UNIVERSITY OF BAHRAIN

College of Engineering **Department of Mechanical Engineering**

Modeling of Late Payments for Contractors Working for MoW Building Construction Projects.

A Thesis Submitted in Partial Fulfillment of the Requirements for the Master Degree in Engineering Management

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Abstract

The problem of late payment is considered one of the major issues in the construction industry, it is an important issue that many countries including Kingdom of Bahrain face and it has many consequences on building construction projects. The main objectives of this research are to identify the factors, consequences of delay in payment and their importance, to determine solutions to overcome this issue. To create a prediction model to predict the payment delay in days for Interim payments (Model I) and variation payments (Model V) for MoW building construction projects.

The objectives of the study are achieved through a comprehensive literature review about three main issues; causes of payment delay; effects of payment delay and effective solutions to overcome payment delay. Secondly, information on these issues is collected by surveying experts working in building construction engineering field in both governmental and private sectors. Finally, prediction models to predict payment delay for two types of payments in MoW are developed.

The application of an artificial neural network (ANN) and multi linear regression network (MLRN) to predict the payment delay in days is presented in this work in order to have a more reliable prediction for the actual duration needed for a payment to be processed. This helps in better risk estimation and payment scheduling for governmental projects. The important factors are ranked by their relative importance indecies. Twelve and ten input factors are used for the development of (Model I) and (Model V), respictively, using two MATLAB tools and one Excel analysis tool.
Finally, the study compares the ANN approach with MLRN analysis and concludes that the estimation accuracy of ANN approach is better than MLRN analysis for payment delay as it showed more promising results. The best ANN delay models are found to be Model I-48 and Model V-60, respictively. Both models are developed using MATLAB nftool, Bayesian algorithm and tan-sigmoid function. The study recommends solutions to overcome the payment delay issue in governmental building construction projects. The highest ranked solutions are: Improve and ease the process of payments valuation and certification; Awarding the contract to competent contractors; Proper planning and budgeting of all governmental projects; Proper management of cash flow; Manage to anticipate any risk related to payment issues; and Briefings and meetings prior start of works.

Dedication

I would like to dedicate this to Allah the grateful who helped me through this long journey. My dear husband, who supported me, stood by my side and believed in me. My daughter Badriya, her beautiful smile took me all the way through. My parents for their prayers, support and unconditional love since I took my first steps and until this day, they are my paradise on earth. My brother and sisters, for their support, help, concerns and love. Finally, to my sister by heart and my dearest friends, their continuous support and great love cannot be forgotten. This is dedicated to all of you, thank you for being a part of my life.

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List of Content

Subject	Page
Accreditation by Jury	I
Abstract	II
Dedication	III
Acknowledgement	IV
List of Content	V
List of Tables	IX
List if Figures	XII
List of abbreviations	XVI
List of Notations	XVII
List of Appendices	XVIII
Chapter One **Introduction**	
1.1 Background	2
1.2 Problem Statement	3
1.3 Problem Questions	4
1.4 Objectives of the Study	4
1.5 Significance of the Research	4
1.6 Study Limitation	4
1.7 Summary of Chapters	4

Chapter Two **Literature Review**		
2.1	Introduction	7
2.2	Payment Definition and Types	7
2.3	Causes and Consequences of Payment Delay	8
2.4	Modeling with Artificial Neural Network (ANN) in Construction Project Management	13
2.5	Regression Modeling in Construction Project Management	16
2.6	Chapter Summary	20
Chapter Three **MoW Payment Practices**		
3.1	Introduction	21
3.2	Ministry of Works Payment Clauses	21
3.3	Payment Approval Processes in MoW	22
3.4	Additional Payment (Variation) Approval Process	25
3.5	Remedies (Interest) on Overdue Payment	29
3.6	Chapter Summary	29
Chapter Four **Research Methodology**		
4.1	Introduction	31
4.2	Data Collection and Questionnaire Design	31
4.3	Questionnaire Distribution	33
4.4	Data Measurement	35
4.5	Data Analysis	35
4.6	Development of the Model	36
4.7	Chapter Summary	37

Chapter Five **Results and Analysis of Survey Collected Data**		
5.1	Introduction	39
5.2	General Information	39
5.3	Factors Contributing to Payment Delay	43
5.4	Consequences of Payment Delays	61
5.5	Effectiveness of Suggested Solutions to the Payment Delay	73
5.6	Chapter Summary	79
Chapter Six **Historical Data Collection and Analysis for Modeling**		
6.1	Introduction	82
6.2	Independent and Dependent Variables	82
6.3	Historical Data Collection and Types	92
6.4	Chapter Summary	97
Chapter Seven **Modeling with Neural Network and Regression**		
7.1	Introduction	100
7.2	Artificial Neural Networks	100
7.3	Regression **Modeling**	104
7.4	Design of Models	105
7.5	Building ANN Models	107
7.6	Chapter Summary	125

Chapter Eight **Development of Interim Payment Delay Model (Model I)**		
8.1	Introduction	127
8.2	Developing Model I Using MATLAB nntool	127
8.3	Developing Model I using MATLAB nftool	141
8.4	Developing Model I using Regression Excel Tool	154
8.5	Comparison and Discussion of Model I Results	165
8.6	Chapter Summary	168
Chapter Nine **Conclusions and Recommendations**		
9.1	Introduction	169
9.2	Developing Model V using MATLAB nntool	169
9.3	Developing Model V using MATLAB nftool	182
9.4	Developing Model V using Regression Excel tool	197
9.5	Comparison and Discussion of Model V Results	207
9.6	Chapter Summary	209
Chapter Ten **Conclusions and Recommendations**		
10.1	Introduction	211
10.2	Conclusions	211
10.3	Recommendations	214
10.4	Limitation of the Study	216
10.5	Further Recommended Studies	216
11	References	218
12	Appendices	225

List of Tables

No.	Subject	Page
Table 4-1	Five-Level Frequency Likert Scale	35
Table 4-2	Ranges of the Intervals for Likert Scale	36
Table 5-1	Place of Work	39
Table 5-2	Participant's Age	40
Table 5-3	Participant's Professional Background	41
Table 5-4	Participant's Total Work Experience (years)	41
Table 5-5	Participant's Total Projects Accomplished	42
Table 5-6	Participant's Opinions on the Payment Delay Problem	43
Table 5-7	The Relative Indices and Ranks of Factors Causing Payment Delay	44
Table 5-8	Factors of Payment Delay Related Groups	47
Table 5-9	The Top Ten Factors by Contractors Perspective	59
Table 5-10	The Top Ten Factors by Consultant’s Perspective	60
Table 5-11	The Relative Indices and Ranks of Consequences of Payment Delay	61
Table 5-12	Consequences of Payment Delay Related Groups	64
Table 5-13	Consequences of Payment Delays (Consultant Perspective)	66
Table 5-14	Consequences of Payment Delays (Contractors Perspective)	67
Table 5-15	The Suggested Solutions for Payment Delay Issue	77
Table 6-1	Factors Causing Payment Delay	89
Table 6-2	Interim Payment Factors Used for Model I	92
Table 6-3	Variation Order Payment Factors Used for Model V	92
Table 8-1	Performance of Test Sample Model I Using	129

Table 8-2	Test Sample and Predicted Results for Model I-8 (nntool)	130
Table 8-3	Performance of Test Sample Model I Using	132
Table 8-4	Test Sample and Predicted Results for Model I-22 (nntool)	134
Table 8-5	Performance of Test Sample for Model I Using	136
Table 8-6	Test Sample and Predicted Results for Model I-33 (nntool)	137
Table 8-7	Selected Models for Model I Using MATLAB (nntool)	139
Table 8-8	Performance of Test Sample for Model I Using	142
Table 8-9	Test Sample and Predicted Results for Model I-38	144
Table 8-10	Performance of Test Sample for Model I Using	146
Table 8-11	Test Sample and Predicted Results for Model I-48	147
Table 8-12	Performance of Test Sample for Model I Using	148
Table 8-13	Test Sample and Predicted Results for Model I-61	149
Table 8-14	Selected Models for Model I Using MATLAB (nftool)	151
Table 8-15	Goodness of Fit of Model I-70 Using Equation (8-1)	154
Table 8-16	Regression Coefficients for Model I-70 Using Equation (8-1)	155
Table 8-17	Significant & Non-Significant Variables Model I-70 Using Equation (8-1)	158
Table 8-18	Goodness of Fit of Model I-70 Using Equation (8-2)	159
Table 8-19	Regression Coefficients for Model I-70 Using Equation (8-2)	159
Table 8-20	Performance of Test Sample of Regression Model (Model I-70) Using Equation (8-1)	161
Table 8-21	Performance of Test Sample of Regression Model (Model I-70) Using Equation (8-2)	162
Table 8-22	Comparison of the Selected Models for (Model I)	166

Table 9-1	Performance of Test Sample Model V Using	171
Table 9-2	Test Sample and Predicted Results for Model V-6 (nntool)	172
Table 9-3	Performance of Test Sample Model I Using	174
Table 9-4	Test Sample and Predicted Results for Model V-20 (nntool)	175
Table 9-5	Performance of Test Sample for Model V Using	177
Table 9-6	Test Sample and Predicted Results for Model V-29 (nntool)	178
Table 9-7	Test Sample and Predicted Results for The Selected Models	179
Table 9-8	Performance of Test Sample for Model V Using	183
Table 9-9	Test Sample and Predicted Results for Model V-37	185
Table 9-10	Performance of Test Sample for Model V Using	187
Table 9-11	Test Sample and Predicted Results for Model V-54	189
Table 9-12	Performance of Test Sample for Model V Using	191
Table 9-13	Test Sample and Predicted Results for Model V-63	193
Table 9-14	Selected Models for Model V Using MATLAB (nfool)	195
Table 9-15	Goodness of Fit for Model V-76 Using Equation (9-1)	198
Table 9-16	Regression Coefficients for Model V-76 Using Equation (9-1)	199
Table 9-17	Significant and Non-Significant Variables Model V-76 Using Equation (9-1)	200
Table 9-18	Goodness of Fit for Model V-76 Using Equation (9-2)	202
Table 9-19	Regression Coefficients for Model V-76 Using Equation (9-2)	202
Table 9-20	Test Sample of The Regression Model (Model V-76) Using Equation (9-1)	204
Table 9-21	Test Sample of the Regression Model (Model V-76) Using Equation (9-2)	205
Table 9-22	Comparison of the Selected Models for (Model V)	208

List of Figures

No	Figure	Page
Figure 3-1	Types of Funding in CPD	23
Figure 3-2	Interim Payments Approval	24
Figure 3-3	Variation Payment Approval for Locally Funded Projects	27
Figure 3-4	Variation Approval for Externally Sponsored Projects	28
Figure 5-1	Changes in Scope of Work	48
Figure 5-2	Drop Between the 10th & 11th Consequences (Contractor Perspective)	65
Figure 5-3	Drop Between The 12th & 13th Consequences (Consultant Perspective)	65
Figure 6-1	Effect of Change in Scope on Other Factors	84
Figure 7-1	Architecture of Ann	101
Figure 7-2	Approaches Adopted for Models Development	106
Figure 7-3	ANN Models Development	108
Figure 7-4	Validation and Test Data Window in MATLAB	109
Figure 7-5	Tan-Sigmoid Activation Function	110
Figure 7-6	Mapminmax Normalization Command in MATLAB	112
Figure 7-7	De-Normalization Command in MATLAB	112
Figure 7-8	New Network Creation Using nntool	113
Figure 7-9	Testing the Network	114
Figure 7-10	nftool Data Selection	116
Figure 7-11	nftool Validation and Test Data Percentages	117
Figure 7-12	Number of Hidden Neurons Selection	118
Figure 7-13	Training Algorithm Selection	119

Figure 7-14	Opening the Data Analysis Tool	120
Figure 7-15	Defining the Input Y Range and the Input X Range	121
Figure 7-16	Regression Analysis Results	122
Figure 8-1	Performance of Model I Using	129
Figure 8-2	Test Sample and Predicted Results for Model I-8 (nntool)	131
Figure 8-3	Performance of Test Sample Model I Using	133
Figure 8-4	Test Sample and Predicted Results for Model I-22 (nntool)	135
Figure 8-5	Performance of Test Sample Model I Using	136
Figure 8-6	Test Sample and Predicted Results for Model I-33 (nntool)	138
Figure 8-7	Selected Models for Model I from MATLAB (nntool)	139
Figure 8-8	ANN Diagram for Model I-12	139
Figure 8-9	Training Performance for Model I-12	140
Figure 8-10	Training Sample R-Value Result for Model I-12	140
Figure 8-11	Performance of Test Sample for Model I Using	143
Figure 8-12	Test Sample and Predicted Results for Model I-38 (nftool)	145
Figure 8-13	Performance of Test Sample for Model I Using	146
Figure 8-14	Test Sample and Predicted Results for Model I-48	148
Figure 8-15	Performance of Test Sample for Model I Using	149
Figure 8-16	Figure 8 16 Test Sample and Predicted Results for Model I-61	151
Figure 8-17	Selected Models for Model I from MATLAB (nftool)	152
Figure 8-18	ANN Diagram for Model I-48	152
Figure 8-19	Training Performance for Model I-48	153
Figure 8-20	Training and Test Samples R-Value Result	153

Figure 8-21	Extension of Time and Variation Orders Effect on Payment Delay	158
Figure 8-22	Effect of Nonsignificant Factors on Payment Delay	158
Figure 8-23	Performance of Test Sample of Regression Model	164
Figure 8-24	Performance of Test Sample of Regression Model	164
Figure 8-25	Comparison of the Selected Models for (Model I)	167
Figure 9-1	Performance of Test Sample Model V Using	171
Figure 9-2	Test Sample and Predicted Results for Model V-6 (nntool)	172
Figure 9-3	Performance of Test Sample Model V Using	174
Figure 9-4	Test Sample and Predicted Results for Model V-14 (nntool)	176
Figure 9-5	Performance of Test Sample for Model V Using	177
Figure 9-6	Test Sample and Predicted Results for Model V-27 (nntool)	179
Figure 9-7	Selected Models for Model V Using MATLAB (nntool)	180
Figure 9-8	Selected Models for Model V from MATLAB (nntool)	180
Figure 9-9	Training Performance for Model V-14	181
Figure 9-10	Training Sample R-Value Result for Model V-14	181
Figure 9-11	Performance of Test Sample for Model V Using	184
Figure 9-12	Test Sample and Predicted Results for Model V-37	186
Figure 9-13	Performance of Test Sample for Model V Using	188
Figure 9-14	Test Sample and Predicted Results for Model V-60	190
Figure 9-15	Performance of Test Sample for Model V Using	192
Figure 9-16	Test Sample and Predicted Results for Model V-63	194
Figure 9-17	Selected Models for Model V from MATLAB nftool	195

Figure 9-18	ANN Diagram for Model V-60	195
Figure 9-19	Training Performance For Model V-60	196
Figure 9-20	Regression Results for Model V-60	196
Figure 9-21	Performance of Test Sample of The Regression Model (Model V-76) Using Equation (9-1)	206
Figure 9-22	Performance of Test Sample of The Regression Model (Model V-76) Using Equation (9-2)	206
Figure 9-23	Comparison of the Selected Models for (Model V)	209

List of Abbreviations

MoW	Ministry of Works, Municipalities Affairs and Urban Planning (Consultant)
CPD	Construction Project Directorate
CED	Cost Engineering Directorate
MAE	Mean Absolute Error
MSE	Mean Square Error
MAPE	Mean Absolute Percentage Error
MLRN	Multi Linear Regression Network
ANN	Artificial Neural Network
RII	Relative Importance Index
nftool	Network Fitness Tool
nntool	Neural network tool
MoF	Ministry of Finance
R	Coefficient of Determination
VO	Variation Orders
FIDIC	The International Federation of Consulting Engineers

List of Notations

n	Sample Size for Finite Population
n°	Sample Size from Infinite Population
N	Population Size
z^2	Abscissa of the Normal Curve
e	Desired Level of Precision
p	Estimated Proportion of an Attribute
q	1- p
1 - α	Desired Confidence Level
n_1	Number of Respondents Who Scored 1
n_2	Number of Respondents Who Scored 2
n_3	Number of Respondents Who Scored 3
n_4	Number of Respondents Who Scored 4
n_5	Number of Respondents Who Scored 5

List of Appendices

No	Appendix
(1)	Questionnaire Format
(2)	Questionnaire Results and Calculations
(3)	Historical Cases for Governmental Buildings Projects for Models Design
(4)	nntool Code for Data Entry and Normalization
(5)	Model I nntool Performance for the Training and Validation Samples
(6)	Performance of Test Sample for Model I Using nntool
(7)	Model I nftool Performance for the Training and Validation Samples
(8)	Performance of Test Sample for Model I Using nftool
(9)	Model V nntool Performance for the Training and Validation Samples
(10)	Performance of Test Sample for Model V Using nntool
(11)	Model V nftool Performance for the Training and Validation Samples
(12)	Performance of Test Sample for Model V Using nftool
(13)	Simulation Function for Model I-48
(14)	Simulation Function for Model V-60

CHAPTER 1
Introduction

1.1 Background
1.2 Problem Statement
1.3 Problem Questions
1.4 Objectives of the Study
1.5 Significance of the Research
1.6 Study Limitation
1.7 Summary of Chapters

Chapter 1
Introduction

1.1 Background

Construction projects may face many problems and one major problem affecting construction projects is delay. Delay is a very serious problem with many dimensions influencing a project. One of the important dimensions is delay in payments, which is a dimension affecting the success and completion of projects on time, and within budget and quality. Late payment can severely affect a construction project and performance. Identifying the causes of the late payments and their solutions can help in reducing the occurrence of other delay factors (Enshassi, 2015). These causes can affect the cash flow for the contractors and sub-contractors through the construction pyramid structure starting from the client at the top of the pyramid to other parties in the lower level of the pyramid (Prisim, 2013). Productivity of the construction industry is also damaged by late-payments, which affects the construction parties in the supply chain. Payment delay is an important internal constraint to the productivity of the on-site labor in New Zealand construction projects (Durdyev and Mbachu, 2011). Kadir et al. (2005) stated that payment delays are the cause of material delivery slippages that have impact on the productivity of the labors in the construction industries.

