden layer, and one node in the output layer, the two most influential groups determined by the model were “owner’s group related factors” and those “related to consultant”. Table (6-7) summarizes the main factors’ group influencing cost overrun in highway construction projects in Bahrain using NN model.

**Table (6-7)**  
**Main Factors' Group Influencing Cost Overrun in Highway Construction**  
**Projects in Bahrain (NN model)**

| Group                                   | Weight | Rank |
|-----------------------------------------|--------|------|
| Owner related factors                   | 0.784  | 1    |
| Consultant related factors              | 0.773  | 2    |
| Contractor related factors              | 0.747  | 3    |
| Environment related factors             | 0.653  | 4    |
| Project characteristics related factors | 0.642  | 5    |
| Estimation related factors              | 0.631  | 6    |

It is worth to mention again that the model results are based on actual interviews with project managers for each specific project. In other words, the data entered in the model are specific for each project's cost overrun based on actual interviews with individual project managers. The results however are almost as expected since the "change orders" from owner and "specification changes" are among the top ranked "owner's group related factors", followed by the "consultant's group related factors" group such as "estimator's experience", and "lack of communication".

However, the model showed that "project characteristics' group related factors", and "estimation's group related factors" were least affecting cost overrun.

# **CHAPTER SEVEN**

## **COMPARISON OF RESULTS**

# **CHAPTER SEVEN**

## **COMPARISON OF RESULTS**

### **7.1 Introduction**

This thesis discussed cost overrun in highway construction projects in Bahrain. It studied the frequency and severity of cost overrun causes. The research is a field survey through a questionnaire directed to contractors, consultants, and MoW. Statistical and modeling approaches were used to analyze the data.

### **7.2 Comparison of Results**

For the statistical results, the six groups of the identified fifty-two factors causing cost overruns in highway construction projects in Bahrain are ranked based on average IMPI. The results show that the top-affecting group is the owner related group (IMPI = 74.22%), followed by estimation related group (IMPI = 71.03%) and consultant related group (IMPI = 68.07%). The results also show that the groups' importance indices are ranging from 59% to 74%, and the environment group is the one with the lowest importance index.

For the model results, the top ranked factor is the owner related group with weigh of (0.784), followed by consultant related group with weight of (0.733) and contractor related group with weight of (0.747). The results also show that the groups' weights are ranging from (0.631) to (0.784), and the estimation related group is the one with the lowest

weight.

Both the model and the statistical results show that the owner's group factors are the most contributing factors to cost overrun in highway construction projects in Bahrain as shown in Table (7-1). However, the "consultant related factors" are ranked second by the model whereas the statistical approach ranked the "estimation related factors" in second place. This difference can be explained by the fact that statistical approach is based on opinions of stakeholders, the participants in the questionnaire, who believe that "estimation related factors" come as second. However, highway construction experts, who were interviewed about the causes of cost overrun in their 38 projects (data entered in the model), have agreed that the "estimation related factors" are ranked as the last factor contributing to cost overrun, whereas the "consultant related factors" are ranked as second.

Moreover, the difference between the model ranking and the statistical ranking of the "factors related to estimation" can be explained due to the fact that responses of engineers from consultants and contractors are included in the statistical survey, whereas the model includes only responses from MoW project managers. This may have had an effect on the ranking of factors in the statistical approach results, as the engineers from consultants and contractors may have been biased in filling the survey.

Moreover, Table (7-1) shows that both approaches determined that "project characteristics related factors" are ranked as fifth in contributing to cost overrun of highway construction projects in Bahrain.

**Table (7-1)**  
**Comparison of Results Using Statistical and NN Analyses**

| Group                                   | NN Ranking<br>(Experts' Opinion) | Statistical Ranking<br>(Stakeholder's Opinion) |
|-----------------------------------------|----------------------------------|------------------------------------------------|
| Owner related factors                   | 1                                | 1                                              |
| Consultant related factors              | 2                                | 3                                              |
| Contractor related factors              | 3                                | 4                                              |
| Environment related factors             | 4                                | 6                                              |
| Project characteristics related factors | 5                                | 5                                              |
| Estimation related factors              | 6                                | 2                                              |

The contractor's contribution to cost overrun as determined by the model comes after the owner's and the consultant's. Thus, the model had identified that external factors leading to cost overrun such as environment, project characteristics, and estimation methods are not as significant as those related to the stakeholders of the highway construction project.

**CHAPTER EIGHT**

**CONCLUSIONS, RECOMMENDATIONS  
AND FUTURE WORK**

# **CHAPTER EIGHT**

## **CONCLUSIONS, RECOMMENDATIONS AND FUTURE WORK**

### **8.1 Conclusions**

In this section the main findings from the results will be presented.

#### **8.1.1 Most frequent and severest factors of cost overrun in highway construction projects in Bahrain**

##### **a. Factors related to owner**

Modeling results showed that MoW has a major contribution to cost overrun. The top ranked factors are “frequent change orders/variations by owner”, “low speed in decision-making” and “specification change”.

##### **b. Factors related to consultant**

It has been presented that one of the main problems related to consultant is the “lack of experience”. This problem leads to bad cost estimation, delay in solving design problems, and discrepancies between specifications and drawings. As well as that, “lack of communication” is among the main causes of cost overrun. Problems of communication between consultant and owner may lead to major changes in design since the consultant may not understand exactly the owners’ needs from the beginning. Moreover, the “lack of qualified project manager” is found to be one of the top three causes.

### **c. Factors related to contractor**

Modeling results showed that the contractor has a major contribution to cost overrun as well. The top ranked factors are somehow similar to those of the consultant's such as "communication with suppliers"; "lack of qualified project manager"; and "lack of project knowledge". The "communication with suppliers" is ranked as the first cause, as not having proper communication channels with the suppliers may cause the contractor to put unrealistic/not-updated material prices.

### **d. Factors related to environment**

It has been found that the most frequent and severest causes related to environment are "government interference", "tender period and market condition" and "cultural heritage issues".