Late payments are also affecting the projects of the Construction Projects Directorate (CPD) in Ministry of Works (MoW) – Bahrain. “The Ministry of Works is the construction arm of the government of the Kingdom of Bahrain”. The construction of Government buildings is undertaken through the (CPD). “The (CPD) is responsible for the design,

planning, execution, and quality control of public sector building projects in the Kingdom of Bahrain" ("Ministry of Works, Kingdom of Bahrain", 2016). Since the regulations of MoW oblige the contractor to continue working in the situation of payment delay occurrence, and according to the previous studies which is stating "There are no cost borne by the party that delays payment (Client), on the other hand cost are borne entirely by the party whose payment is delayed (Contractor) unless that party can further off-load to another party, which mostly will be below him in the construction pyramid (Subcontractor)" (Ramachandra and Rotimi, 2015).

This study aims to investigate the late payment causes and effects based on the perspective of the engineers and contractors working for MoW. Importance of the late payments factors is identified through interviews and questionnaire, and a prediction model is created to establish the interim payment delay (days) and variation payment delay (days) faced by the contractors working for MoW. This model helps in predicting the delay in payment and ensures smooth completion of work.

1.2 Problem Statement

Late payment or delay in payment affects the completion of construction projects. The problem of late payment is considered one of the major issues in the construction industry. It affects the progress of the work and the cash flow of the contractor, which causes payment difficulties, and leads to inability of delivering a project on the schedule, cost and quality. Inevitably, the contractor will be exposed to a risk burden associated with the delay in payment.

1.3 Problem Questions

- What are the causes and effects of payment delay and their importance ranking?

- What is the amount of risk in (days) for interim payment and variation payment that contractor may face due to payment delay?

1.4 Objectives of the Study

The main objectives of this research are: -

- To identify the factors and consequences of delay in payment and to determine the solutions to overcome this issue.

- To develop models to predict the payment delay in days for two types of payments, namely; interim payments and variation payments for the contractors working for MoW.

1.5 Significance of the Research

This research is relevant to the government and the contractors, especially contractors with modest capital; it addresses the problem of late payments and reduces its further effect. Furthermore, it provides a better understanding of the risks associated with this factor.

1.6 Study Limitation

The cases used in the creation of the models are for interim payments and variation payments. Advanced payments and final payments are not included in this model. Also, the questionnaire results of the study are based on the perspective of A and B contractors listed in MoW prequalified contractor's list.

1.7 Summary of Chapters

The research consists of ten chapters. The first chapter comprises an introduction on late payment and its significant effect on the progress of work, in addition to an introduction about MoW. Chapter two includes a comprehensive literature review about payment delay and the results of

previous studies. The third chapter includes MoW payment processes and cluses. The fourth chapter involves the methods used for questionnaire, the data collection, stages of the data identification, and design of the questionnaire. Moreover, it includes the methods used for the model development. Whereas, Chapter five illustrates the questionnaire results and analysis. Data collection for the models design is presented in Chapter six. While the Modeling techniques are shown in Chapter seven. Chapters eight and nine include the development and verification of Model I and Model V, respectively. Finally, Chapter ten includes conclusion, recommendations, and limitations of the research with suggestion for future studies.

CHAPTER 2
Literature Review

2.1 Introduction
2.2 Payment Definition and Types
2.3 Causes and Consequences of payment delay
2.4 Modelling Artificial Neural Network (ANN) in Construction Project Management
2.5 Regression Modelling in Construction project management
2.6 Chapter Summary

Chapter 2
Literature Review

2.1 Introduction

Payment is one of the most important factors that can be affected by delay risks leading to late payment consequences. This shows that late payment is an important problem that many countries face in their construction industries which can influence the structure of the construction industry pyramid starting from the client to the main contractor and so on (Judi and Rashid, 2010). This is why this chapter's purpose is to survey previous studies and understand their results and facts to extenuate the research.

2.2 Payment Definition and Types

As mentioned previously payment is a very important element in construction industry. Late payment can cause many consequences and almost occurs in most construction industries. Payment is any payment given to any party of the construction industry structure and as Kennedy (2005) commented on payment: "not unexpectedly, it has always been the main subject of disputes. It is anticipated that conflict if unsettled will escalate into disputes which can also cause late and non-payment."

Payment defaults as per (Ali, 2006) are divided into three parts under payment, late payment and non-payment. As he described under payment is when the payment amounts certified and paid by the client is lower in value than the work executed by the contractor, whereas late payment is when the client takes a long time than the time allocated and over the honoring certificated period given to issue the payment to the contractor. Finally, non-payment is when no payment is released to the contractor even if the contractor has completed the work or certain areas of the work.

As per Amoako (2011) there are three types of payment which are phase payment, advance payment and payment after completion. Phase payment is used when the payments are made at specific stages during construction. This type is commonly used in lump sum contracts where a part of the total sum is planned to be paid over a number of work phases (Amoako, 2011). Advance payment is the amount paid by the client to the contractor before the execution of work and is usually practiced in governmental contracts to help the contractor to start up and finance the contract without leading to needless external lending. Payment after completion is the payment made to contractor after the attainment of the contract milestone of practical or substantial completion or the handing over of the works to the client (Ansah, 2011).

2.3 Causes and Consequences of Payment Delay

Payment problems are frequently occurring, and has affected many industries in construction, this is the reason why many researches have been carried out to study and address the issues and problems in payment to mitigate or find solutions to prevent its effects on the parties of a construction industry.

Abdul-Rahman et al. (2011) addressed construction projects issues related to financial delays. The study data was collected through a questionnaire and a survey follow up by an interview with a mix of clients, consultants, contractors and bankers. The results showed that major factors are: poor management of finance and business by the client, refuse of payment by client, invalid claims by the contractors, consultant interim payment delay in valuations and certification, inaccuracy of the valuation of implemented work, insufficient valuation or incorrect information and documentation, participation of many parties in the honoring certification

process, and finally consultants heavy workloads to evaluate the work done. The researchers indicated that the client and main contractor are the major reasons of the problems and the issue should be mitigated through many recommendations such as risk management.

In 2010 a study by Ye and Abdul Rahman (2010) was conducted in Malaysia to identify the core causes of late payment from the contractor's perspective and to recommend operative solutions to overcome late payment problems. The study established seven significant factors out of a total of forty-one factors that can cause late payment problems, which are: cash flow problems due to deficiencies in client's management capacity, client's ineffective utilization of funds, lack of capital to finance the project, clients failure to generate income from bank when sales of houses do not hit the targeted amount, poor cash flow because of lack of proper process implementation, delay in releasing of the retention monies to contractor, and delay in the evaluation and certification of interim and final payment.

Amoako (2011) stated that there are major problems in delayed payments remaining in the Ghanaian Road Construction Industry. The related objective in his study was to establish the effects of delay in payment problems and their consequences on the contractors and other stakeholders associated to roads in Ghanaian. The methods used to collect data for the study is a survey. The results from the survey exposed that there are many effects of payment delay to the contractors which causes many conflicts between the parties. Some of the major factors are: contractors are forced to take money from the financial institutes, cash flow problems that lead to cost overrun, effects on the reputation of the contractors leading to temporary suspension of work. As respondents

pointed out that there should be payment interests on payment, regular periodic payments, and a defined payment time frame.

In 2011 a study was conducted by Ansah (2011) to investigate the important factors of delay in payment done by clients in the Ghanaian construction projects industry. The data of the study were collected by distributing questionnaire to a randomly selected sample of 210 individuals among contractors, subcontractors and clients in the Ghanaian construction industry. Some of the identified causes of delayed payment discovered in the study are: Employer's poor financial management, conflict among parties involved in the contract, and delay in certification. The suggested solution by the study to overcome the payment issues are to enforce clauses of delayed payment in contracts, imposing charges on late payments and the establishment of a payment section to be accountable for saving the history of delayed payment and penalties given to those who fail to pay on time as specified in the contract.

Ayudhya (2012) studied the factors that cause delay in payment in Thailand for residential building projects. The method used consists of a random distributed questionnaire and interviews to evaluate the severity of 24 identified factors of delay in payment, which includes a selected sample of practitioners in construction from owners, consultants and main contractors. The results showed that the causes of delay in payment that had the highest ranking are: owner's financial problems, disputes between the owner and main contractor, delay in approval, improper or accuracy of bill of quantity.

In 2014 a study that aims to inspect the causes of late and non-payment in the Malaysian construction industry was done by Azman et al. (2014), it included a sample of 100 contractors. The results showed that the

major causes of late and non-payment are: local attitude and culture, delay in certification by consultant, client poor financial management, and communication between contract parties. The study results can help in addressing problems associated with late and non-payment by government in an effective and timely manner to create a fair situation for all parties in the Malaysian construction industry.

A research was conducted in 2015 by El-Sawalhi and Nasser (2015) to recognize the causes, effects and solutions of payment delay and to create a model to quantify the risk of payment delays. Three methods were used to achieve study objective, the first method is through a literature review about the causes, effects and effective solutions for late payment issue. The second method was through distributing questionnaire to 140 participants in order to rank the causes, effects and solutions of payment delay. The last method was distributing a hypothetical case study through structured interview to (31) contractors to measure the risk of payment delays through indicating a weight for each of the highest ranked consequences. The study results showed that the contractor is the main player in the payment delay causes. The highest ten ranked consequences were included in the design of the model which are: Late payment of salaries, Time overrun of project, Cash flow problems, Slow down the progress until payment is paid, Difficult to procure material and services, Difficult to tender for new projects, Sub-contractor refuse to continue works on the project, Bad reputation of the contractor, and high interest rate due to loans. The Neurosolution (5.07) program was selected to build the model, the performance accuracy of the adopted model recorded (93.47%) indicating good performance. El-Sawalhi and Nasser (2015) recommended that the contractors should have enough cash before beginning projects, and to submit timely accurate invoices with complete

documents. The owners were advised to work within stipulated budget kept in bank account before starting the project execution, to pay progress payment to the contractors on time, and to introduce payment bonds to contractors.

Hailu (2015) noted that there are several factors that influence the increase of payment problems in public building construction projects. These factors are: addition of a new item in the project is decided by the owner; change parts of the job that has been defined by either deleting, adding, modifying, or reducing a portion; discovering during construction of unexpected site conditions that may require change to the project such as soil condition, hazardous materials or archaeological findings; discovery of contract document discrepancies; changes in contract due to changes in codes or regulations after the contract is signed; and finally unavailability of equipment, products or materials specified originally in the scope of work.

In 2015 a study was conducted by Okeyo et al. (2015) in Kenya to address late payment issue and its effect on projects. The study established the effects of delayed payment which are: productivity and efficiency loss, increase in time-related costs, works re-scheduling, extension of time, and delay in early completion. The study concluded that payment on time by the owner is very important to assure the smooth performance of work within time, budget, and quality specifications. The study recommended the need of appropriate actions against potential payment risks, such as delay in payment by external financiers, delayed approval of payment requests, improving the management of project funds, and expedite payment of funds for subsequent project phases.

A study was conducted by Ramachandra and Rotimi (2015) to investigate the main causes of payment delays and to recommend

solutions. The study implemented a survey using an online questionnaire targeting the practitioners from New Zealand construction industry (consultants, head contractors and subcontractors). The study found that the main causes of payment delay are related to: financial power of industry players; contractual issues; disputes; and time needed for payment processes. The conclusion of the study addressed solutions that have proven to be significant to overcome the main causes of payment delay: such as providing a possible method of financial security at the beginning of a project; and the pre-qualification of the financial standing of project participants.

In 2016 a study was implemented in Malaysia by Badroldin et al. (2016) to examine the late payment problems observed in the Malaysian construction industry. The data of the study were obtained through thirty-seven questionnaires from contractors and subcontractors in the state of Selangor. The collected data were analyzed by using frequency distribution and relative important index (RII). The highest three influences of late payment are: negative chain effect on other parties (RII = 0.827); delay in project completion (RII = 0.827); and sluggish company growth (RII = 0.778). The study stated that most of the contractors often faced payment delay.

2.4 Modeling with Artificial Neural Network (ANN) in Construction Project Management

Börner et al. (2012) stated that a proper description of a model is that it's a structural illustration of a certain object that has critical features to present the actual situation for a set of data in the visual, mathematical or as a computer simulation form. Waziri et al. (2014) stated that the most positive outcomes were found in the analysis done using regression and artificial intelligence for the building construction industry. These two

methods showed high understanding of the elements affecting construction durations and their relationships.

A Neural network that can predict time-delay in days is very important in construction project management. This is essential for construction projects scheduling, because by predicting the actual duration of a project and the overrun days, one knows the amount of risk in days for the delay in different project activities such as the delay in extension of time approval, payment delay etc... Predicting the delay risk in days can be essential for project planner for estimating accurate durations for different activities and processes comprehended in the project. The capability of ANN models for prediction of time delay was tested and employed in some of the previous studies.

Yahia et al. (2011) developed an ANN model to predict time contingency in construction projects by identifying the important factors based on a comprehensive survey filled by the Egyptian construction experts. The model was developed in order to have a more reliable prediction for the amount of time contingency that should be added to the scheduled completion time by project planner. In 2011 an ANN model was developed by Elsawy et al. (2011) for estimating site overhead cost using 52 actual real-life cases of building projects, constructed in Egypt, as training materials. The model presented the site overhead costs as a percentage from the total project cost.

In 2015 ANN model was developed by Naik and Radhika (2015) for the estimation of cost and duration for highway road construction projects. The database was collected from previous projects, normalized and then used as inputs and targets for the ANN models development. The models are trained, tested and validated using MATLAB R2013a Software. The

model was trained with feed forward back propagation learning algorithm. The performance evaluation of the ANN was done using MAPE (Mean Absolute Percent Error) by comparing the output values from the ANN with the actual values. The best results were given by the ANN with training function trainlm which is a function that uses Levenberg-Marquardt algorithm and (nftool approach) with 2 layers and a hidden layer of 10 neurons.

In 2015 an ANN was applied by Amita et al. (2015) for the development of a bus travel time prediction model. The model was developed to give real time bus arrival information to the passenger and transit agencies for applying proactive strategies. For development of ANN model, the input data were the factors affecting the time arrival of buses. Comparative study revealed that ANN model outperformed the regression model in terms of accuracy and robustness.

Parminder (2016) developed an ANN model for predicting the time duration of construction projects in India, by first selecting the important factors through extensive literature study. A multi-layers model with back propagation learning algorithm was developed with several cases. The best model obtained was with one hidden layer containing 20 neurons, and with minimum root mean square error of 0.9845. The proposed ANN model was compared with other project planning techniques where it has found to be the most accurate and reliable tool for project duration prediction.

In 2016 an ANN was used by Mensah et al. (2016) to predict the duration of prefabricated steel bridge projects in Ghana. Data for 18 completed bridge construction projects were collected to get the independent items to be used as an as input variables and the actual durations as output variables. The model was developed with a feed

forward back propagation algorithm and the number of neurons in the hidden layer was obtained by trial and error. The Accurate results of the model was obtained with a coefficient of determination (R2 =0.998) and MAPE of 4.05%. The study has shown that the developed model is suitable for estimating the duration of a bridge project.

2.5 Regression Modeling in Construction Project Management

In 2004 Bordat et al. (2004) analyzed and assessed the extent of cost overruns, time delays, and change orders problem associated with Indiana Department of Transportation (INDOT) construction projects. Factors such as design, unexpected site conditions, increases in project scope, weather conditions, and other project changes were collected from literature review and agency survey. After identifying influential factors, regression models were developed to estimate the extent of future cost overruns, time delay and change orders of any future project given its project characteristics and any available contract details. The models were created using 2000 randomly selected projects to estimate values of cost overruns, time delay and change orders for future projects. The model provided information about the significant factors affecting cost overruns, time delays, and change orders, which are: bid amount, project type, location by district, weather, and bid comparison variables. These conclusions are similar to those found from the literature review.

A study by Blyth and Kaka (2006) was implemented for the purpose of finding a simple and fast technique for accurate forecasting of cash flow in construction projects. A multiple linear regression model was developed for forecasting the programme of works and hence S-curves for a historical sample of data from 50 projects. A further six projects were used to validate and test the model. The model developed was compared with previous

models and evaluated. It was concluded that the model produced more accurate results than existing value and cost models.

Ayman et al. (2008) study was about risk prediction, which was inducted in Jordan by proposing a probabilistic model to predict the risk effects on time and cost of construction projects. Statistical regression model was developed using real data of 140 projects, it estimated project cost and duration based on historical data. The results of the model could be used to validate the schedule critical path time and project budget in the planning phase. Customized multiple regression models were developed for each project type to obtain statistically reliable results. In conclusion, at a probability of 95%, the proposed model predicted the project cost and duration with a precision of ±0.035% of the mean cost and time.

Odabaşi (2009) conducted a study on estimating construction duration based on many factors, such as: cost, location, site characteristics, procurement methods, area of construction, footprint of the building and its height, etc. Simple Linear Regression (SLR) and Multiple Linear Regression (MLR) analyses were conducted by investigating the influencing factors, using data from seven case study buildings, to predict the construction duration of a project. The confidence in estimation of the regression analyses was investigated, and finally an MLR model was obtained which was based on two parameters: the area of the building, and the area of its front. As a conclusion and contrasting to previous studies, no significant effect was noticed for the cost on project duration.

Karanci (2010) conducted a study on conceptual (early) range cost estimations of mass housing projects. Combinations of regression analysis, neural networks, case – based reasoning and bootstrap method were used using 41 bid offers of mass housing projects. Results of the three different

approaches were compared for predictive accuracy and predictive variability, and suggestions for early range cost estimation of construction projects were made.

In 2016 a statistical model was developed by Samarghandi et al. (2016) to quantitatively determine each delay factor's importance in construction project management. The statistical model categorized the delay factors under four major classes and determined the most significant delay factors in each class: owner defects; contractor defects; consultant defects; and law, regulation and other general defects. The regression models established significant differences between the initial and final project duration and cost. According to the models, the average delay per year was 5.9 months and the overall cost overrun was 15.4%. These findings could help in determining the core causes in construction delay, and could assist project managers and companies in revising initial timelines and estimated costs.

In 2017 a model was developed by Renuka et al. (2017) to estimate the expected percentage of the time overrun for a particular construction project during the planning stage, which could be highly useful in taking the necessary action to minimize the delay and to complete the construction project on time and within budget. Six major groups causing projects time delay were identified from literature survey and opinions from the experts in construction sectors. A questionnaire was answered by project managers by asking them to fill the percentage of delay for each group related issues and the overall delay duration of the construction projects. Thereafter, a regression model was used to analyze the collected data, and the results of the model were used to study the relationship between the percentage of delay and the major group related issues that causes delay.

2.6 Chapter Summary

Payment has been described as a very important element in the construction industry which can be hugely affected by delay risk. Payment delay results in accumulated problems through the construction pyramid starting from the owner and all the way to contractors and sub-contractors. After reviewing various studies in this chapter; the causes and effects of payment delay issue in construction projects were identified and discussed. Moreover, types of models and the different applications of neural network Modeling and regression Modeling in construction projects management were reviewed. The study referred to many previous researches that underlined the problem of payment delay encountered in different engineering fields from different countries worldwide. It was found that most of the previous researches did not include Modeling of payment delay and mainly discussed and identified the causes and effects of this issue. Furthermore, no research was found to study the payment delay in Kingdom of Bahrain and precisely in governmental building construction projects. Therefore, this study is aimed to identify the causes and effects of payment delay in governmental construction projects in Bahrain and to model the delay in payment based on real case studies in this field.

CHAPTER 3
MoW Payment Practices

3.1 Introduction
3.2 Ministry of Works Payment Clauses
3.3 Payment Approval Processes in MoW
3.4 Additional Payment (Variation) Approval Process
3.5 Remedies (Interest) on Overdue Payment
3.6 Chapter Summary

Chapter 3
MoW Payment Practices

3.1 Introduction

MoW conditions of contract followed by Construction Project Directorate (CPD) is normally based on the Joint Contracts Tribunal (JCT) "Standard Form" edition 1963, revision of July 1977. The contract reflects the legal and regulatory requirements of Kingdom of Bahrain, and the laws of Bahrain are the proper laws of the contract.

3.2 Ministry of Works Payment Clauses

The method of payment in CPD projects are mostly a lump sum payment method. Reference to Clause 60 of MoW's condition of contracts, there are three types of payment which are: Advanced payment, Interim payment and Final payment:

a) Advanced payment: reference to Clause 60.1 from MoW condition of contracts "If provision is made in the appendix to tender for an advanced payment, an application by the contractor may be submitted to the engineer for an advanced payment certificate and the engineer shall issue to the contractor the certificate within 14 days after receiving such application". CPD funded projects are the one mostly having advanced payments and the contractor repays that advanced payment by installment from amounts included within interim certificate with a percentage of 10% in each interim payment (MoW Condition of Contracts, 2014).
b) Interim Payment: reference to Clause 60.2 and 60.3 the contractor submits a payment notice at the end of each month to MoW engineer showing the estimated value for the works executed, a list of materials

delivered to the site, and any other amount the contractor is entitled under the term of contract with all the deduction to be made with respect to any advanced payment. The date for the interim payment certification shall be within 14 days from the date of submission of payment notice by the contractor, Final date for payment is the date the payment actually has to be made, and the employer shall pay to the contractor within 42 days after the certification of any payment. (MoW Condition of Contracts, 2014)

c) Final payment: After the date of taking over certificate the contractor shall submit to the engineer statement of the final account within the specified period in appendix to tender. The final statement must contain the contract sum, as adjusted, less the sums already paid to the contractor. Final amount is evaluated with all claims and variations etc. If the contractor did not submit the final statement within the period specified in appendix to tender (expiry of period of submission), the engineer shall issue to employer and contractor a final certificate stating the balanced amount (with excluding any retention money) final account statement which is to be signed by the contractor. Such balance shall be paid within 42 days after such certificate has been delivered to the employer and contractor. (MoW Condition of Contracts, 2014)

3.3 Payment Approval Processes in MoW

Payment certificate is issued for the approval of advanced, interim and final payment, but in case of additional payment (variation) a different process is implemented for the approval of variations prior to the approval of payment certificate as a last step which will be further discussed later. CPD is designing and constructing two types of projects as shown in Figure (3-1) the first type is the projects funded by kingdom of Bahrain government, where the payment certificates issuance for these projects

follows the process starting from step (1) to step (6) as shown in Figure (3-2). The process starts by: 1) receiving the monthly valuation from the contractor, 2) evaluating the valuation by Cost Engineering Directorate (CED), 3) certifying the valuation by CPD, 4) forwarding payment certificate to Finance Resources Directorate (FRD), 5) sending certificate to Ministry of Finance (MoF), and finally 6) issuing cheque by MoF to the contractor.

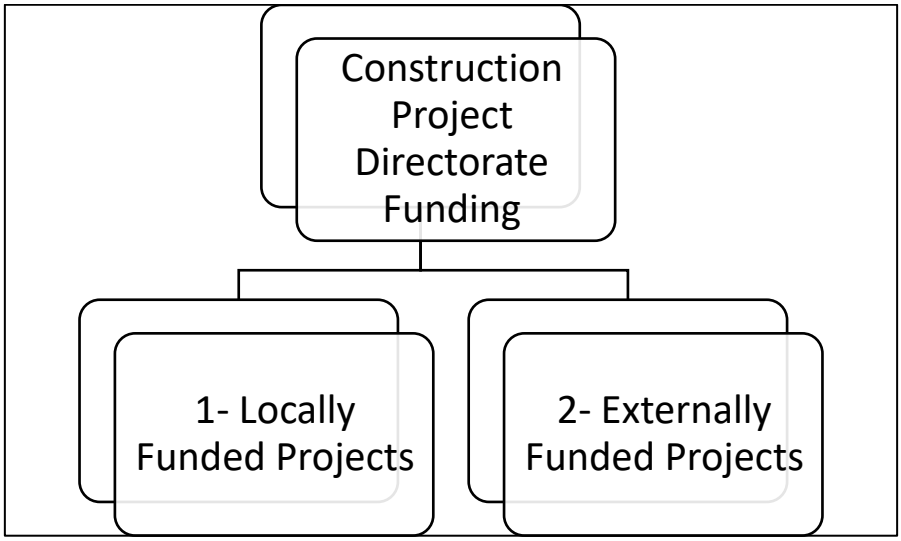


Figure 3-1 Types of Funding in CPD

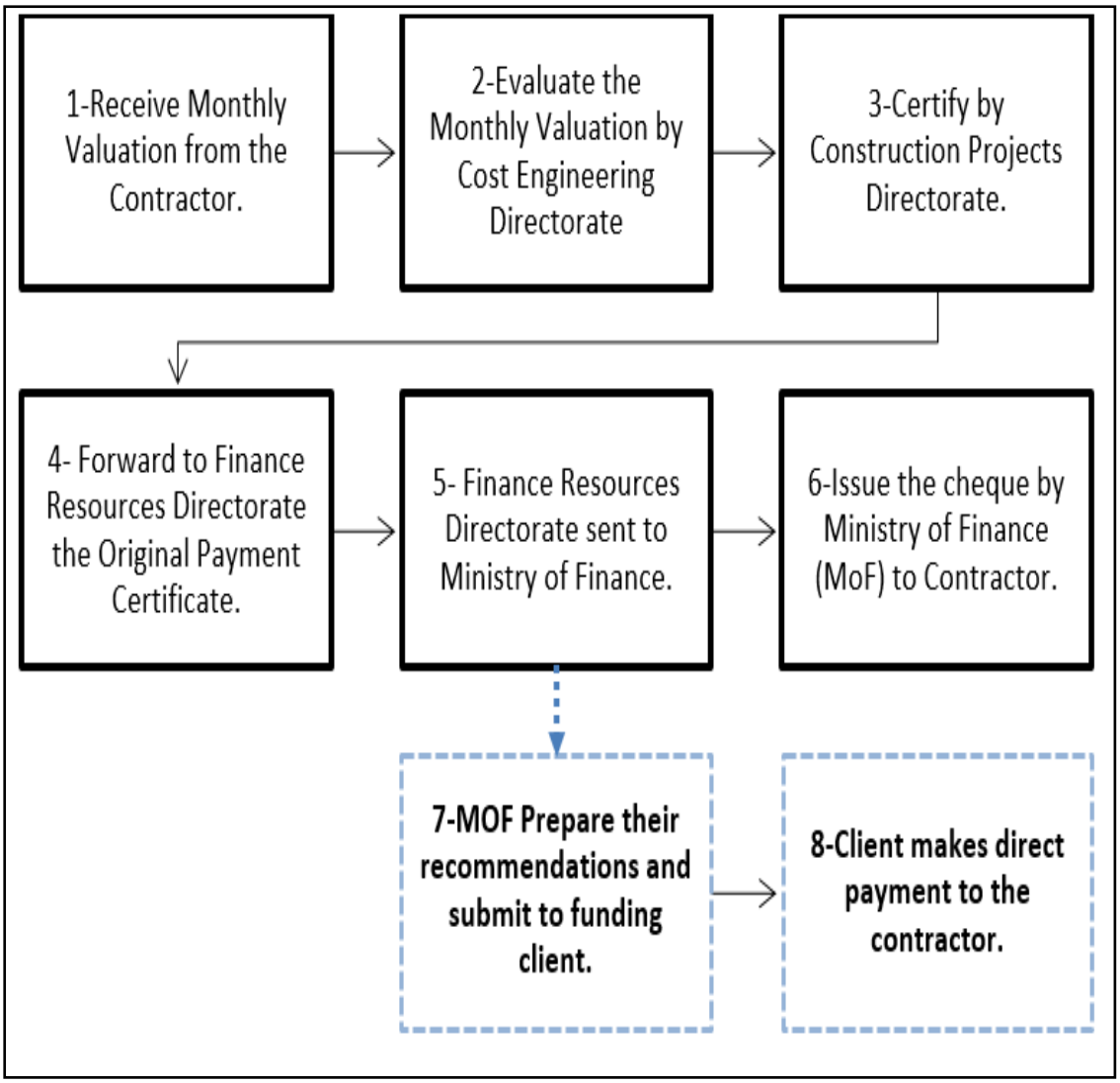


Figure 3-2 Interim Payments Approval

The second type is the Projects that are under MoW (design and constructions) but are financially sponsored by other entities that can be from outside of Bahrain. The Payment process for these funded projects is following the same previous process as shown in Figure (3-2) excluding step (6) and moving directly to step (7) where MoF Prepares their recommendations and submit it to the sponsoring client and finally step (8) where client makes direct payment to the contractor. Funded projects may face a higher risk for late payment because of their longer process.

3.4 Additional Payment (Variation) Approval Process

In accordance to JCT conditions of contract Clauses no.23, 24, 33 and 34 "The contractor must send once every month an account giving detailed particulars of all claims and stating any additional payment to which the contractor may consider itself entitled. Whenever the contractor wishes to make a claim, which would bring about an increase in the contract sum, he shall notify CPD in writing within a reasonable time from the time of occurrence of the event giving rise to such claim. Job Supervisor studies and prepares a report on the validity of such claim in consultation with CED for MoF and National Economy review and approval".

Reference to Clause 51.6 from MoW condition of contracts, in case of sufficiently urgent variation that might result in a delay in the project time table (schedule) or for any other reasons, the contractor is instructed to proceed with variation and it is to be valued and approved after implementation, in this case the delay of the variation request approval might affect the cash flow of the contractor and cause many consequences. Reference to Clause 51.4 and Clause 53.1 of Condition of Contract, the process of variation approval for projects funded by government of Bahrain upon receiving of any changes by client or design section during construction period is shown in Figure (3-3).

The variation process includes 2 stages, the first stage from step (1) to step (8) and second stage includes 2 steps. The first stage starts, when a change is done by the client or the design section during construction period, by: 1) studying the request by the job supervisor and coordinating with design in order to issue revised drawing along with all details, 2) sending the same to (CED) for cost evaluation, 3) ensure if funds are available for this request, 4) evaluate time implication for these changes, 5) after the acceptance of step 3 and 4 a site instruction is issued to the

contractor in order to submit their variation, 6) contractors submit their detail variation to CPD, 7) CPD evaluates the variation and send a control form to CED for financial evaluation, 8) CED carries out the financial evaluation and submits back to CPD for their approval. The second stage is for the payment certification and includes the following steps: 1) the contractors includes the approved variations in their monthly statement based on the progress of work, 2) CED conducts joint evaluation with the contractor and CPD and advice the contractor to include it in the interim payment certification.

The process of variation approval for projects financially sponsored by other entities is shown in Figure (3-4). The process includes 3 stages, the first stage includes 4 steps, second stage includes 6 steps, and third stage includes 2 steps. The first stage is implemented to obtain the prior approval from the external funding entity and starts by the following: 1) CPD prepares detailed description of works and providing technical justification and issue it to the contractor for estimation purpose, 2) Contractor submits his time and cost estimate to CPD, 3) CPD submits its estimates to the external funding entity for prior approval, 4) Obtain the external funding entity approval.

The second stage is for the purpose of formalizing the variations by the following steps: 1) After obtaining prior approval, CPD issues site instruction to the contractor to proceed with the variation, 2) Contractor submits his detailed variation statement to CPD, 3) CPD evaluates the contractor's variation and send it through control form to CED for financial evaluation, 4) CED carries out the financial evaluation and submits back to CPD for their approval, 5) CPD approves and submits to the external funding entity for their final approval, 6) Upon final approval CPD advises the contractor to include the variations in their monthly statements.

The third stage is for the certification of payments and includes two steps which are: 1) The contractor includes the approved variations in his monthly statement based on the progress of work, 2) CED conducts joint evaluation with the contractor and CPD and advice the contractor to include it in the interim payment certification.