### **e. Factors related to project characteristics**

Modeling results shows that the "project characteristics' factors" are ranked as the fifth group. The "project size"; "location of the project"; and the "services relocation costs" are among the top 3 factors in this group as determined from this research. This research shows that the bigger the project size, the more tendency there is for cost overrun. However, the other two top factors are related in a way, as the location of the project can be related to non-accounted-for underground services, which can increase the cost of executing the project.

### **f. Factors related to estimation**

The results of the model shows that "factors related to estimation" are in last place. However, it has been found that the most frequent and severest causes related to estimation are "estimator's experience"; "cost estimation methods"; and "time allowable for preparing the cost

estimate” as this may rush the cost estimator and he might use a rough estimation technique causing cost overrun.

## **8.2 Recommendations**

This section presents general recommendations to minimize cost overrun in highway construction projects in Bahrain.

1. Minimizing change orders during construction as this is the most contributing factor to cost overrun as identified from the study.
2. Providing sufficient time period for the designs and especially for the design review to avoid design changes during construction.
3. Considering the contractor financial status and level of experience.
4. Using risk assessment when estimating construction projects to help decision makers to define unforeseen situations more reliably ahead of time, so that corrective measures can be better taken into account in project design and estimating.
5. Developing human resources through continuous training programs. As “unqualified project managers” is one of the factors identified from the research which is causing cost overrun.
6. Using managers with high level of work experience and knowledge on managing the critical conditions. Good managers have the ability to run the project successfully with cost limitations.
7. Keeping unqualified and inexperienced staff under supervision, because unskilled employees impose slow progress of work, thus increases the cost overrun chances of occurrence.
8. Planning and scheduling should be done properly by the contractor, to ensure continuous progress of the project, and to match allocation of resources to the schedule requirements to avoid cost and time overruns.

The cost overrun developed model showed that stakeholders groups (owner, consultant and contractor) have a significant effect on cost overrun such as communication with suppliers, lack of experience, change orders,... etc. Construction managers should not overlook these basic elements as they have significant influence on cost overrun.

### **8.3 Future Work**

The following can be recommended for future studies in the field of this research:

1. A comprehensive study can be done for all G.C.C. countries, on the highway construction projects cost overruns' causes and effects.
2. A cost estimation model can be developed, which estimates the cost of highway construction projects with acceptable accuracy.
3. A similar type of research can be done for other government infrastructure projects in Bahrain, such as sanitary and schools construction.
4. A study can be done including the non-direct factors affecting cost overrun such as mobilization factors and increase of fuel prices.

## REFERENCES

Akinci, B. and Fischer, M. (1998). Factors affecting contractors' risk of cost overburden. *Journal of Management in Engineering*, 14(1), pp. 67-76.

Akintoye, A. (2000). Analysis of factors influencing project cost estimating practice. *Construction Management and Economics*, 18(1), pp. 77-89.

Aibinu A.A and Jagboro G.O. (2016). The effects of construction delays on project delivery in Nigerian construction industry. *International Journal of Project Management*, Vol. 20, No. 8, pp. 593-599.

Akpan and Igwe (2001). Methodology for determining price variation in project execution. 127(5), 367–373.

Arafa, M. and Alqedra, M. (2011). Early stage cost estimation of buildings construction projects using ANN. *Journal of Artificial Intelligence*, 4(1), pp. 63-75.

Attalla, M., and Hegazy, T. (2003). Predicting cost deviation in reconstruction projects: *Artificial Neural Networks Versus Regression*, 129(4), pp. 405–411.

Attal, A. (2010). Development of neural network models for prediction of highway construction cost and project duration, 145(3), pp. 345–411.

Al-Najjar, H. (2005). Prediction of ultimate shear strength of reinforced concrete deep beams using artificial neural networks, Gaza strip, *Master Thesis in Construction Management*, The Islamic University of Gaza Strip.

Al-Momani, A. (2000). Cost estimation of highway projects in developing country, *Construction Management and Economics*, Vol. 14, pp. 311-317.

Al-Momani, A. (1996). Construction cost prediction for public school buildings in Jordan. *Construction Management and Economics*, Vol. 14, No. 4, pp. 311-317.

Aje, O.I., K.T. Odusami and D.R. Ogunsemi, 2009. *The impact of contractors' management capability on cost and time performance of construction projects in Nigeria*, 14(2): pp.171-187.

Al-Khaldi (1990). Factors affecting the accuracy of construction costs estimating in Saudi Arabia. Master thesis King Fahd University of petroleum and minerals, Dhahran, Saudi Arabia.

Al- Khalil M. and AL-Ghafly M., (2015). Cost overrun in public utility projects in Saudi Arabia. *International Journal of Project Management*, Vol.17, No.2, pp.101-106.

Al-Juwairah (1997). Factors affecting construction costs in Saudi Arabia. Master thesis, King Fahd University of Petroleum and Minerals, Dhahran, Saudi Arabia.

Al-Shanti, Y. (2003). A cost estimate system for Gaza strip construction contractors, Palestine, Master thesis in construction management, The Islamic University of Gaza Strip.

Al-Zarooni, S. and Abdou, A. (2000). Risk management in pre-design stage and its potential benefits for UAE public projects. In, 28th World Congress on Housing Challenges for the 21st Century, 15-19 April, Abu Dhabi, UAE, pp. 109-18.

Al-Homidan A. (2013). Factors affecting cost overrun in road construction projects in Saudi Arabia”, *International Journal of Civil and Environmental Engineering*, Vol. 13, No. 3, pp. 1-4.

Al-Hammad,1993. Factors affecting the relationship between contractors and their sub-contractors in Saudi Arabia. *Building Research and Information*, 21(5), pp. 269–73.

Azhar et al. (2008). Cost overrun factors in construction industry of Pakistan. Proceedings of the First International Conference on Construction in Developing Countries, Karachi, Pakistan.