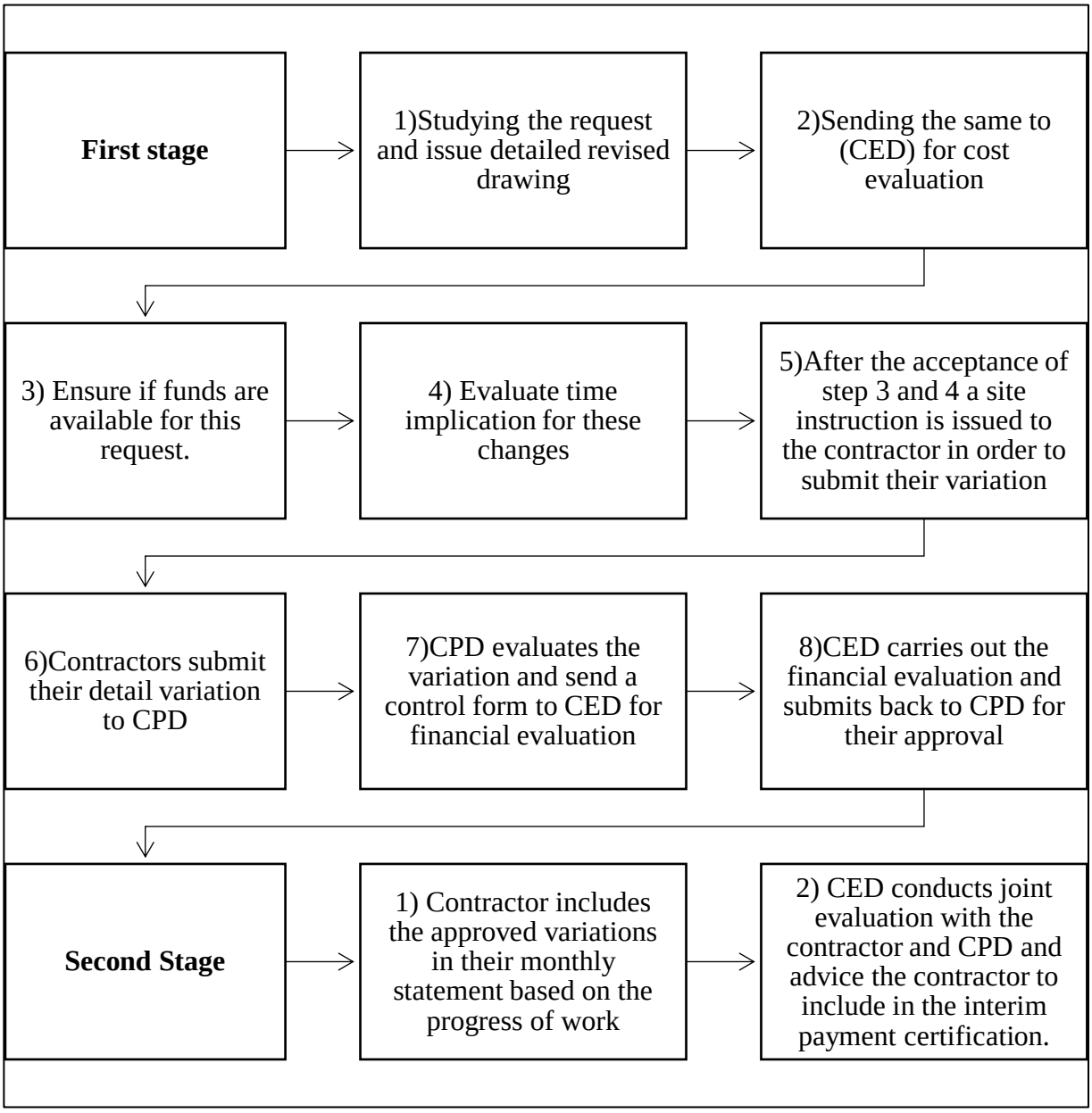


Figure 3-3 Variation Payment Approval for Locally Funded Projects

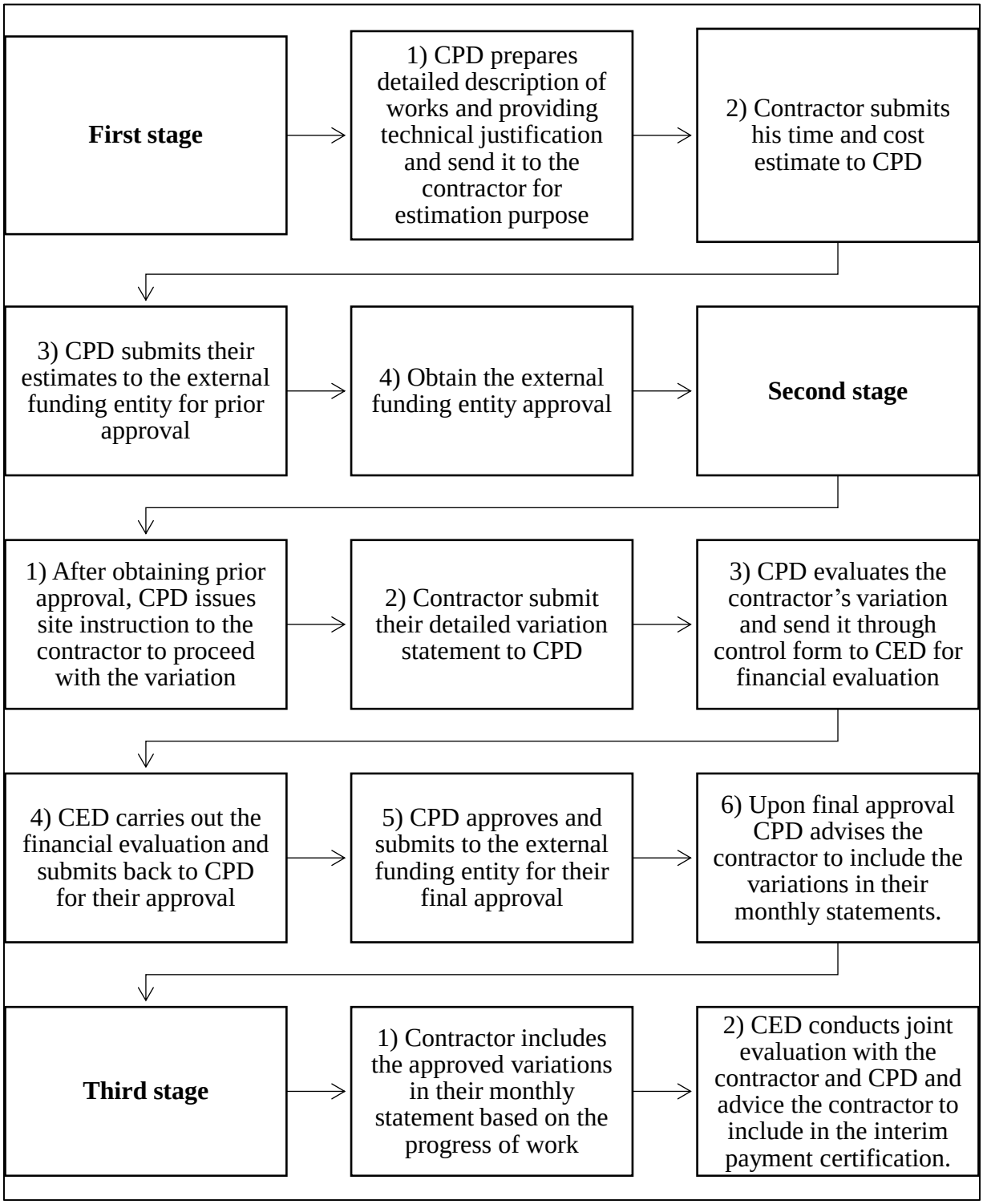


Figure 3-4 Variation Approval for Externally Sponsored Projects

3.5 Remedies (Interest) on Overdue Payment

Reference to Clause 14.7 as per FIDIC (The International Federation of Consulting Engineers) condition 1999 "If the contractor does not receive payment in accordance with Sub-Clause 14.7 [Payment], the contractor shall be entitled to receive financing charges compounded monthly on the amount unpaid during the period of delay. This period shall be deemed to commence on the date for payment specified in Sub-Clause 14.7 [Payment]" (Berger, 2017). Reference to Clause 14.14 JCT05 "Failure of the employer to pay the amount properly due pursuant to a certificate entitles the contractor to terminate his own employment" (Ndekugri and Rycroft, 2009). Reference to (MoW Condition of Contract, 2014) Clause 60.7, "the employer shall pay the contractor interest upon any overdue payment at the rate stated in the appendix of tender from the latest date when the payment should have been made". In Kingdom of Bahrain's civil law interest is considered to be contrary to the Islamic sharia's and any obligation to pay interest is void in any dispute, based on that rate of interest on overdue payment is considered to be 0% in the tender document appendix.

3.6 Chapter Summery

This chapter describes the payment practices in MoW including payment clauses, payment types, approval process, and finally the remedy for overdue payments in building governmental projects were identified and discussed. The payment clauses and approval process will be used for the assessment of the payment case studies used for the development of the models.

CHAPTER 4
Research Methodology

4.1 Introduction
4.2 Data Collection and Questionnaire Design
4.3 Questionnaire Distribution
4.4 Data Measurement
4.5 Data Analysis
4.6 Development of the Models
4.7 Chapter Summary

Chapter 4
Research Methodology

4.1 Introduction

The study is conducted in Kingdom of Bahrain. It addresses the issue of payment delay in governmental projects based on case studies of MoW. The methodology determines the most appropriate methods used for the study based on its objectives, resources and limitations. This chapter comprises the techniques undertaken to collect data, conduct analysis, and develop predictive payment models.

4.2 Data Collection and Questionnaire Design

The factors and consequences of late payment and the possible solutions to mitigate payment problems were identified through interviews targeting the experienced engineers, historical data of previous projects, and previous literature studies. The questionnaire covered both the causes and effects of late payment that had been identified above and the suggested solution based on the perspective of the concerned parties. The questionnaire results were ranked thereafter based on how frequent it occurred. The questionnaire results were analyzed accordingly using appropriate analysis techniques and statistical methods. The questionnaire was distributed to both CPD Engineers and the contractors working for MoW. The questionnaire was designed in four sections: Section A, Section B, Section C and Section D. The distributed questionnaire is shown in Appendix (1).

Section A: General information

This section was used to obtain the information about the respondents. The section included the following:

1. The respondent place of work.
2. The respondent age.
3. The respondent profession background.
4. The number of years of working experience for the respondent in the construction industry.
5. The respondent's number of projects accomplished.
6. The respondent experience with payment delay issue in building construction of governmental projects.

Section B: Factors contributing to payment delay

This section was used to obtain the factors (causes) of payment delay in Bahrain's governmental construction projects. The targeted parties were asked to rank the factors based on how frequent it occurs according to their opinions and their working experience. This section was grouped into four major subsections, which are: Owner related factors (other governmental ministries), Consultant related factors, Contractor related factors; and others. The questionnaire was mainly based on a format of five-level Likert's scale.

Section C: Consequences and effects of payment delay

This section was used to obtain the consequences of payment delay on governmental construction projects. The targeted parties were asked to rank the consequences based on how frequent it occurred according to their opinions and their working experience. This section was grouped into two major subsections which are: Consultant and project characteristics related consequences; and Contractor related consequences. The questionnaire was mainly based on a format of five-level Likert's scale.

Section D: Effective solutions to payment delay

This section was used to obtain the effective solutions that were suggested by the industry experts through several interviews. These possible solutions were expected to mitigate the payment delay problem in the governmental building construction projects. The questionnaire was mainly based on Likert's scale of five ordinal measures from one (1) to five (5) according to level of effectiveness.

Pilot study was conducted by presenting the survey to some of the industry experts and targeted respondents for identifying technical errors and the content validity prior of the survey distribution. This was essential to assure that the question's formulation satisfying the objective of the study, and understood by the respondents. Reference to Conelly (2008), pilot study sample should be 10% of the sample projected for the study, a pilot study was conducted with 10 employees from MoW and contracting companies with different positions such as: project manager, site engineer and quantity surveyor engineer. The pilot study respondents agreed that the questionnaire was appropriate to achieve the study objective with some minor modifications.

4.3 Questionnaire Distribution

The questionnaire was distributed to the respondents through email, social media, and personal meetings. The targeted groups in this study were contractors working with MoW building construction projects and MoW engineers. According to MoW approved contractors list, there were 49 contracting companies classified as (A and B) classes. Also, according to MoW engineers list, there were about 62 engineers working in building construction sector. The owners were other governmental ministries. Israel

(1992) showed that the sample size can be calculated for 95% confidence level using the following equation:

$$n.=. \quad \frac{n°}{1+\frac{n°-1}{N}} \tag{4-1}$$

Where n and n° are the sample sizes for finite and infinite population, respectively, and N is the population size. The sample size for infinite population can be adjusted using Equation (4-2) developed by Cochran (1963) for populations that are large to yield a representative sample for proportions:

$$n° = \quad \frac{z^2 \rho q}{e^2} \tag{4-2}$$

Where z^2 is the abscissa of the normal curve that cuts off an area α at the tails (1 - α equals the desired confidence level), to achieve a confidence level of 95% z = 1.96 from statistical tables, e is the desired level of precision, p is the estimated proportion of an attribute that is present in the population, and q is 1-p.

To calculate the sample size from infinite population (assuming p = 0.5 maximum variability, e = ±5%), with 95% confidence level: -

$$n° = \frac{z^2 \rho q}{e^2} = \frac{1.96^2(0.5)(1-0.5)}{0.05^2} = 385$$

On that basis, for 49 contracting companies classified as (A and B) classes:

$$n = \frac{n°}{1+\frac{n°-1}{N}} = \frac{385}{1+\frac{385-1}{49}} = 46$$

This indicates that the questionnaire should be distributed to 46 contractor companies, namely 46 engineers representing these companies, in order to achieve 95% confidence level.

For 62 engineers (consultant) working in building construction sector:

$$n = \frac{n°}{1 + \frac{n° - 1}{N}} = \frac{385}{1 + \frac{385 - 1}{62}} = 54$$

This indicates that the questionnaire should be distributed to 54 consultant engineers in order to achieve 95% confidence level.

According to the results of sample sizes mentioned above, 111 questionnaires were distributed as follows: 62 to (MoW) consultant engineers and 49 to contractor engineers. One hundred and four (response rate of 80.71%) questionnaires were received as follows: 58 (55.77%) from consultants and 46 (44.23%) from contractors.

4.4 Data Measurement

In this research, a format of five-level frequency Likert scale was used for the ranking of the factors and consequences of late payment shown in the questionnaire Sections (B) and (C) in Appendix 1. The ordinal Likert scale categories were: always, often, sometimes, rare and never. Whereas, for Section (D) an interval Likert scale was used to address the effectiveness of the suggested solution to the payment delay ranging from 1 to 5 as shown in Table (4-1) below:

Table 4-1 Five-Level Frequency Likert Scale

Rate of scale	1	2	3	4	5
Classification	Very low effectiveness	Low effectiveness	Moderate effectiveness	High effectiveness	Very high effectiveness

4.5 Data Analysis

The procedure used in analysis of data was aimed at examining each factor contribution to payment delay by using the relative importance index (RII) shown in Equation (4-3). Thereafter, the factors were ranked to determine the important ones.

$$\text{RII}= \quad \frac{n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{5 * (n_1 + n_2 + n_3 + n_4 + n_5)} \quad \times 100 \qquad (4\text{-}3)$$

Where $n_1,\ n_2,\ n_3,\ n_4, and\ n_5$ are the number of respondents who scored 1, 2, 3, 4, 5, respectively; score (1) is less frequent or very low effectiveness and (5) is highest frequent or very high effectiveness.

For Section (D) since an interval Likert scale of (5) levels was used, there were five intervals each had a length of $\frac{5-1}{5} = 0.8$. The ranges of the intervals are shown in Table (4-2).

Table 4-2 Ranges of the Intervals for Likert Scale

1-1.79	1.80 to 2.59	2.60 to 3.39	3.40 to 4.19	4.20 to 5.00
Very low	Low	Medium	High	Very high

As shown in Table (4-2), factors scoring a mean of 3.4 or above were considered as high, and those with a score of 4.2 and above were considered as very high. The mean of the data for each factor was calculated using Equation (4-4). To achieve the research goal, Microsoft Excel program was used for calculating and analyzing the data.

$$\text{Mean} = \quad \frac{n_1 + 2n_2 + 3n_3 + 4n_4 + 5n_5}{(n_1 + n_2 + n_3 + n_4 + n_5)} \qquad (4\text{-}4)$$

4.6 Development of the Model

Development of the models were achieved through the following steps:

1- Once the significant factors are identified from the distributed questionnaire, the input factors for the models are identified according to the availability of data and compatibility with construction project directorate (CPD) cases.
2- The input data for the significant factors are collected from CPD real case studies and is used for the model's development as independent variables (Input) to predict the dependent variable (Output), which is the payment delay (days).
3- Models verification is carried out using some of the collected data.

These models support the study by predicting the payment delay for governmental building construction projects, and give a better understanding for the actual duration needed for a payment to be approved and actually received from the employer. This increases the attention to risk in order to overcome the payment delay when encountered without affecting the contractors, consultant or the progress of the project.

4.7 Chapter Summary

This chapter describes the methodology implemented in this study starting from the literature review and all the way to the design of the models. This methodology achieves the earlier mentioned study objectives, explains the way of data collection, data analysis, model design and evaluation, hence, to achieve the best prediction of delay (days) for the two types of payment delay in building governmental projects.