Ayed, A. S. (1997). Parametric cost estimating of highway projects using neural networks, Canada: National Library of Canada.

Battaineh (2002). Causes of construction overrun: “traditional contracts”, *International Journal of Project Management*, 20, pp. 67-73

Bakhary, N., Yahya, K. and Nam, N. C. (2004). Univariate artificial neural network in forecasting demand of low cost house in Petaling Jaya. *Journal Technology*, 40(B), June, pp. 67-75.

Bode, J. (1998). Decision support with neural networks in the management of research and development: *Concepts and application to cost estimation*, Volume 34, pp. 33-40.

Bouabaz, M. and Hamami, M. (2008). A cost estimation model for repair bridges based on artificial neural network. *American Journal of Applied Sciences*, 5(4), pp. 334-339.

Caputo, A. and Pelagagge, P. (2008). Parametric and neural methods for cost estimation of process vessels. *Int. J. Production Economics*, Volume 112, p. 934–954.

Cavalieri, S., Maccarrone, P. and Pinto, R. (2004). Parametric vs. neural network models for the estimation of production costs: A case study in the automotive industry. *Int. J. Production Economics* , Volume 91, pp. 165–

177.

Cengiz, Y., Gunes, F. and Caglar, M. (2005). Soft computing methods in microwave active device modeling. *Turkish Journal of Electrical Engineering and computer science*, 13(1).

Choon, T. and Ali, K. N. (2008). A review of potential areas of construction cost estimating and identification of research gaps. *Journal Alam Bina*, 11(2), pp. 61-72.

Chan, D.W.M and Kumaraswamy, M.M. (1997). A comparative study of causes of time overruns in Hong Kong construction projects, *International Journal of Project Management*, 15 (1), pp. 55-63

Chimwaso, K.D., (2016). An evaluation of cost performance of public projects; case of Botswana. *Department of Architecture and Building Services, Journal Technology*, 40(B), June, pp. 63-67.

Cheng et al. (2009). Applying data mining techniques to explore factors contributing to occupational injuries in Taiwan's construction industry, *Accident Analysis and amp prevention*, 48(0), pp.214-222.

Dindar, Z. (2004). Artificial neural networks applied to option pricing., s.l.: s.n.

Duran (2016). Predictors of cost-overrun rates. *Journal of Construction Engineering and Management*, 116(3), pp. 145-158.

Dowler, J. (2008). Using neural networks with limited data to estimate manufacturing cost, *Master thesis in science*. Ohio University.

Doğan, S. (2005). Using machine learning techniques for early cost estimation of structural systems of buildings, İZMİR: İzmir Institute of

Technologyin.

Dysert, L. R. (2006). Is "estimate accuracy" an oxymoron?, *AACE International Transactions*, s.l.: EST01.1 - 01.5.

Edara, P, (2003). Mode choice modeling using artificial neural networks, Virginia. *Master Thesis in Civil Engineering*, Virginia Polytechnic Institute and State University.

Emsley et al. (2002), Data modelling and the application of a neural netowrk approach to the prediction of total construction costs. *Construction Management and Economics*, 20, pp.465-72

Enshassi, A., Mohamed, S. and Madi, I. (2007). Cost estimation practice in the Gaza Strip: A case study. *The Islamic University Journal*, 15(2), pp. 153-176.

ElSawy, I., Hosny, H. and Abdel Razek, M. (2011). A neural network model for construction projects site overhead cost estimating in Egypt. *International Journal of Computer Science Issues (IJCSI)*, 8(1).

Feng, W., Zhu, W. and Zhou, Y. (2010). The application of genetic algorithm and neural network in construction cost estimate, pp. 151-155.

Frimpong, Y. et al. (2003). Causes of delay and cost overruns in construction of highway projects in a developing countries: *Ghana as a Case Study*, Vol. 3, pp. 321–326.

Frimpong, Y. (2000). Project management in developing countries: causes of delay and cost overruns in construction of groundwater projects. *Unpublished Masters Research Project, University of Technology, Sydney, Australia*.

Flyvbjerg et al. (2004). Megaprojects and Risk: An Anatomy of Ambition (Cambridge: Cambridge University Press).

Flyvbjerg et al. (2003). How common and how large are cost overruns in transport infrastructure projects?, *Transport Reviews*, Vol. 23, No.1, pp. 71–88.

Flyvbjerg et al. (2002). Cost underestimation in public works projects: error or lie?, *Journal of the American Planning Association*, 68(3).

Flyvbjerg, B. (2003) Machiavellian Tunneling. *World Tunneling*, p.43.

Flyvbjerg, B. (2005). Design by Deception: The politics of megaproject approval, *Harvard Design Magazine*, 22, pp.50-59.

Flyvbjerg, B. (2007). Curbing optimism bias and strategic misrepresentation in planning, *European Planning Studies*, 16(1), pp.3-21.

Flyvbjerg, B. (2009). Survival of the unfittest: why the worst infrastructure gets built—and what we can do about it. *Oxford Review of Economic Policy*, 25(3), pp.344-367.

Flyvbjerg et al. (2002). Understanding costs in public works projects: Error or lie? *Journal of the American Planning Association*, 68 (279-295).

Flyvbjerg et al. (2004). What causes cost overrun in transport infrastructure projects? *Transport Reviews*, 24(1), pp.3-18.

Gunaydın, M. and Dogan, Z. (2004). A neural network approach for early cost estimation of structural systems of buildings. *International Journal of Project Management*, Volume 22, p. 595–602.

Harding, A. et al. (1999). Implementation of a neural network model for the comparison of the cost of different procurement approaches, pp. 763-772.

Hassanein, and Afify (2007). Risk management practices of contractors: A case study of power station projects in Egypt, *Journal of Financial Management of Property and Construction*, Vol 12, No. 3, pp. 164 – 179.

Hegazy, T. and Ayed, A. (1998). Neural network model for parametric cost Estimation of highway projects. *Journal of Construction Engineering and Management*, pp. 210-218.

Hegazy, T., Moselhi and O. (1994). Developing practical neural network applications using back-propagation. *Microcomputers in Civil Engineering*, Volume 9, pp. 145- 159.

Hegazy, T. and Moselhi, O. (1995). Elements of Cost Estimation: A survey in Canada and the United States. *Cost Engineering*, 37(5), pp. 27-31.

Hensey (1993). Essential tools of total quality management. *Journal of Construction Engineering and Management*, ASCE, 9(4), pp. 329–39.

Ibrahim Mahamid (2011). Cost overrun causes in road construction projects-consultants perspective, Vol 15, pp. 102-109.

Islam, S., Zhou, L. and Li, F. (2009). Application of artificial intelligence (artificial neural network) to assess credit risk: *A Predictive Model for Credit Card Scoring*, Karlskrona, Sweden: Blekinge Institute of Technology.

Iyer, K. C., and Jha, K. N. (2004). Critical factors affecting schedule performance: Evidence from Indian construction projects. *J. Constr. Eng. Manage.* 132(8), 871–881.

- Iyer, K. C., and Jha, K. N. (2005). Factors affecting cost performance: Evidence from Indian construction projects. *Int. J. Project Manage*, 23(4), pp. 283–295.
- Jahren, C. T. and Ashe, A. M. (1990). Predictors of cost-overrun rates, *Journal of Construction Engineering and Management*, 116(3), pp. 548-552.
- Jahren et al. (1990). Predictors of cost-overrun rates. *Journal of Construction Engineering and Management*, 116(3), pp. 548-552.
- Jitendra, Vikas, Kuldeep and Samiksha (2011). Cost prediction using neural network learning techniques. *IJCSMS International Journal of Computer Science and Management Studies*, 11(2).
- Kaming et al. (1997). Factors influencing construction time and cost overruns on high-rise projects in Indonesia, *Constr. Manag. Econ.* 15 (1), 83–94.
- Koleola et al. (2015). Factors affecting the accuracy of a pre-tender cost estimate in Nigeria, *Journal of Cost Engineering*, 50(9): pp32 – 35.
- Karna, K. N. and Breen, D. M. (1989). An artificial neural networks tutorial, *the international journal of neural networks*, 1(1), pp. 4-23.
- Kim et al. (2004). Comparison of construction cost estimating models based on regression analysis, neural networks, and case-based reasoning. *Building and Environment*, February, Volume 39, pp. 1235 – 1242.
- Koushki et al. (2009). Delays and cost increases in the construction of private residential projects in Kuwait, *Construction Management and Economics*, 23(3): 285–294.

Kinney, C.L. and Soubiran, N. (2004). An interactive roadmap to conceptual estimating. *Cost Engineering*. Volume 46/No. 9. Morgantown, West Virginia.

Kriesel, D. (2005). A brief introduction to neural networks. Germany: s.l.:www.dkriesel.com.

Kshirsagar, P. and Rathod, N. (2012). Artificial neural network, *International Journal of Computer Applications*, 45(5): pp32 – 41

Leng, K. C. (2005). Principles of knowledge transfer in cost estimating conceptual model, Malaysia: University Teknologi Malaysia.

Liu, L. and Zhu, K. (2007). Improving cost estimates of construction projects using phased cost factors, *Journal of Construction Engineering and Management*, 133(1), pp. 91-95.

Mansfield, N. R., O. O. Ugwu, and T. Doranl. (1994). Causes of delay and cost overruns in Nigerian construction projects, *International Journal of Project Management*, 12, 4, pp 254-260.

Mahamid (2013). Cost deviation in road construction projects: The case of Palestine, *Australasian Journal of Construction Economics and Building*, 12(1), pp. 58 – 71.

Morris, P. and Hough, G. (1980). The Anatomy of Major Projects, John Wiley and Sons Ltd, New York.

Morris S. (2016). Cost and time overruns in public sector projects. *Economic and Political weekly*, Nov.24, 2016, Vol. xxv, No.47, pp. 154-168.

Nassar et al. (2005). Evaluating cost overruns of asphalt paving projects using statistical process control methods. *ASCE Journal of Construction Engineering and Management*, 131(11): pp. 1173-1178.

Nicholas Chileshe (2010). Causes of project cost overruns within the Ghanaian road construction sector, Vol.1, pp. 68.

Odeck, J. and Skjeseth, T. (1995). Assessing Norwegian highway projects and delay causes, Vol. 2, pp. 89-98.

Odeck, J. (2004). Cost overruns in road construction—what are their sizes and determinants? *Transport Policy*, 11(1), pp.43-53.

Oberlender and Trost (2003). Project management for engineering and construction. New York: McGraw-Hill.

Odusami, K.T. and Onukwube, H.N. (2008). Factors affecting accuracy of pre-tender cost estimate in Nigeria, *Cost Engineering*, 50(9): pp. 32–35.

Oberlender and Trost (2001). Predicting accuracy of early cost estimates based on estimate quality. *Journal of Construction Engineering and Management*, no. 3 (May/June 2001): 173-182.

Odeyinka and Yusuf (1997). The causes and effects of construction delays on completion cost of housing projects in Nigeria, *Journal of Financial Management of Property and Construction*, 2(3), 31- 44.

Ogunlana et al. (1996). Construction delays in a fast growing economy: Comparing Thailand with other economies, *International Journal Project Management*, 14(1), pp. 37-45.

Okpala et al. (2003). Causes of high costs of construction in Nigeria, *Journal of Management in Engineering*, ASCE 1988; 114:233–44.