CHAPTER 5
Results and Analysis of Survey Collected Data

5.1 Introduction
5.2 General Information
5.3 Factors Causing Payment Delay
5.4 Consequences of Payment Delays
5.5 Effectiveness of Suggested Solutions to the Payment Delay
5.6 Chapter Summary

Chapter 5
Results and Analysis of Survey Collected Data

5.1 Introduction

This chapter presents the results of the study questionnaire collected from (104) respondents working in building construction engineering field in both governmental and private sectors. The collected results of questionnaire are shown in Appendix (2).

5.2 General Information

This section includes general information about the respondents in terms of place of work, respondent's age, respondents educational background, respondents years of experience, number of construction projects that the respondent has participated in, the participants opinion of the payment delay problem in building construction projects in kingdom of Bahrain.

5.2.1 Place of work

Table (5-1) shows the percentages and the number of respondents from MoW (consultant) and contracting companies, where the response percentage of consultant is (55.77%) of the sample size, while that of the contractors is (44.23%). This means that the majority of respondents are from consultant who represents MoW. The total number of responses is 104 engineers from both consultant and contractors.

Table 5-1 Place of Work

Place of work	No of Responses	Percentage of responses
Ministry of Works	58	55.77%
Contracting companies	46	44.23%
Total	104	100%

5.2.2 Participant's age

Table (5-2) shows the age distribution of the sample. The range of 25-30 years age shows the largest number of responses (29 responses), in the second place comes the range of 36 to 40 years old with 28 responses, then comes the range of 46 and above years old with 21 responses. Finally, the ranges between 31 to 35 years and 41 to 45 years, with 18 and 8 respondents, respectively. The sample of respondents is quite well spread, and combines the opinion of experienced engineers in the field and youth engineer's opinion.

Table 5-2 Participant's Age

Age range	No of responses	Percentage (%)
(25-30)	29	27.88
(31-35)	18	17.31
(36-40)	28	26.92
(41-45)	8	7.69
(46 and above)	21	20.19
Total	104	100

5.2.3 Participant's professional background

Table (5-3) shows the number of responses and percentage of each profession for both consultant and contracting companies. The response percentages for Civil, Architectural, Quantity Survey, Electrical, Mechanical, and others, are 72.12%, 6.73%, 11.54%, 5.77%, 2.88% and 0.96%, respectively. As realized, more than 90% of the respondents have professional background in civil, architectural, and quantity survey engineering. The important roles of these three professions in the payment procedure insure the high quality of the results.

Table 5-3 Participant's Professional Background

Professional background	No of responses	Percentage (%)
Civil Engineering	35	72.12
Architectural Engineering	45	6.73
Quantity Survey Engineering	11	11.54
Electrical Engineering	9	5.77
Mechanical Engineering	3	2.88
Others	1	0.96
Total	104	100

5.2.4 Participant's work experience

Table (5-4) shows the number of responses and percentages versus range of work experience (years) in building construction sector. The responses show highest percentages are in the ranges of "3 - 7 years", "8 – 11 years" and "12– 15 years" work experience with 27.9%, 17.3%, and 21.2%, respectively. The table shows more than 70% of respondents have work experience of more the 7 years, out of whom about 33% with experience of more than 15 years. These percentages of long experience give confidence on the collected results.

Table 5-4 Participant's Total Work Experience (years)

Total Work Experience	No of responses	Percentage (%)
3-7	29	27.9
8-11	18	17.3
12-15	22	21.2
16-19	6	5.8
20-23	10	9.6
24-27	9	8.7
28-31	4	3.8
32 and above	6	5.8
Total	104	100

5.2.5 Participant's accomplished number of projects

Table (5-5) shows the number of responses and percentages versus range of projects accomplished. The response percentages for "5 – 10", "10 – 20", "20 – 30", "30 - 40", "40 - 50", and "50 and more projects" are 28.16%, 55.34%, 7.77%, 7.77%, 1.94% and 28.16%, respectively. The fact that more than (71.4%) of the participants have accomplished more than 10 building construction projects will be reflected in the level of reliability and accuracy of the provided information.

Table 5-5 Participant's Accomplished Number of Projects

Number of completed projects	No. of responses	Percentage (%)
5-10	29	28.16
10-20	57	55.34
20-30	8	7.77
30-40	8	7.77
40-50	2	1.94
50 and more	29	28.16
Total	104	100

5.2.6 Participant's opinions on payment delay problem

Table (5-6) shows the participant's opinion on whether the payment delay problem of the building construction projects is an issue worth to be investigated or not. The response percentages are: for " Strongly Agree " is (28.16%), for " Agree " is (55.34%), for " Unsure/Uncertain " is (7.77%), for " Disagree " is (7.77%), and for " Strongly Disagree " is (0.97%) of the sample size. It's concluded that most participant's opinions consider payment delay as an issue in building construction projects that should be investigated.

Table 5-6 Participant's Opinions on the Payment Delay Problem

Is payment delay an issue in Bahrain public building construction projects?	No. of responses	Percentage (%)
Strongly Agree	29	28.16%
Agree	57	55.34%
Unsure/Uncertain	8	7.77%
Disagree	8	7.77%
Strongly Disagree	1	0.97%
Total	103	100.00%

5.3 Factors Causing Payment Delay

The factors of late payment were identified through interviews with experienced engineers, historical data of previous governmental projects and previous literature studies. Thirty-five factors were chosen for the questionnaire design. The factors are grouped into four groups: Owner related factors (five factors); Consultant related factors (twelve factors); Contractor related factors (fifteen factors); and Other factors (three factors). The relative importance indices (RII) of factors were calculated using Equation (4-3). The factors were then ranked as per consultant and contractor's perspective as shown in Table (5-7).

Table 5-7 The Relative Importance Indices and Ranks of Factors Causing Payment Delay

No	Factors	Contactors perspective		Consultant perspective	
		Relative Index (%)	Rank	Relative Index (%)	Rank
	(1) Owner related factors				
1	Changes in scope	74.35	1	78.28	1
2	Long and bureaucratic process	72.61	3	75.17	3
3	Unavailability of funds	58.26	14	62.07	28
4	Refusal to pay for materials stored on job site	45.65	34	62.41	35
5	Refusal to pay interest on late payment	65.22	8	57.59	33
Average		**63.218**		**67.104**	
	(2) Consultant related factors				
1	Delay in claim review and evaluation process	71.30	4	66.21	21
2	Delay in issuance of payment certificate Process	65.22	7	58.97	31
3	Slow processing of variations orders	70.43	5	69.66	16
4	Excess work load on the consultant employees	48.70	29	66.90	24
5	Consultant's experience (years)	56.09	18	72.41	29
6	Delays of required documentation needed to fulfill payments	56.52	16	72.07	10

7	Bureaucracy or wrong channels of communication	47.83	32	65.52	27
8	Slow processing of final accounts	70.00	6	70.00	15
9	Lack of periodical meetings to address payment problems	56.52	17	66.55	20
10	Lack of decision making during construction	63.04	9	68.97	17
11	Delay in extension of time approval	72.61	2	73.45	6
12	Inaccurate bill of quantities	60.87	11	64.48	23
Average		**61.59**		**67.93**	
(3) Contractors related factors					
1	Submission of claims with calculation mistakes.	54.78	20	72.41	7
2	Delay in the submission of payment evaluation (Claim)	51.74	26	67.59	5
3	Contractor’s experience with governmental projects (years)	54.78	21	72.41	8
4	Incomplete documents for variation claims	56.96	15	76.21	2
5	Delay in progress of works and activities	43.45	35	75.15	4
6	Failure to understand the contract agreement	48.26	30	64.14	13
7	Inability to follow certain procedures of MoW	50.87	27	64.14	11
8	Failure to do work based on bill of quantity	48.26	31	70.34	22

9	Inaccuracy of payment scheduling program	52.61	24	70.34	18
10	Inappropriate implementation of projects program	60.87	10	72.41	9
11	Duplication of work	55.22	19	57.59	34
12	Inappropriate project team	51.74	25	73.79	25
13	Inattention of risk	46.96	33	62.41	28
14	Inaccuracy of estimation	53.91	23	70.69	14
15	Inadequate Financial resource	50.00	28	71.03	19
Average		**52.03**		**69.38**	
(4) Others related factors					
1	Delay in MoF process	54.35	22	75.17	12
2	Rules and regulations changes	60.43	12	57.24	34
3	Economic changes	60.00	13	60.34	30
Average		**58.26**		**64.25**	

Table (5-8) displays the relative indices and ranks of the factors as per their related groups that contribute to the occurrence of payment delay issue in construction projects. As shown in the table the factors related to contractor has the highest relative index (RII) of 69.38% as per consultant perspective, while the group of owner related factors have the highest RII of 63.218% as per contractor's perspective. These results reflect the disagreement between the different parties of respondents who responded to the survey. Each party is holding the responsibility of payment delay to the other parties in the construction pyramid. The group of contractor's related factors has the highest RII% as per consultant's perspective and the highest number of factors causing payment delay. These results indicate that the contractor factors group has a very major role in the payment delay

issue, and by rectifying the factors related to this group the payment delay may be reduced effectively.

Table 5-8 Factors of Payment Delay Related Groups

Factors Related	Contactors perspective		Consultant perspective	
	Average Relative Index (%)	Rank	Average Relative Index (%)	Rank
1- Owner related factors	63.218	1	67.104	3
2- Consultant related factors	61.59	2	67.93	2
3- Contractor related factors	52.03	4	69.38	1
4- Other factors	58.26	3	64.25	4

In the following subsections the factors of Table (5-7) and their evaluations by contractors and consultants will be discussed and analyzed.

5.3.1 Owner related factors (other Ministries)

1- Changes in Scope of work: Table (5-7) shows that the rank of "Changes in scope of work" by the owner comes in the first position with RII of 74.35% and 78.28% from contractor and consultant perspectives, respectively. Changes in scope of work mostly occurs by the client and in some cases by the design section during construction stage, for example: the case of requesting an additional floor by the client for an office building during the construction stage, which requires new design, revision and may results in extension of time, variations orders, slows down the progress of work and eventually results in payments delay. As shown in Figure (5-1) the long processes of the variation

orders and the extension of time approval may result in delaying the payment, these processes will be discussed further as they turn to be two of the highest occurring factors according to the survey analysis.

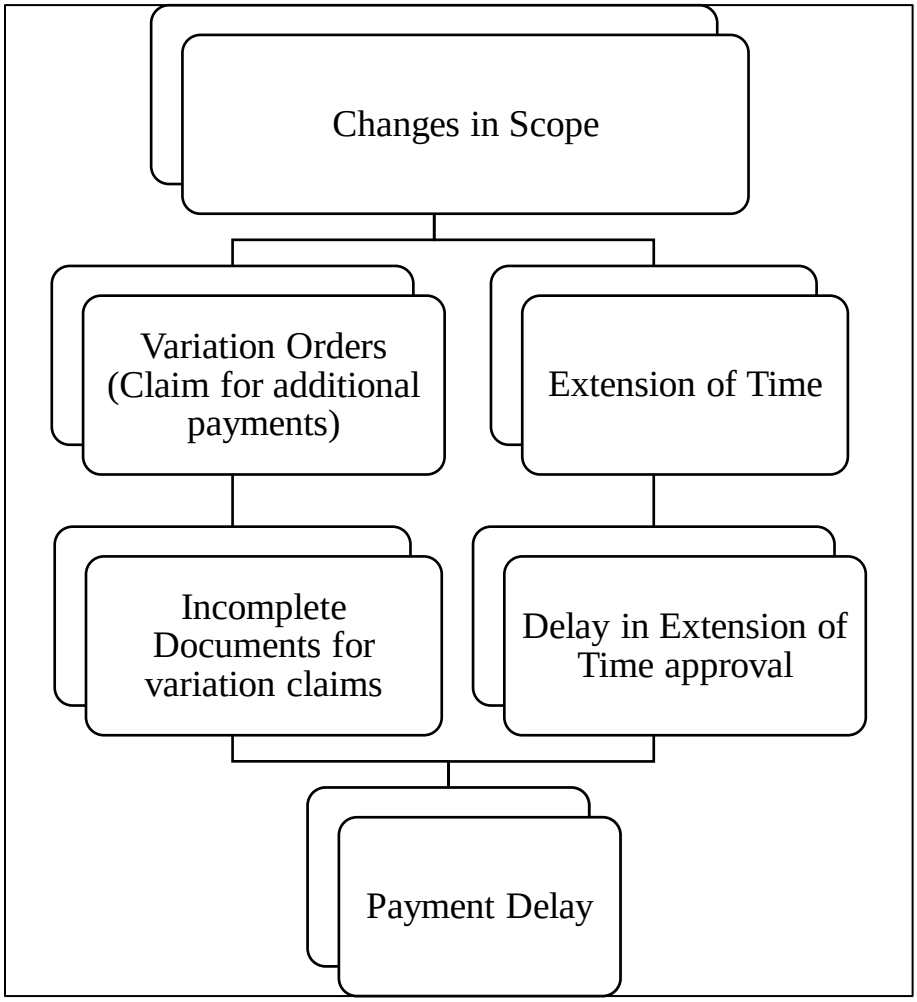


Figure 5-1 Changes in Scope of Work

2- Long and bureaucratic process in governmental departments: The common view of the functioning in the governmental departments is mostly the idea of a bureaucratic and long processes functioning. The survey results are RII of 72.61% from the contractor's group perspective and RII of 75.17% from the consultant's group perspective, which ranks this factor at the third place for these groups. However, in this study it will be unfair to conclude that this is the system of work in

all governmental departments where some of the cases reflect excellent work performance and fast response.

3- Unavailability of funds: The table shows that the contractors and consultants rank this factor at the 14th and 28th positions, with RII of 58.26 % and 62.07%, respectively. The fund for the governmental projects is allocated from the governmental budget or in some cases from funding sources; the tenders for projects are not requested prior to the confirmation of the budget availability. It is therefore unlikely for the funds to be unavailable during the execution of the projects, unlike some of the private projects cases.

4- Refusal to pay for materials stored on job site: The responses show that this issue is not faced with the owner in building governmental projects, because the materials on the site are paid for as per the governmental processes and regulations. The contractors and consultants rank this factor at the 34th and 35th positions, with RII of 45.65% and 62.41%, respectively.

5- Refusal to pay interest on late payment: This factor is ranked at the 8th position by the contractors group while ranked at the 33rd position by the consultants with RII of 65.22% and 57.59%, respectively. This result shows the huge difference in opinion between the two groups where the contractors consider the interest a compensation for their delayed payments while most of the consultants responses are based on Kingdom of Bahrain's civil law, which stipulates that interest is violating to the Islamic sharia's and any obligation to pay interest is void in any dispute.

5.3.2 Consultant related factors (MoW)

1- Delay in claim review and evaluation process: "Delay in claim review and evaluation process" is ranked from contractor's perspective in 4th position with RII of 71.30%, and from consultants perspective in 21st position with RII of 66.21%. Whenever the contractor wishes to make a claim, which would bring about an increase in the contract sum, he should notify CPD in writing within a reasonable time from the occurrence of the event. Job Supervisor studies and prepares a report on the validity of such claim in consultation with CED for the review and approval of MoF. Any delay in claim review and approval may eventually results in a payment delay for the variation payment.

2- Delay in issuance of payment certificate process: Projects which are funded by government or by any other entities are subjected to the same clauses of MoW condition of contract. As discussed earlier, any valuation submitted by the contractor shall be reviewed, evaluated and issued within 14 days from the date of submittal, and any additional time will be considered as a delay in issuance of payment certificate process. Table (5-7) shows that respondents rank the "delay in issuance of payment certificate process" in the 7th position from contractors perspective, while from the consultant perspective it is ranked in the 31st position where MoW engineers confirms that no delay occurs from their side. The corresponding RIIs are 65.22% and 58.97%, respectively.

3- Slow processing of variation's orders: "Slow processing of variation orders" is ranked at 5th position with RII of 70.43% as per contractor's perspective and at 16th position with RII of 69.66% as per consultant's perspective.

4- Excess work load on the consultant employees: Excess work load on the consultant employees is ranked at 29th position with RII of 48.70% as per contractor's perspective, and at 24th position with RII of 66.90% as per consultant's perspective.

5- Consultant's experience: "Consultant's experience" is ranked from contractor perspective in 18th position with RII of 56.09% and from consultant perspective in 29th position with RII of 72.41%. From the consultant point view "consultant's experience" is not having a very high impact on the payment delay while from the contractors this factor is ranked within the top twenty factors effecting payment delay issue.

6- Delays of documentation required to fulfill payments (site instructions, control forms, material approval forms… etc): This factor is ranked at the 16th position by the contractor's group and at the 10th position by the consultant with RIIS of 56.52% and 72.07%, respectively. This result shows that to some extent both parties agree on the importance of this factor and its effect on payment delay. They see that the delay of these documentations especially the one coming from other departments can have a very high impact in increase of delay. This delay may occur because of miss of communication between sections and departments, because of the work circumstances, or as a result of delay in submittal by the contractor.

7- Bureaucracy or wrong channels of communication: Bureaucracy or wrong channels of communication is ranked at 32nd position with RII of 47.83% as per contractor's perspective and at 27th position with RII of 65.52% as per consultant's perspective.

8- Slow processing of final accounts: "Slow processing of final accounts" is ranked from contractor's perspective in 5th position with RII of 70.43% and from consultant's perspective in 16th position with RII of 69.66%.

9- Lack of periodical meetings to address work and payment problems: The responses show that both parties agree on the high impact of "Less periodical meetings to address work and payment problems" on payment delay issue. It is ranked within the top twenty most affecting factors by taking the 17th and 20th position from the contractors and consultants point of view, respectively. Projects meetings are conducted by MoW on a weekly and monthly basis during which the progress of civil, electrical and mechanical works are monitored, the schedule of materials list is reviewed and any other business involving payment problems, future progress, safety measures, etc. are discussed.

10- Lack of decision making on issues arising during the course of construction: This factor is ranked from contractor perspective in 9th position with RII of 63.04% and from consultant perspective in 17th position with RII of 68.97%. Delay in decision making results in delay in approvals and progress of work which is eventually reflected on payments.

11-Delay in extension of time approval: Table (5-7) shows that the contractor and consultants rank the delay in extension of time approval at the 2nd and 6th positions from the contractors and consultants point of view with RIIs of 72.61% and 73.45%, respectively. Delay in the approval of extension of time occurs because of its long procedure. Reference to Clause 44.1 of MoW condition of contract: Whenever the progress of work is delayed for reasons beyond the contractor's control,

then the contractor shall give a written notice of the causes of the delay and if in the opinion of the Job Supervisor the completion of the works is likely to be or has been delayed beyond the Date of Completion, then the Job Supervisor recommends a fair extension of time for completion of the works (MoW condition of contracts, 2014). The procedure involves completing a set of forms involving all Civil, electrical and mechanical sections, for their comments, justification and approval. On the assessment completion, the Job Supervisor drafts a letter for the extension of time, which is to be signed by the appropriate officer as per the level of authority (Chappell, 2011). Until this process is approved no payment is to be issued to the contractor which may cause cash flow problems, slow down the progress of work and many other consequences that can affect the contractor.

12- Inaccurate bill of quantities: "Inaccurate bill of quantities" is ranked at 11th position with RII of 60.87% as per contractor's perspective and at 23rd position with RII of 64.48% as per Consultant's perspective.

5.3.3 Contractor related factors

1- Submit claims with calculation mistakes: This factor is ranked at 20th position with RII of 54.78% as per contractor's perspective and at 7th position with RII of 72.41% as per consultant's perspective. Submitting claims with calculation mistakes results in doubling the work for both the contractor and the consultant, which it will be rejected and to be resubmitted by the contractor and will eventually result in payment delay.

2- Delay in submitting the payment evaluation by the contractor: This factor is ranked from contractor perspective in 26th position with RII of 51.74% and from consultant perspective in 5th position with RII of

67.59%. From the contractor point of view "Delay in submitting the payment evaluation" is not having a very huge impact on the payment delay while from the consultant point of view, on the other hand, it is ranked within the top five factors affecting payment delay.

3- Contractor’s experience with governmental projects: Both contractors and consultants have almost agreed on the importance of this factor as a high effector on payment delay issue in construction. The factor is ranked at 21st position with RII of 54.78% as per contractor's perspective and at 8th position with RII of 72.41% as per consultant’s perspective. A contractor's experience in governmental projects may assist in a better preplanning for payment program and payments submittals to decrease any submittals delay, also less calculations mistakes, better progress of work and a better implementation of MoW procedures.

4- Incomplete documents for variation’s claims: This factor is ranked at 15th position with RII of 56.96% as per contractor’s perspective and at 2nd position with RII of 76.21% as per consultant’s perspective, which shows that both parties are ranking it within the top twenty factors. Incomplete documents for variation claims will lead to potential payment delay for variation orders.

5- Delay in the progress of works and activities: Progress delay in a construction project is a very important factor that has many effects on the project element's including payments. The delay in projects activities results in a delay on its working programme and therefore it delays the payments programme. This factor is ranked at 35th position with RII of 43.45% as per contractor’s perspective and at 4th position with RII of 75.15% as per consultant’s perspective.

6- Failure to understand the contract agreement: This factor is ranked at 30th position with RII of 48.26% as per contractor's perspective and at 13th position with RII of 64.14% as per consultant's perspective.

7- Inability to follow certain procedures of MoW: It is ranked at 27th position with RII of 50.87% as per contractor's perspective and at 11th position with RII of 64.14% as per consultant's perspective. Ignorance of the contractor of MoW procedures and approval system can lead to delay in the project's activities and the paper works approvals such as claims approvals, variation order approvals which result thereafter in payment delay issues.

8- Failure to do work based on bill of quantity: This factor is ranked at the 31st position by the contractor's group while ranked at the 22nd position by the consultant with RIIs of 48.26% and 70.34%, respectively. Mismanagement of projects activities, unavailability of money or resources causes failure in performing the work based on bill of quantity which leads to slow down the works and causes delays.

9- Inaccuracy of payment scheduling program: It is ranked at 24th position with RII of 52.61% as per contractor's perspective and at 18th position with RII of 70.34% as per consultants perspective. Accuracy of payment scheduling program is very important to assure the proper flow of cash during the project. Planning the payment schedule is the responsibility of the contractor in which any errors or un proper planning can lead to delay in the payments and problems in the project's cash flow.

10- In-appropriate implementation of projects programme: This factor is ranked at 10th position with RII of 60.87% as per contractor's

perspective and at 9th position with RII of 72.41% as per consultant's perspective. Un-appropriate implementation of projects programme especially the critical activity on the critical path causes significant delay in time and in payments and the contractor is held the responsibility.

11- Duplication of work: This factor is ranked at the 19th position by the contractor's group while ranked at the 34th position by the consultant with RIIs of 55.22% and 57.59%, respectively. Low quality of works and improper performance of project's activities result in rejection of work by the consultant during the work inspection, thus rework is needed by the contractor which may lead to delay in the project's programme and payments delay also.

12- Inappropriate project team: It is ranked at 25th position with RII of 51.74% as per contractor's perspective and at 25th position with RII of 73.79% as per consultant's perspective. Inappropriate project team may occur because of incapability of the contractor's staff to perform proper management of project's resources, time management, document management and communication with other parties in the contract. Leading the contractor to undertake the responsibility of the consequences such as payment delay.

13- Inattention of risk: It is ranked at 33rd position with RII of 46.96% as per contractor's perspective and at 28th position with RII of 62.41% as per consultant's perspective. If the risk management is not properly planned and strictly implemented by the contractor, it leads the projects to face significant risk factors such as time delays, cost overrun, payment delay etc.

14- Inaccuracy of estimation: This factor is ranked at the 23rd position by contractor's perspective while ranked at the 14th position by the consultant with RIIs of 53.91% and 70.69%, respectively. Inaccuracy of estimation by the Contractor at the tendering stage may lead to financial difficulties during the construction stage, which may lead eventually to abandon the work and lose his reputation.

15- Inadequate financial resource: It is ranked at 28th position with RII of 50.00% as per contractor's perspective and at 19th position with RII of 71.03% as per consultant's perspective. Mismanagement or deficiency of financial resources of the contractor may lead to performance reduction and delays, for example delays in payments.

5.3.4 Other factors

1- Ministry of Finance processes: This factor is related to MoF processes and regulations, and it can delay the payment starting from the day after the certificate is issued until it is actually received by the contractor. It is ranked amongst the highest factors affecting the delay of payments from consultant's perspective. This factor is ranked at the 22nd position by the contractor's perspective while ranked at the 12th position by the consultant with RIIs of 54.35% and 75.17%, respectively.

2- Changes in rules and regulations: This factor is ranked at 12th position with RII of 60.43% as per contractor's perspective and at 34th position with RII of 57.24% as per consultant's perspective. Changes in rules and regulations may require from the contractors more time to undertake the routine procedures they are used to it. These changes may be for example new quality requirements, changes in permit requirements, or the green buildings requirements which have changed most of the standards in design and require environment friendly

materials with new specifications. These changes may cause risk of delay by the contractor and may lead to delay his payments.

3- Economic changes: It is ranked at 13th position with RII of 660.00% as per contractor's perspective and at 30th position with RII of 60.34% as per consultant's perspective. Economic changes may be for example an increase in market material costs, or the global financial crises which have affected many deep-rooted companies and governments and have led to bankruptcy of these entities.

Table (5-9) and Table (5-10) show the top ten factors ranked by the contractors and consultant, respectively. The top ten factors as per contractors perspective are: Change in scope, Long and bureaucratic process in governmental departments, Delay in extension of time approval, Delay in claim review and evaluation process, Slow processing of variations orders, Slow processing of final accounts, Refusal to pay interest on late payment, Delay in issuance of payment certificate Process, Weakness in making decisions on issues arising in the course of construction, and finally Inaccurate bill of quantities. The top ten factors as per consultant's perspective are: Changes in scope, Incomplete documents for variation claims, Long and bureaucratic process in governmental departments, Delay in the progress of works and activities, Delay in submitting the payment evaluation (claim) by the contractor, Delay in extension of time approval, Submit claims with calculation mistakes, Contractor's experience with governmental projects, Un-appropriate implementation of projects program, and finally Delays of documentation required to fulfill payments. Three out of ten factors as per the perspective of both parties are the same which are: Changes in scope, Long and bureaucratic process in governmental departments and Delay in extension of time approval.

Table 5-9 The Top Ten Factors by Contractors Perspective

No	The Causes of payment delay	The factor's source	Contactors perspective (Total 42 responses)	
			Relative Index (%)	Rank
1	Changes in scope	Owner	58.97	1
2	Long and bureaucratic process in governmental departments	Owner	57.59	2
3	Delay in extension of time approval	Consultant	57.59	3
4	Delay in claim review and evaluation process.	Consultant	56.55	4
5	Slow processing of variations orders.	Consultant	55.86	5
6	Slow processing of final accounts	Consultant	55.52	6
7	Refusal to pay interest on late payment	Owner	51.72	7
8	Delay in issuance of payment certificate Process.	Consultant	51.72	8
9	Weakness in making decisions on issues arising in the course of construction	Consultant	50.00	9
10	Inaccurate bill of quantities	Consultant	48.28	10

Table 5-10 The Top Ten Factors by Consultant's Perspective

No	The Causes of payment delay	The factor's source	Consultant perspective (Total responses 58)	
			Relative Index (%)	Rank
1	Changes in scope	Owner	78.28	1
2	Incomplete documents for variation claims.	Contractor	76.21	2
3	Long and bureaucratic process in governmental departments	Owner	75.17	3
4	Delay in the progress of works and activities.	Contractor	75.15	4
5	Delay in submitting the payment evaluation (claim) by the contractor.	Contractor	67.59	5
6	Delay in extension of time approval	Consultant	73.45	6
7	Submit claims with calculation mistakes.	Contractor	72.41	7
8	Contractor's experience with governmental projects.	Contractor	72.41	8
9	Un-appropriate implementation of projects program	Consultant	72.41	9
10	Delays of documentation required to fulfill payments (site instructions	Consultant	72.07	10

5.4 Consequences of Payment Delays

The relative indices and ranks of the consequences of payment delay in building construction projects are shown in Table (5-11). This section contains two groups; Consultant and project characteristics group contains twelve consequences, and Contractor group contains twelve consequences.

Table 5-11 The Relative Indices and Ranks of Consequences of Payment Delay

	Consequences	Consultant perspective		Contactors perspective	
		RII (%)	Rank	RII (%)	Rank
(1) Consultant and project characteristic related consequences					
1	Consultant spend longer time than planned	70.34	6	65.65	7
2	Accumulation of uncompleted projects due to payment delay	65.86	9	68.26	3
3	Inability to start new projects in the waiting list	61.72	14	53.91	18
4	Extension of project time	75.86	1	63.04	11
5	Contractor stop/abandon the works	55.86	19	65.22	9
6	Contractor slow down progress until receiving his payment	70	7	69.57	1
7	Inability to control project and deliver it on time	74.48	2	66.96	4
8	Dispute between contract parties	68.27	8	65.65	8

9	Low quality works	62.06	13	47.39	22
10	Poor site safety	58.97	18	47.39	23
11	Termination of contract by owner or contractor	51.38	23	47.39	24
12	Bad reputation of consultant	55.17	22	50.00	21
Average		**64.16**		**59.20**	
(2) Contractor related consequences					
1	Inability of contractor to procure material, equipment and services	73.79	3	69.57	2
2	Inability of contractor to pay his staff salaries	71.03	4	66.96	5
3	Forcing contractor to take loans with high interest rate to pay due expenditures (Borrow from financial organization)	60	17	60.00	14
4	Bankruptcy of contractors	55.86	20	64.78	10
5	Cash flow problems	70.68	5	66.96	6
6	Difficulty for tendering for new projects	65.86	10	60.43	13
7	Contract termination	51.03	24	51.30	20
8	Seek legal entity to resolve payment issues	55.52	21	51.74	19
9	Refusal of sub-contractors to continue works on the project	64.82	12	60.87	12
10	Loss of good reputation	65.51	11	57.83	17

11	Loss of materials	61.38	15	59.13	16
12	Escape of labors and engineers	61.38	16	59.57	15
Average		**63.07**		**60.76**	

Results of Consultant and project characteristics consequences group shows that "Extension of time" and "slowing down the work by contractor until receiving his payment" come in the first place by consultant and contractor's perspective, respectively, as illustrated in Table (5-11) Contractors consequences group shows that "Inability of the contractor to procure material, equipment and services" comes in first place as per consultant's and contractor's perspective. Table (5-12) displays the relative indices and ranks of consequences as per their related groups affected by the occurrence of payment delay. The groups are consultant and project characteristics related consequences group, and contractor related consequences group. As shown in the table, from consultant perspective the consequences related to consultant and project characteristics has the highest average value of RII of 64.16%. While; from contractors perspective the group of contractor related consequences has the highest average value of RII of 60.76%. Both groups of consequences are most affected by payment delay from the point of view of consultants than that of contractors as indicated by RII values for consequences.

Table 5-12 Consequences of Payment Delay Related Groups

Groups	Consultant perspective		Contactors perspective	
	RII (%)	Rank	RII (%)	Rank
Consultant & project consequences	**64.16**	**1**	**59.20**	**2**
Contractor consequences	**63.07**	**2**	**60.76**	**1**

The results of the analysis done on Section C demonstrate the consequences of payment delays on the consultant and project characteristics and also on the contractor. This analysis was based on the perspective of MoW (consultants) and the contractors. The twenty four consequences were ranked from high to low. For the contractor's perspective three drops are noticed in the RII values: the first one at the 11th consequence with a value of (63.04% - 60.87% = 2.17%), the second one at the 17th consequence with a value of (57.83% - 53.91% = 3.91%), and the third one at the 21st consequence with a value of (50% - 47.39% = 2.61%) as shown in Figure (5-2). However, up to consequence 11 of contractor's perspective will be further discussed. For the consultant's perspective five drops are noticed in the RII values: the first one at the 3rd consequence with a value of (73.79% - 71.03% = 2.76), the second one at the 8th consequence with a value (68.27% - 65.86% = 2.41), the third one at the 12th consequence with a value of (64.82% - 62.06% = 2.76%), the forth one at the 18th consequence with a value of (58.97 - 55.86 = 3.10%) and the fifth one at the 22nd consequence with a value of (55.17 – 51.38 = 3.79%) as shown in Figure (5-3). However, up to consequence 12 of consultant's perspective will be further discussed.