- Principe, J. et al. (2010). NeuroSolution Help, s.l.: NeuroDimension, Inc.
- Rezaian, A., (2011). Time-Cost-Quality-Risk of construction and development projects or investment. *Middle-East Journal of Scientific Research*, 10(2), pp. 218-223.
- Pawar, R. (2007). Predicting bid prices in construction projects using non-parametric statistical models. USA: Texas A and M University.
- Radford et al. (1987). Infrastructure delays and cost escalation: causes and effects in United States. *Proceedings of Sixth International Postgraduate Research Conference*, Delft University of Technology and TNO, the Netherlands. 3-7 April.
- Rowland (1981), Analysis of time and cost overrun in southern United States, Vol. 1, pp. 90-99.
- Rezaian, A. (2011). Time, cost, quality and risk of construction and development projects or investment. *Middle-East Journal of Scientific Research*, 10(2), pp. 218-223.
- Skamris, M.K., and Flyvbjerg, B. (1996). Accuracy of traffic forecasts and cost estimates on large transportation projects. *Transportation Research Record*, 11(4), pp. 223-231
- Shehu, Z., Endut, I., Akintoye, A. and Holt, G. (2014). Cost overrun in the Malaysian construction industry projects: A deeper insight. *International Journal of Project Management*, 32 (8), pp. 1471 – 1480.
- Sonmez, R. (1993). Range estimation of construction costs using neural networks with bootstrap prediction intervals, *Expert Systems with Applications*, Issue 38, p. 9913– 9917.
- Sonmez, R. (2004). Conceptual cost estimation of building projects with

regression analysis and neural networks, *Canadian Journal of Civil Engineering*, 31(4), pp. 677- 683.

Sonmez and Ontepeli (2009). Predesign cost estimation of urban railway projects with parametric modeling, *Journal of Civil Engineering and Management*, Vol. 15, No. 4, pp. 405-409.

SimBrain, Inc., (2012), s.l.: SimBrain Help, Inc.

Skitmore, M., and Wilcock, J. (1994). Estimating processes of smaller builders, *Constr. Manage. Econ.*, Vol. 12 (No. 2), PP 139-154

Sodikov, J. (2005). Cost estimation of highway projects in developing countries: artificial neural network approach, *The Eastern Asia Society for Transportation Studies*, Volume 6, pp. 1036 - 1047.

Tah et al. (1993). Contractor project risks contingency allocation using linguistic approximation. *Computing Systems in Engineering*, 2(4), pp281–93

Wang et al. (2012). Artificial neural networks as cost engineering methods in a collaborative manufacturing environment. *Int. J. Production Economics*, Volume 109, pp 53–64.

Wagner (1998). Cost and time overruns in public sector projects. *Economic and Political Weekly*, Nov.24, 1990, Vol. xxv, No.47, PP. M 154 to M 168.

Watson et al. (1992), Expert system that estimates budgets for residential construction projects, *Proceedings, Applications of Artificial Intelligence in Engineering, Computational Mechanics*, UK, pp. 955–68.

Wu (2009). Cost overrun and cause in Korean social overhead capital projects: roads, rails, airports, and ports, *Journal of Urban Planning and Development*, 134, 59-62.

Williams, T. P. (2003). Predicting final cost for competitively bid construction projects using regression models, *International Journal of Project Management*, 21, pp.593-99.

Willmott, C. and Matsuura, K. (2005). Advantages of the mean absolute error (MAE) over the root mean square error (RMSE) in assessing average model performance. *Climate Research*, Volume 30, pp. 79–82.

Weckman, G. et al. (2010). Using neural networks with limited data to estimate manufacturing cost, *Journal of Industrial and Systems Engineering*, 3(4), pp. 257-274.

## **Appendix (A)**

### **QUESTIONNAIR FORM AND STATISTICAL TABLE**

**A1. Survey Questionnaire**

**A2. Required Sample Size Table**

## **A1. Survey Questionnaire**

Dear Mr. / Mrs.:

I am a graduate student at University of Bahrain and I am preparing a master thesis in the Engineering Management Program.

The title of the thesis is: “Root Causes of Cost Overrun in Highway Construction Projects in Bahrain”

The scope of this research will be limited to roads’ construction projects in Bahrain. This questionnaire is a survey of the frequency of factors of cost overrun and their significance in roads’ construction projects in Bahrain.

As you are one of the organizations working in this field, your participation in filling this questionnaire with the required data is a significant element in this research and offering valuable results for all.

I appreciate your cooperation in answering this questionnaire, which may take few minutes of your valuable time.

All data will be analyzed and used for the purposes of scientific research only.

Please fill out this questionnaire and return it as soon as possible.

Please read these notes before filling out the questionnaire:

## **INTRODUCTION**

This questionnaire aims to identify the frequency and significance of cost overrun factors in roads' construction projects in Bahrain.

The questionnaire consists of two parts which are parts (A) and (B)

Part (A) includes general information related to your experience and educational level, Part (B) includes a list of cost overrun factors based on literature review and actual historical data in Bahrain, for which you are required to choose the frequency of occurrence and significance based on Likert-scale ranging from 1 to 5 which was categorized as follows; extremely significant, strongly significant, moderately significant, slightly significant and not significant.

## **DEFENITIONS**

Frequency: The frequency of occurrence of a cost overrun factor throughout a road construction project.

Significance: The significance of impact of the factor on cost overrun of a project.

Owner: MoW.

## **RESPONSES**

For Part (B), the responses are based on 5-degree Likert scales as follows:

### Frequency of Occurrence:

1. Always: Occurs all the times and situations
2. Often: Occurs most of the times and situations
3. Sometimes: Occurs from time to time
4. Rare: Occurs only rarely

5. Never: Doesn't occur at all

Significance:

1. Very significant: Factor has a great effect on cost overrun
2. Significant: Factor has an appreciable effect on cost overrun
3. Somewhat significant: Factor has some effect on cost overrun
4. Little significance: Factor has little effect on cost overrun
5. No significance: Factor has negligible or no effect on cost overrun

## Part (A): General information

You are kindly requested to choose the appropriate answer for the following questions:

1. Which area of construction are you involved in?

- ☐ Owner (Roads Planning and Design Directorate)
- ☐ Owner (Roads Projects and Maintenance Directorate)
- ☐ Owner (Cost Engineering Directorate)
- ☐ Contractor
- ☐ Consultant

2. What is your position in your organization/company?

- ☐ Director      ☐ Section Chief      ☐ Group Head      ☐ Project Manager
- ☐ Engineer/Designer      ☐ Other, specify

.....