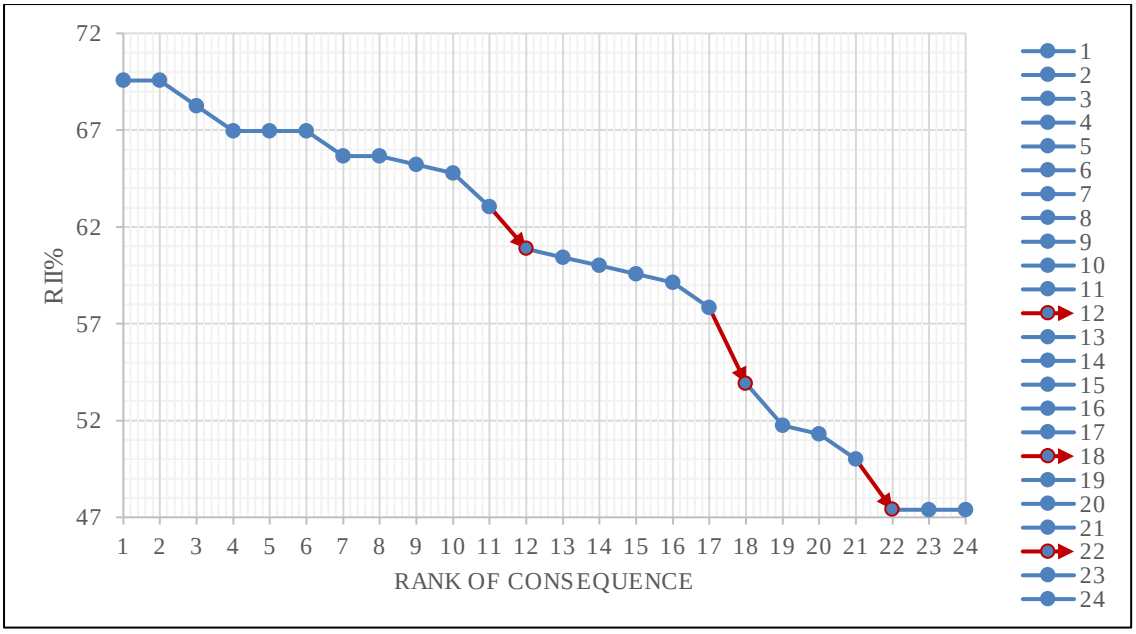


Figure 5-2 Drop Between the 10th & 11th Consequences (Contractor Perspective)

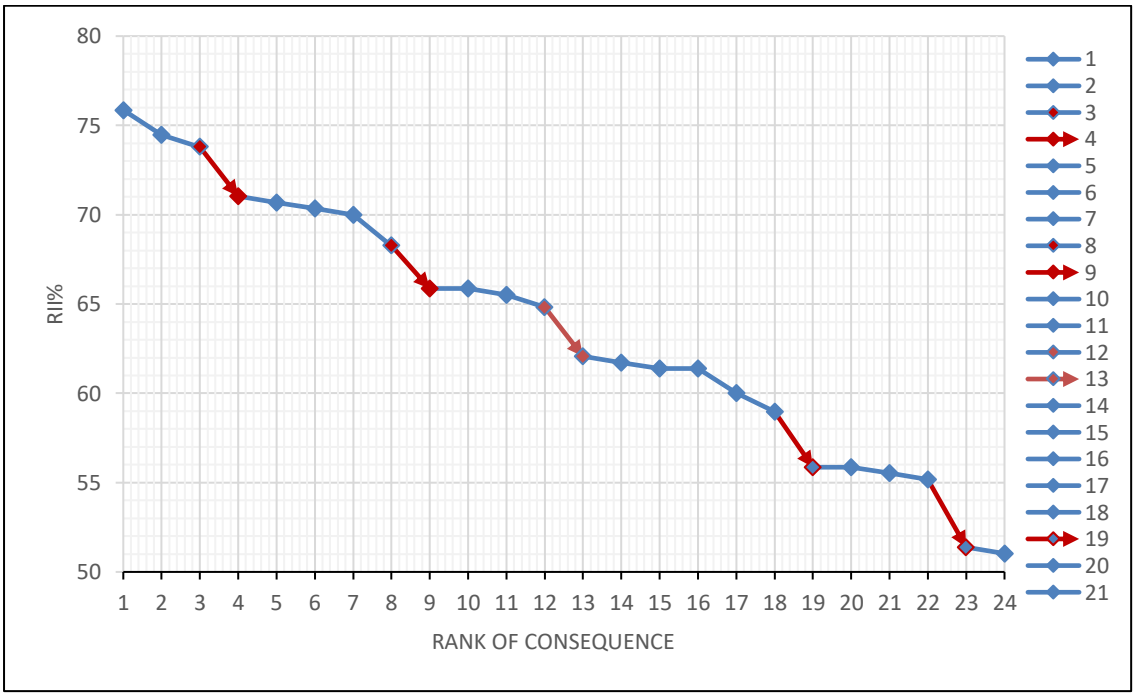


Figure 5-3 Drop Between The 12th & 13th Consequences (Consultant Perspective)

As mentioned previously, this analysis illustrates the consequences of payment delays affecting two groups: consultant and project characteristics group, and the contractors group from consultant's and contractor's

perspective. The top twelve and the top ten consequences by consultant's and contractor's perspectives are shown in Table (5-13) and Table (5-14), respectively.

Table 5-13 Consequences of Payment Delays (Consultant Perspective)

No	Consequences of payment delays.	Affected group	Rank	RII%
1	Extension of project time	Project	1	75.86
2	Inability to control project and deliver it on time	Project	2	74.48
3	Inability of contractor to procure material, equipment and services	Contractor	3	73.79
4	Inability of contractor to pay his staff salaries	Contractor	4	71.03
5	Cash flow problems	Contractor	5	70.68
6	Consultant spend longer time than planned.	Consultant	6	70.34
7	Contractor slow down progress until receiving his payment	Project	7	70
8	Dispute between contract parties	Project	8	68.27
9	Accumulation of uncompleted projects due to payment delay	Consultant	9	65.86
10	Difficulty for tendering for new projects	Contractor	10	65.86
11	Loss of good reputation	Contractor	11	65.52
12	Refusal of sub-contractors to continue works on the project	Contractor	12	64.82

Table 5-14 Consequences of Payment Delays (Contractors Perspective)

No	Consequences of payment delays.	Affected group	Rank	RII%
1	Contractor slow down the progress until payment is received	Project	1	69.57
2	Inability of the contractor to procure material, equipment's and services	Contractor	2	69.57
3	Accumulation of uncompleted projects due to payment delay	Consultant	3	68.26
4	Inability to control the project and deliver it on time	Project	4	66.96
5	Inability of the contractor to pay his staff salaries	Contractor	6	66.96
6	Cash flow problems	Contractor	5	66.96
7	Consultants spend longer time than planned	Consultant	7	65.65
8	Dispute between contract parties	Project	8	65.65
9	Contractor stop/abandon the works	Contractor	9	65.22
10	Bankruptcy of contractors	Contractor	10	64.78
11	Extension of project time	Project	11	63.04

Table (5-13) and Table (5-14) show that nine consequences from the top ranked consequences by consultants and contractors are common in both tables, which are: -

1- Contractor slow down progress until receiving his payment.
2- Inability of contractor to procure material, equipment and services.
3- Accumulation of uncompleted projects due to payment delay.
4- Inability to control project and deliver it on time.

5- Cash flow problems.
6- Inability of contractor to pay his staff salaries.
7- Dispute between contract parties.
8- Consultant spend longer time than planned.
9- Extension of project time.

The rest of the top consequences are either top listed by the consultants or the contractors only, these consequences are: -

1- Difficulty for tendering for new projects.
2- Loss of good reputation.
3- Refusal of sub-contractors to continue works on the project.
4- Contractor stop/abandon the works.
5- Bankruptcy of contractor.

Further analysis of these consequences is given below.

1- "Contractor slow down the progress until receiving his payment" has the 7th rank out of 24 based on consultant perspective with an RII value of 70% as shown in Table (5-13). On the other hand, from the contractor's perspective it has the highest ranking, 1st out of 24 with an RII of 69.57% as shown in Table (5-14). According to the technical expert's opinion this consequence is one of the most expected and executed acts by the contractors in case of payment delay. They use this way as a tactic pressure in order to expedite their payments knowing that the client interest is against any delay in the project progress.

2- "Inability of contractor to procure material, equipment and services" has the 3rd rank out of 24 from consultant perspective with an RII of 73.79% as shown in Table (5-13). On the other hand, the contractor's perspective has a higher ranking, 2nd out of 24 with an RII of 69.57%

as shown in Table (5-14). Inability of the contractor to procure material has a high ranking by both parties showing its importance. This impact might arise due to the lack of material availability, increased material costs, specifications of a material that is not available in Bahrain which requires time to order and is not received on time, and obviously unavailability of funds due to delay in payments which is the most direct reason within all. A contractor who is handling many projects in the market won't be properly able to handle the procuring of huge amount of materials in case of occurrence of payment delay problems. This consequence is highly important because it can paralyze the whole project progress.

3- "Accumulation of uncompleted projects due to payment delay" has the 9th rank out of 24 from consultant's perspective with an RII of 65.86% as shown in Table (5-13). While from contractor's perspective, it has a higher ranking of 3rd out of 24 with an RII of 68.26% as shown in Table (5-14). Payment delay as mentioned previously can have direct effect on implementation, schedule and finalization of a project. The accumulation of uncompleted projects due to payment delay can interfere with the projects submissions and causes delay in handling new projects.

4- "Inability to control project and deliver it on time" is the second highest ranking (2 out of 24) from consultant perspective with an RII of 74.48% as shown in Table (5-13). On the other hand, the contractor's perspective has shown a ranking of 4 out of 24 with an RII of 66.96% as shown in Table (5-14). Inability to control the project and deliver it on time may also be due to many reasons similar to the above discussed consequence reasons. In addition, this consequence may occur due to changes made by the stakeholders, delay in payment, late approvals

and decisions, duplication of work, design changes, lack of experience and knowledge and financial difficulties.

5- "Inability of contractor to pay his staff salaries" has the 4th rank out of 24 based on consultant's perspective with an RII of 71.03% as shown in Table (5-13). Whereas from the contractor's perspective, it has a ranking of 5th out of 24 with an RII of 66.96% as shown in Table (5-14). Inability of the contractor to pay his staff salaries is a serious consequence of payment delay that can lead the contractor to lose his staff, reputation and even may lead him eventually to bankruptcy. This consequence mostly occurs in lower grades' contracting companies where there is no big amount of cash in hand available, while for higher grades' companies' payment delay will not prudently results in this consequence.

6- For "Cash flow problems" has the 5th rank out of 24 based on consultant's perspective with RII of 70.68% as shown on Table (5-13). Whereas from the contractor's perspective. It has a ranking of 6th out of 24 with an RII of 66.96% as shown in Table (5-14). The progress of the project is related directly to the cash flow, any problem encountered in the cash flow or any delay can have direct effect on the project progress or implementation.

7- "Consultants spend longer time than planned" has the 6th rank out of 24 from consultant's perspective with an RII value of 70.34% as shown in Table (5-13). On the other hand, from the contractor's perspective it has a lower ranking of 7th out of 24 with an RII value of 65.65% as shown in Table (5-14). When payment delays affect the project's progress and resulting in time delay, the working load for both contractors and consultants employees are highly increased, resulting

in longer and unplanned working hours. These extra hours could have been spent managing new projects.

8- "Dispute between contract parties" both consultant's and contractor's perspective have the same ranking result which is 8th out of 24 with RII of 68.27% Table (5-13) for the consultants, and RII of 65.65% as shown in Table (5-14) from the contractors. Dispute between the parties of contract can be due to miscommunication between all the parties such as contractor, stakeholder, consultant, supplier and subcontractor which leads to the risk of delay. Such miscommunication and disputes cause changes in work and schedule leading to payment delay. Also, when payments problems occur, more commitment issues will rise up between the parties starting from the client to the contractor and moving down to the subcontractors and suppliers at the bottom of the payment pyramid.

9- "Extension of project time" has the top rank among the 24 consequences as indicated from consultant's perspective with an RII value of 75.86% as shown in Table (5-13). With reference to the contractor's perspective, it has shown a lower ranking of 11 out of 24, with an RII of 63.04%. Extension of project time by extending its schedule is a consequence that occurs due to many reasons such as change in work, variation order, obstruction that might occur on site, delay in approvals, and many more, which all cause the occurrence of delay in payment. Extension of project time is not one of the highest ranked consequences for the contractor because the impact on the projects and consultants is higher.

10- "Difficulty for tendering for new project" has the 10th rank out of 24 from consultant's perspective with an RII value of 65.86% as shown in Table (5-13). On the other hand, from the contractor's perspective, it has a ranking of 13th out of 24 with an RII value of 60.43%. Since a project might be affected by delay and change in schedule as a result of payment delay, the contractor will be financially limited and stuck to a certain project without being able to move and tender for a new project.

11- "Loss of good reputation" has the 11th rank out of 24 from consultant's perspective with an RII value of 65.51% as shown in Table (5-13). While from the contractor's perspective, it has a lower ranking of 17th out of 24 with an RII value of 57.83%. Every contractor is always seeking good reputation, and he achieves it by providing high quality projects, and commitment to pay other parties of the contract on time such as (suppliers and subcontractors). All these elements cannot be achieved without a proper cash flow, and with the occurrence of payment delay a contractor reputation may be highly harmed and may lose his credibility.

12- "Refusal of sub-contractors to continue works on project" " has the 12th rank out of 24 from consultant's perspective with an RII value of 64.82% as shown in Table (5-13). On the other hand, from the contractor's perspective it has a rank of 12th out of 24 with an RII value of 60.87%. This consequence occurs as a result of non-payments or delay in payments by the main contractor, which may occur because of the delay in payment by the client himself, or because of the main contractor own financial problems.

13- "Contractor stop/abandon the work" has the 9th rank out of 24 from contractor's perspective with an RII value of 65.22% as shown in Table (5-14). From the consultant's perspective, it has a lower ranking of 19th out of 24 with an RII value of 55.86%. All other consequences of payment delay related to the financial problems may force the contractor eventually to abandon or stop the work.

14- "Bankruptcy of contractor" has the 10th rank out of 24 from contractor's perspective with an RII value of 64.78% as shown in Table (5-14). On the other hand, from the consultant's perspective it has a lower ranking of 20th out of 24 with an RII value of 55.86%. The inability of the contractor to deal with financials problem will force him to compulsory loans to solve such financial problems. If these problems remain unsolved due to payment delay, this will lead the contractor eventually to the stage of bankruptcy.

5.5 Effectiveness of Suggested Solutions to the Payment Delay

This section is designed to indicate the possible solutions to mitigate the payment delay problem in governmental building construction projects. The solutions shown in this section are identified through interviews targeting the experienced engineers, historical data of previous projects and lessons learned of previous projects as mentioned earlier. The RIIs and the means have been calculated for each of the subject solutions as per consultant and the contractor's responses shown in Table (5-15). Based on these measures, the effectiveness of each solution on payment delay problem is evaluated as high, medium, or low. The suggested solutions are:

Solution (1) is awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time.

This solution can take place by improving the pre-awarding procedures such as the technical evaluation and pre-qualification of contractors. The aim of these procedures is to assure that the contractors added to MoW contractor's list have the proper qualifications to achieve the requirements of MoW specifications and procedures. This solution can be very effective in overcoming many factors causing payment delay such as: inappropriate project team; inadequate financial resources of the contractor; inattention to risk; duplication of work; inappropriate implementation of project programme; failure to do work based on bill of quantity; delay in progress of works and activities; incomplete document by contractor; and delay of submittals by contractor.

Solution (2) is calculating the work load of each staff of the consultant and contractor, and distribute the work load fairly and evenly. The proper scheduling of work load among employees is a success key of any entity. This solution can help in overcoming many causes of delay in payment that can occur because of: the overload each employee is carrying, and mainly the factor of excess work load on consultant's employees; delay in review and approvals by consultant's employees; delay of required documents to fulfill payments; slow processing of final accounts; delay in extension of time approval; inaccurate bill of quantities; delay in submittals by the contractor; and incomplete documents for variation orders by contractor.

Solution (3) is to introduce a well-studied regulation that will grant an advanced payment for the contractor to allow ordering the required materials to expedite the works. This solution can provide the contractor with a finical support to implement the project programme until further payments are received.

Solution (4) is raising contractor's awareness of contracts and payment process in governmental projects. This solution can help in decreasing the risk of two payment delay factors, which are: contractor's failure to understand the contract agreement, and inability of contractors to follow certain procedures of MoW.

Solution (5) is to improve and ease the process of payments valuation and certification. The implementation of this solution will help in decreasing or eliminating the delay during payment process such as: delay in claim review and evaluation process; delay in issuance of payment certificate process; slow processing of variations orders; and delay in MoF payment process.

Solution (6) is proper planning and budgeting of all governmental projects. This solution can be through appropriate design, planning and budgeting during design stage. This can be implemented by including all the requirements requested by the owner, also proper revision of drawings and bill of quantities to avoid design mistakes and to incorporate all the comments included in the lessons learned of similar previous projects. These steps help in avoiding change in scope of work by owner during construction stage, unavailability of funds for additional changes and inaccurate bill of quantities.

Solution (7) is proper management of cash flow as per approved scope of work and schedule program. This solution helps in avoiding unavailability of funds during construction stage and insure the smooth implementation of the project activities.

Solution (8) is managing to anticipate any risk that may delay the project due to payment issues. This anticipating can help in avoiding "inattention

of risk" factor and incorporating proper precautions to avoid the occurrence of this risk that can cause delay in payment.

Solution (9) is briefings and meetings prior start of works. This solution insures well management of project's issues by providing proper communication channel with the contract parties, addressing payment problems during these meetings, helps in proper decision making during construction and help in decreasing the effect of long and bureaucratic processes in governmental departments.