3. How long have you been in the roads' construction industry?

- ☐ 0-5 years      ☐ 6-10 years      ☐ 11-20 years      ☐ 21 years and more

4. Please indicate your educational level.

- ☐ Diploma of Engineering, specify specialization

.....

- ☐ Bachelor of Engineering, specify specialization

.....

- ☐ Master of Science, specify specialization

.....

☐ PhD , specify specialization

.....

☐ Professional Qualifications and type of institution

.....

5. How many roads construction projects have you been involved in?

☐ 1-5

☐ 6-10

☐ 11 -20

☐ more than 20

**PART (B): Evaluating the Importance of Cost Overrun Factors**

| Group                         | Factors                                                  | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|-------------------------------|----------------------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                               |                                                          | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to consultant | 1. Design errors and omissions                           |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 2. Estimator's experience                                |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 3. Extent of completion of pre-contract design           |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 4. Slowness in inspection and testing of completed works |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 5. Lack of communication                                 |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 6. Lack of qualified project manager                     |                         |             |                  |              |               |                                        |   |   |   |   |

| Group                         | Factors                                                                 | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|-------------------------------|-------------------------------------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                               |                                                                         | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to contractor | 1. Contractor's deficiencies in planning and scheduling at tender stage |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 2. Effective monitoring and feedback process                            |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 3. Improper control over site resource allocations                      |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 4. Poor procurement programming of materials                            |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 5. Low speed at decision-making                                         |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 6. Staff training in the skill areas relevant to project                |                         |             |                  |              |               |                                        |   |   |   |   |

| Group                         | Factors                                             | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|-------------------------------|-----------------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                               |                                                     | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to contractor | 7. Availability and supplies of labor and materials |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 8. Contractor's financial difficulties              |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 9. Inadequate contractors experience                |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 10. Lack of project knowledge                       |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 11. Lack of qualified project manager               |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 12. Methods/techniques of construction              |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 13. Planning and scheduling deficiencies            |                         |             |                  |              |               |                                        |   |   |   |   |

| Group                         | Factors                                         | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|-------------------------------|-------------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                               |                                                 | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to contractor | 14. Poor site management and supervision        |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 15. Rework from poor materials quality          |                         |             |                  |              |               |                                        |   |   |   |   |
| Factors related to estimation | 1. Accuracy and reliability of cost information |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 2. Cost estimation methods                      |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 3. Deficiencies in cost estimates prepared      |                         |             |                  |              |               |                                        |   |   |   |   |
|                               | 4. Procedure for updating cost information      |                         |             |                  |              |               |                                        |   |   |   |   |

| Group                                       | Factors                                             | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|---------------------------------------------|-----------------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                                             |                                                     | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to estimation               | 5. Time allowed for preparing the cost estimate     |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 6. Availability of data of similar projects         |                         |             |                  |              |               |                                        |   |   |   |   |
| Factors related to projects characteristics | 1. Project duration                                 |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 2. Build-ability (including on-site prefabrication) |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 3. Complexity of design and construction            |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 4. Location of project                              |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 5. Services relocation costs                        |                         |             |                  |              |               |                                        |   |   |   |   |

| Group                                       | Factors                                             | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|---------------------------------------------|-----------------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                                             |                                                     | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to projects characteristics | 6. Project size                                     |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 7. Construction techniques required                 |                         |             |                  |              |               |                                        |   |   |   |   |
| Factors related to owner                    | 1. Delays in work approval waiting for information  |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 2. Cash flow during construction                    |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 3. Low speed at decision-making                     |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 4. Disputes                                         |                         |             |                  |              |               |                                        |   |   |   |   |
|                                             | 5. Form of procurement and contractual arrangements |                         |             |                  |              |               |                                        |   |   |   |   |

| Group                          | Factors                                      | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|--------------------------------|----------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                                |                                              | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to owner       | 6. Frequent Change orders/Variation by owner |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 7. Payment delay                             |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 8. Specifications Change                     |                         |             |                  |              |               |                                        |   |   |   |   |
| Factors related to environment | 1. Tender period and market condition        |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 2. Cultural heritage issues                  |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 3. Escalation of material prices             |                         |             |                  |              |               |                                        |   |   |   |   |

| Group                          | Factors                                         | Frequency of occurrence |             |                  |              |               | Degree of severity; (5) is very severe |   |   |   |   |
|--------------------------------|-------------------------------------------------|-------------------------|-------------|------------------|--------------|---------------|----------------------------------------|---|---|---|---|
|                                |                                                 | Never<br>(1)            | Rare<br>(2) | Sometimes<br>(3) | Often<br>(4) | Always<br>(5) | 1                                      | 2 | 3 | 4 | 5 |
| Factors related to environment | 4. Frequent breakdown of construction equipment |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 5. Government interference                      |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 6. Inflation                                    |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 7. Lead times for delivery of materials         |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 8. Monopoly of material suppliers               |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 9. Weather                                      |                         |             |                  |              |               |                                        |   |   |   |   |
|                                | 10. Unexpected geological conditions            |                         |             |                  |              |               |                                        |   |   |   |   |
|                                |                                                 |                         |             |                  |              |               |                                        |   |   |   |   |

## A2. Required Sample Size

| Required Sample Size |                  |                 |       |       |                  |                 |       |        |
|----------------------|------------------|-----------------|-------|-------|------------------|-----------------|-------|--------|
| Population Size      | Confidence = 95% |                 |       |       | Confidence = 99% |                 |       |        |
|                      | 5.0%             | Margin of error |       |       | 5.0%             | Margin of Error |       |        |
|                      |                  | 3.5%            | 2.5%  | 1.0%  |                  | 3.5%            | 2.5%  | 1.0%   |
| 10                   | 10               | 10              | 10    | 10    | 10               | 10              | 10    | 10     |
| 20                   | 19               | 20              | 20    | 20    | 19               | 20              | 20    | 20     |
| 34                   | 30               | 28              | 29    | 30    | 29               | 29              | 30    | 30     |
| 69                   | 50               | 44              | 47    | 50    | 47               | 48              | 49    | 50     |
|                      | 75               | 63              | 69    | 74    | 67               | 71              | 73    | 75     |
| 100                  | 80               | 89              | 94    | 99    | 87               | 93              | 96    | 99     |
| 150                  | 108              | 126             | 137   | 148   | 122              | 135             | 142   | 149    |
| 209                  | 132              | 136             | 160   | 196   | 154              | 174             | 186   | 198    |
|                      | 250              | 152             | 190   | 244   | 182              | 211             | 229   | 246    |
|                      | 300              | 169             | 217   | 291   | 207              | 246             | 270   | 295    |
| 400                  | 146              | 265             | 318   | 384   | 250              | 309             | 348   | 391    |
| 500                  | 217              | 306             | 377   | 475   | 285              | 365             | 421   | 485    |
| 600                  | 234              | 340             | 432   | 565   | 315              | 416             | 490   | 579    |
| 700                  | 248              | 370             | 481   | 653   | 341              | 462             | 554   | 672    |
| 800                  | 260              | 396             | 526   | 739   | 363              | 503             | 615   | 763    |
| 1,000                | 278              | 440             | 606   | 906   | 399              | 575             | 727   | 943    |
| 1,200                | 291              | 474             | 674   | 1,067 | 427              | 636             | 827   | 1,119  |
| 1,500                | 306              | 515             | 759   | 1,297 | 460              | 712             | 959   | 1,376  |
| 2,000                | 322              | 563             | 869   | 1,655 | 498              | 808             | 1,141 | 1,785  |
| 2,500                | 333              | 597             | 952   | 1,984 | 524              | 879             | 1,288 | 2,173  |
| 3,500                | 346              | 641             | 1,068 | 2,565 | 558              | 977             | 1,510 | 2,890  |
| 5,000                | 357              | 678             | 1,176 | 3,288 | 586              | 1,066           | 1,734 | 3,842  |
| 7,500                | 365              | 710             | 1,275 | 4,211 | 610              | 1,147           | 1,960 | 5,165  |
| 10,000               | 370              | 727             | 1,332 | 4,899 | 622              | 1,193           | 2,098 | 6,239  |
| 25,000               | 378              | 760             | 1,448 | 6,939 | 646              | 1,285           | 2,399 | 9,972  |
| 50,000               | 381              | 772             | 1,491 | 8,056 | 655              | 1,318           | 2,520 | 12,455 |
| 75,000               | 382              | 776             | 1,506 | 8,514 | 658              | 1,330           | 2,563 | 13,583 |
| 100,000              | 383              | 778             | 1,513 | 8,762 | 659              | 1,336           | 2,585 | 14,227 |
| 250,000              | 384              | 782             | 1,527 | 9,248 | 662              | 1,347           | 2,626 | 15,555 |
| 500,000              | 384              | 783             | 1,532 | 9,423 | 663              | 1,350           | 2,640 | 16,055 |
| 1,000,000            | 384              | 783             | 1,534 | 9,512 | 663              | 1,352           | 2,647 | 16,317 |
| 2,500,000            | 384              | 783             | 1,536 | 9,567 | 663              | 1,353           | 2,651 | 16,478 |
| 10,000,000           | 384              | 784             | 1,536 | 9,594 | 663              | 1,354           | 2,653 | 16,560 |
| 100,000,000          | 384              | 784             | 1,537 | 9,603 | 663              | 1,354           | 2,654 | 16,584 |
| 300,000,000          | 384              | 784             | 1,537 | 9,603 | 663              | 1,354           | 2,654 | 16,586 |

For a confidence level of 95%, margin of error (d) = 5%, and population of consultants = 34 (between 30 and 50) then by interpolation sample size= 32. Similarly by interpolation samples sizes of contractors and owner are found to be 59 and 136 respectively.

## **Appendix (B)**

### **COLLECTED PROJECTS DATA**

## B. Collected Projects Data

| Rank | Project Name                                         | Estimated cost (BD) | Actual cost (BD) |
|------|------------------------------------------------------|---------------------|------------------|
| 1    | Improvement of Shaikh Hamad Highway                  | 214,674             | 224,497          |
| 2    | Improvement of Wali Al Ahed highway phase 1          | 149,607             | 166,356          |
| 3    | Dualling of AlGhous Hwy phase 2 - Busaiteen          | 148,763             | 156,034          |
| 4    | Improvement of Hawar Highway Phase 2                 | 204,614             | 273,135          |
| 5    | Improvement of Almoaskar Highway Phase 1             | 135,594             | 177,654          |
| 6    | Improvement of Almoaskar Highway Phase 2             | 278,455             | 301,675          |
| 7    | Improvement of Highway 45 Phase 2                    | 236,495             | 241,896          |
| 8    | Improvement of Highway 35                            | 298,584             | 628,076          |
| 9    | Improvement of Highway 96 Phase 1                    | 276,455             | 284,456          |
| 10   | Improvement of Highway 96 Phase 2                    | 273,865             | 279,756          |
| 11   | Janabiya Highway Improvement Phase 3                 | 436,378             | 559,489          |
| 12   | Improvement of Zaid bin Omera Highway: Phase 1       | 465,762             | 718,510          |
| 13   | Improvement of Hawar Highway Phase 4                 | 625,000             | 650,996          |
| 14   | Improvement of Dry Dock Hwy Phase 2                  | 629,949             | 907,957          |
| 15   | Improvement of Shaikh Sakman Highway Phase 3         | 734,990             | 904,990          |
| 16   | Improvement of Highway 96 Phase 3                    | 244,893             | 249,375          |
| 17   | Improvement of Budaiya Highway Phase 5               | 488,573             | 519,753          |
| 18   | Improvement of Hawar Highway (from Askar to Jaww)    | 971,867             | 1,086,432        |
| 19   | Improvement of Budaiya Highway Phase 1               | 904,046             | 1,072,458        |
| 20   | Dualling of Mazarea Hwy Phase 3 - Jasra              | 958,276             | 1,200,809        |
| 21   | Dualling of Mazarea Hwy Phase 1 - Jasra              | 986,812             | 1,010,035        |
| 22   | Improvement of King Faisal hwy Phase 2               | 993,330             | 1,144,981        |
| 23   | Improvement of Shaikh Isa bin Salman Highway Phase 3 | 1,012,661           | 1,620,257        |
| 24   | Improvement of Shaikh Isa bin Salman Highway Phase 2 | 1,018,883           | 1,426,436        |
| 25   | Dualling of Zaid bin Omera Hwy Phase 5               | 1,275,934           | 1,297,643        |

| Rank | Project Name                                          | Estimated cost (BD) | Actual cost (BD) |
|------|-------------------------------------------------------|---------------------|------------------|
| 26   | Dualling of Zaid bin Omera Hwy Phase 2                | 1,354,841           | 1,465,203        |
| 27   | Improvement of Shaikh Isa bin Salman Highway Phase 1  | 1,365,540           | 2,806,185        |
| 28   | Improvement of Shaikh Isa bin Salman Highway Phase 4  | 1,457,042           | 2,185,563        |
| 29   | Improvement of Shaikh Salman Highway Phase 4          | 1,485,000           | 2,305,159        |
| 30   | Improvement of King Faisal Highway Phase 1            | 2,784,432           | 2,986,414        |
| 31   | Improvement of Dry Dock Hwy Phase 3                   | 1,564,274           | 1,624,495        |
| 32   | Improvement of hwy 71 - A'Ali                         | 1,726,000           | 2,133,832        |
| 33   | Dualling of Gulf of Bahrain Hwy                       | 1,837,000           | 3,223,212        |
| 34   | Improvement of King Faisal Highway Phase 4            | 2,785,652           | 2,896,412        |
| 35   | Improvement of Shaikh Jaber AlSobah Highway Phase 1   | 3,972,423           | 4,082,649        |
| 36   | Improvement of Shaikh Jaber AlSobah Highway Phase 1   | 3,186,043           | 3,589,634        |
| 37   | Improvement of Esteqlal Highway                       | 3,986,543           | 4,278,744        |
| 38   | Improvement of Zaid bin Omera Highway: Phases 3 and 4 | 2,748,350           | 3,255,744        |

## الخلاصة

تناقش هذه الرسالة تجاوز الكلفة في مشاريع إنشاء وتطوير الطرق السريعة في البحرين. كما تدرس الرسالة وتيرة وخطورة أسباب تجاوز التكلفة. تم تحديد اثنان وخمسون سبباً يؤدي إلى تجاوز كلفة مشاريع تطوير وإنشاء الطرق السريعة، وذلك من خلال مراجعة الدراسات السابقة، وعبر إجراء مقابلات مع مهندسين يعملون لدى مقاولين، وشركات استشارية، ووزارة الأشغال وشئون البلديات والتخطيط العمراني، حيث تم تصنيف الاسباب إلى ست مجموعات وتم دراسة مدى تكرار هذه الأسباب وخطورتها. إن هذه الدراسة مبنية على إجراء مسح ميداني من خلال استبيان تم توزيعه على ستة وثلاثين مقاول، وأربعة وعشرين شركة استشارية وأربعة وثمانين مهندس طرق في وزارة الأشغال وشئون البلديات والتخطيط العمراني.

هذا وفيما يخص النموذج الذي تم إعداده ضمن هذه الدراسة، فقد تم جمع الأسباب الفعلية عبر إجراء مقابلات مع مديري المشاريع بالوزارة لـ ٣٨ مشروع تطوير وإنشاء طرق سريعة في البحرين من عام (٢٠٠٥-٢٠١٦)، حيث تم الطلب منهم تحديد مدى تكرار المجموعات الست في مشاريعهم ومدى خطورتها. فيما تم استخدام نموذج الشبكات العصبية الاصطناعية (ANN) لتحديد أي مجموعة لها الأثر الأكبر على تجاوز الكلفة، وتمت مقارنة النتائج مع تلك التي تم الحصول عليها من الاستبيان.

لقد خلصت الدراسة إلى أن الأسباب الرئيسية لتجاوز كلفة مشاريع تطوير وإنشاء الطرق السريعة في البحرين متعلقة أساساً بمجموعة مالك المشروع (الوزارة)، ومجموعة الاستشاريين، ومجموعة المقاولين ومن هذه الأسباب: أوامر التغيير المتكررة، ونقص الخبرة لدى مهندس المشروع، وغياب التواصل مع الموردين على التوالي. في حين لم تكن العوامل ضمن مجموعة خصائص المشروع، ومجموعة تقدير الكلفة، ومجموعة الاسباب البيئة ذات تأثير كبير.

في الختام تم اقتراح توصيات من أجل تقليل تجاوز الكلفة في مشاريع تطوير وإنشاء الطرق السريعة في البحرين. كما أنه تم وضع بعض التوصيات للدراسات القادمة.

جامعة البحرين

قسم الهندسة الميكانيكية

كلية الهندسة



## اسباب تجاوز الكلفة في مشاريع إنشاء وتطوير الطرق السريعة في البحرين

رسالة مقدمة كأحد متطلبات الحصول على شهادة الماجستير في الإدارة الهندسية

إعداد:

أحمد غازي الكوهجي

٢٠٠٥٤٧٧٩

إشراف

الدكتور سعد سليمان

(بروفيسور)

جامعة البحرين

مملكة البحرين

يناير ، ٢٠١٧