Solution (10) is compensating the contractor for late payment. This is to recompensate the contractor for the high interest rate burden due to loans, bankruptcy of the contractors and the effect on his reputation.

Solution (11) is proper communication among contract parties (the client, consultants as well as the contractors to resolve payment delay issues). This helps in overcoming the payment delay factor of "bureaucracy or wrong channels of communication".

Solution (12) is that contractors should submit timely accurate invoices with complete documents. This is to avoid the delay in claim submission, submission of claims with calculation mistakes, and incomplete documents for variation claims by contractor. These factors proved to be main causes of payment delay.

Solution (13) is avoiding bureaucracy in governmental system. This is to ease and speed the slow processing of payments in governmental departments.

Table 5-15 The Suggested Solutions for Payment Delay Issue

Suggested solutions	Consultant's perspective			Contractor's perspective		
	RII%	Mean	Result	RII%	Mean	Result
Solution (1)	82.759	4.138	High	71.739	3.587	High
Solution (2)	66.897	3.345	Medium	69.565	3.478	High
Solution (3)	68.621	3.431	High	66.957	3.348	Medium
Solution (4)	75.862	3.793	High	63.478	3.174	Medium
Solution (5)	75.517	3.776	High	72.609	3.630	High
Solution (6)	88.966	4.448	Very high	76.087	3.804	High
Solution (7)	79.310	3.966	High	72.174	3.609	High
Solution (8)	76.897	3.845	High	74.783	3.739	High
Solution (9)	73.103	3.655	High	73.478	3.674	High
Solution (10)	66.897	3.345	Medium	64.348	3.217	Medium
Solution (11)	76.552	3.828	High	66.087	3.304	Medium
Solution (12)	78.966	3.948	High	67.826	3.391	High
Solution (13)	71.379	3.569	High	65.217	3.261	Medium

As a result of the Likert scale analysis and mean results shown in Table (5-15) for the suggested solutions, all the replies are towards medium or high. Table (5-15) shows that one suggested solution is decided on by consultants to be of very high effectiveness, whereas, the contractors decided on as high is "Proper planning and budgeting of all governmental projects" (Solution (6)). The suggested solutions, that consultants and the contractors both have agreed on to be of high effectiveness are:

1. Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time (Solution (1)).
2. Improve and ease the process of payments valuation and certification (Solution (5)).

3. Proper management of cash flow as per approved scope of work and schedule program (Solution (7)).
4. Manage to anticipate any risk that may delay the project due to payment issues (Solution (8)).
5. Briefings and meetings prior start of works (Solution (9)).
6. Contractors should submit timely accurate invoices with complete documents (Solution (12)).

One result that is also agreed on by both parties (contractors and consultants) as medium is “Compensating for late payment" (Solution (10)).

As for the rest of the suggested solution results, eight results show that consultants decided on to be of high effectiveness, whereas, the contractors decided on as medium, which are:

1- To introduce a well-studied regulation that will grant an advanced payment for the contractor to allow ordering the required materials to expedite the works (Solution (3)).
2- Raise contractor’s awareness of contracts and payment process in governmental projects (Solution (4)).
3- Proper communication among contract parties (the client, consultants as well as the contractors to resolve payment delay issues) (Solution (11)).
4- Avoiding bureaucracy in governmental system (Solution (13)).

Finally, one result shows that contractors decided on to be of high effectiveness, whereas, consultants decided on as medium, which is: "calculating the work load of each staff of the consultant and contractor, and distributing the work load evenly" (Solution (2)). These results show that all the suggested solutions are effective to decrease or even overcome the payment delay in governmental projects since all of them fall in the

range between medium and high effectiveness as per consultant's and contractor's perspective.

5.6 Chapter Summary

In this chapter, the results of this study are the output of the questionnaire collected from all the targeted participants. The gathered information are summarized by calculating the percentages, number of respondents, frequencies, relative importance indices, ranks, and mean.

In Section (A) general information about the participants are attained in terms of the respondent place of work, age, professional background, number of working experience years in construction industry, total projects accomplished, opinion about the existence of payment delay issue in governmental construction projects.

In Section (B) the factors that contribute to causes payment delay in construction projects are ranked as per the values of their Relative Indices for the four groups contributing in the payment process, which are: owner related factors group; consultant related factors group, contractor related factors group; and other related factors group. The results show that contractors group is ranked at 1st place for having the most effect on the existence of payment delay problem as per consultant perspective, while the owner factors group is ranked at 1st place for having the most effect on the existence of payment delay problem as per contractor's perspective as shown in Table (5-8). Moreover, the individual factors of payment delay are ranked reference to their Relative Indices as shown in Table (5-9) and Table (5-10); the results show that three out of the top ten ranked factors as per the perspective of consultant and contractors are common. These are: Changes in scope; Long and bureaucratic process in governmental departments; and Delay in extension of time approval.

In Section (C) the consequences of payment delay on construction projects are ranked as per the values of their Relative Indices. This section contains two groups; Consultant and project characteristics group, and contractors group, containing twelve consequences each as shown in Table (5-11). Table (5-12) shows that the consequences related to Consultant and project characteristics has the highest Relative Indices as per consultant perspective, while the group of contractor's consequences has the highest Relative Indices as per contractor's perspective. The top ten ranked consequences as per contractor's and consultant's perspective are displayed in Table (5-13) and Table (5-14), respectively. This section shows that the consultant and project characteristics are the most affected group by payment delay.

In Section (D) the effectiveness of suggested solutions to overcome the payment delay are ranked using Likert scale. All the suggested solutions have shown positive effectiveness in preventing/mitigating the payment delay issue, since all the results are between very high and medium effectiveness as per consultant's and contractor's perspectives. The highest six ranked actions as per consultant and contractor perspectives to overcome payment delay issue are: Improve and ease the process of payments valuation and certification; Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time; Proper planning and budgeting of all governmental projects; Proper management of cash flow as per approved scope of work and schedule program; Manage to anticipate any risk that may delay the project due to payment issues; and Briefings and meetings prior start of works.

Finally, the results show that all consultant responses are of high RIIs compared to those of contractor. This is true for causes, consequences, and

solutions because of the highest number of responses from consultant's side compared to contractor. The responses to the survey were 58 and 46 from the consultant and contractor, respectively. This means that the results are biased to consultant's side. Therefore, the results of the contractor's and consultant's groups were separately ranked, and both groups opinions were separately discussed for the purpose of credibility and highlighting the various views.

CHAPTER 6
Historical Data Collection and Analysis for Modeling

6.1 Introduction
6.2 Independent and Dependent Variables
6.3 Historical Data Collection and Types
6.4 Chapter Summary

Chapter 6
Historical Data Collection and Analysis for Modeling

6.1 Introduction

This chapter presents the data collection and analysis to predict the payment delay in days for interim payment delay (Model I) and variation payment delay (Model V) using historical payment cases for building construction projects accomplished in years (2014-2016). The independent and dependent variables used for the design of the models are presented in this chapter along with their relevant data, which is being collected from real case projects.

6.2 Independent and Dependent Variables

The independent variables (input) used in the models design for payment delay prediction are expressed in terms of the payment delay factors collected from the questionnaire results. The payment delay factors considered for Model I and Model V are chosen based on the top twenty factors ranked by the consultants and the top twenty ranked by contractors as shown in Table (6-1). Eleven of the factors are common in the two rankings of the consultants and contractors, thus, a total of 29 factors are analyzed for inclusion in the models to be developed.

1- "Changes in scope of work": This is considered to be the main reason for variation orders and extension of time in governmental projects. It is ranked in first place as per the contractor’s and consultant’s perspectives. This factor is affecting and causing many other factors as shown in Figure (6-1) where "change in cope" results in the occurrence of "Incomplete documents for variation claims by the

contactor", "Delay in submitting valuation/claim by the contractor", "Delay in extension of time approval by the consultant", "Submission of claims with calculation mistakes by the contractor" and "Slow processing of variations orders by the consultant". The last factor will be expressed indirectly in Model I by the factors: "Occurrence of variations orders" and "Occurrence of extension of time". While it will be expressed in Model V by the factor: "Processing of variation orders".

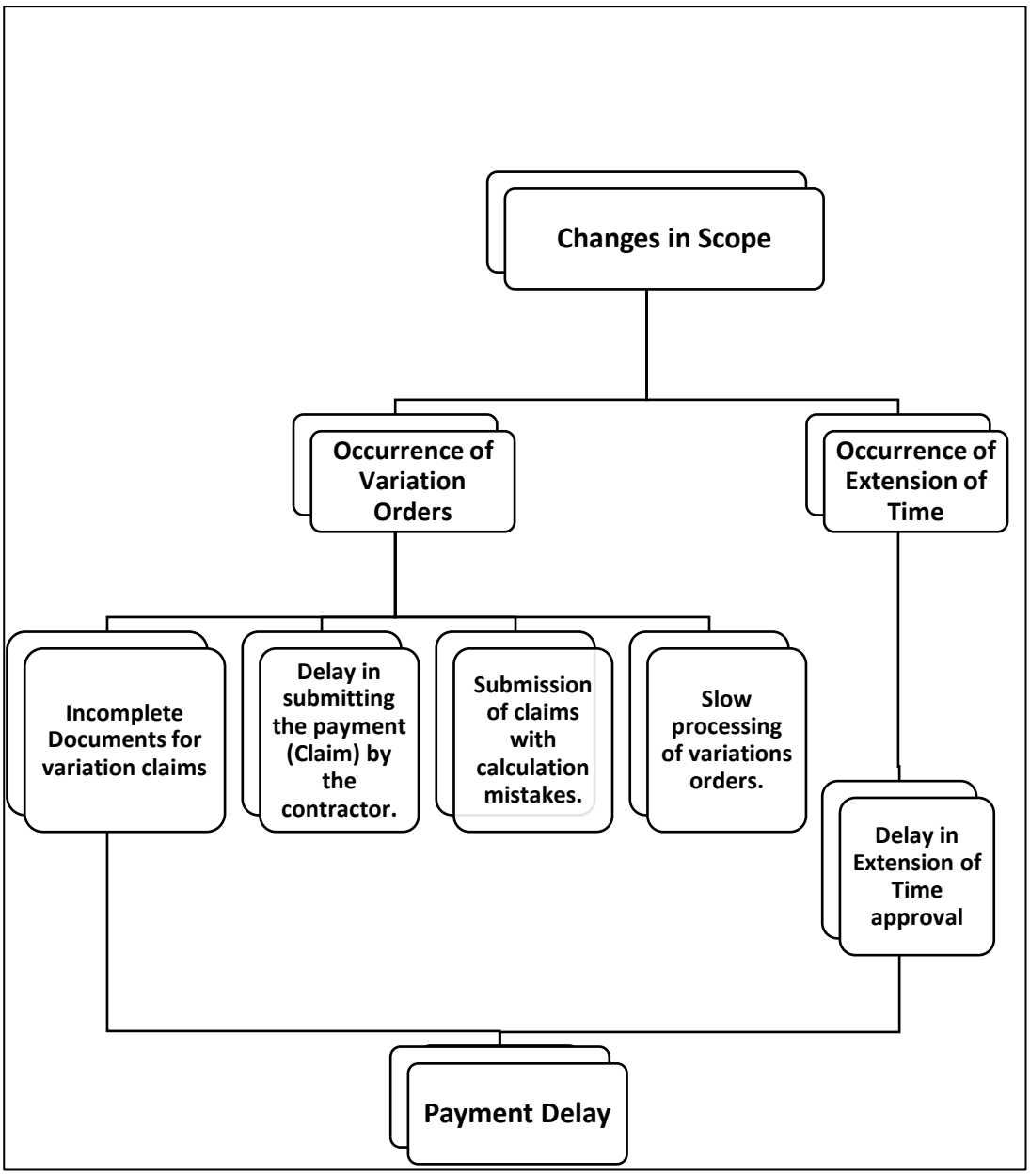


Figure 6-1 Effect of Change in Scope on Other Factors

2- "Incomplete documents for variation claims by the contactor": Variation orders with incomplete documents are rejected by the consultants and the contractor is requested to resubmit it along with complete attachments. The number of the occurrences of this factor is not available for the used historical cases, thus, it will not be considered for Modeling.

3- "Delay in submitting valuation/claim by the contractor": This factor will be used in Model I to represent the number of days delayed by the contractor to raise his valuation (request for interim payment). While for Model V, usually there is no delay in submitting the claims by the contractor. This is because of the contractor's interest in getting extra profits from the variations orders; therefore, he complies in submitting the claims on time.

4- "Delay in extension of time approval by the consultant": The number of delayed days for extension of time approval is not available for the used historical cases; therefore this factor is expressed by the "occurrence of extension of time" in each of the cases by a binary expression.

5- "Submission of claims with calculation mistakes by the contractor": Claims with calculation mistakes are rejected by the consultant and sent back to the contractor for rectifying and resubmission; No data are found for this factor, thus, it will not be considered for Modeling.

6- "Slow processing of variations orders by the consultant": This factor will be used in the development of Model V and is expressed by the number of days required by the consultant to evaluate and approve the variation order submitted by the contractor.

7- "Delay in the progress of work and activities" and "In-appropriate implementation of projects program" are both expressed by the "Delay in progress of work" in days. This factor will be used in the development of Model I and Model V.

8- "Ministry of finance process" is noticed from the historical case studies to have a major effect on payment delay. Moreover, it is ranked in the 12th position as per the consultant's perspective; therefore, this factor will be used in Model I and Model V, and is expressed by the number of days needed for the owner to pay the amounts due to the contractor.

9- "Delay in valuation review and evaluation process" and "Delay in issuance of payment certificate process" are ranked in the 4th and 8th positions, respectively, from contractor's perspective. These factors will be used in Model I and Model V, and are both expressed by the total number of days required for the valuation to be reviewed, approved and issued in the form of payment certificate.

10- "Lack of periodical meetings to address payment problem": This factor occurs in all the cases, and it's evidence of occurrence is availability of minutes of meetings of each periodical meeting. It is not included in the models since it is positively occurring in all used historical cases.

11- The number of years of experience for each of the contractor and consultant are ranked in 8th and 18th position, respectively, as per the consultant's and contractor's perspectives, respectively. These factors will be used in both Model I and Model V.

12- "Long and bureaucratic process in governmental departments", "Inability to follow certain procedures of MoW", "Failure to understand the contract agreement", "Lack of decision making during construction", "Inaccurate bill of quantity" and "Accuracy of payment scheduling program" are intangible factors, therefore they will not be included in the models. These factors have considerable impact on the payment process since they can extend the period of the payment process and make it longer, more complicated, and less flexible. On the other hand, the positive occurrence of these six factors can significantly improve the payment process and decrease the amount of delay.

13- Information on "Delays of documentation required for fulfilling payments", "Inadequate financial resource" and "Slow processing of final accounts" are not available for the used historical cases, therefore, these factors will not be included in the models.

14- "Changes in rules and regulations", "Economic changes" and "Unavailability of funds" do not occur during the used historical cases. All the used historical cases were in years 2014-2016, where no major changes existed with regard to these factors to affect payment process.

15- "Refusal to pay interest on late payment": This factor is not applicable in MoW projects because it is against civil law as discussed earlier in the questionnaire results and literature.

16- "Duplication of work": The frequency of work duplication is not available in the historical cases, therefore this factor is eliminated.

The eleven factors shown in Table (6-2) and the ten factors shown in Table (6-3) are chosen as the input for Model I and Model V, respectively.

The rest of the top twenty factors of Table (6-1) are not included in the Modeling for reasons like: (unavailability of data or non-occurrence of the factor in the real historical cases used to build the model) as shown in the remarks column in Table (6-1). Moreover, additional factors are added to the model as per the experts' recommendations, which include the following: -

a) "Amount paid in Bahraini Dinar": This factor is used in Model I and Model V for each interim payment certificate or variation payment.

b) "Total available contingency in the contract": This factor reflects the total amount of contingency available at the beginning of each project, and it is usually 10% of the project budget. This factor is used for Model V development because it is concerned with variation orders.

c) "Balance of the contingency after each variation payments": This factor is used in Model V, it is shown in the historical data that with the decrease of the contingency amount, approval process for variation orders becomes longer.

d) "Type of funding resource as explained in the literature": There are two types of funding governmental building projects, with different payment approval process for each. This factor is used in Model I only because all the historical cases used for Model V development are externally funded.

Table 6-1 Factors Causing Payment Delay

Rank	Consultant perspective		Contractor perspective	
	Factors causing payment delay	**Remarks**	**Factors causing payment delay**	**Remarks**
1	Changes in scope	Data available	Changes in scope	Data available
2	Incomplete documents for variation claims.	Data unavailable	Long and bureaucratic process	Intangible factor
3	Long and bureaucratic process	Intangible factor	Delay in extension of time approval	Data unavailable
4	Delay in the progress of works.	Data available	Delay in valuation review and evaluation.	Data available
5	Delay in submitting the payment valuation/claim by the contractor.	Data available	Slow processing of variations orders.	Data available
6	Delay in extension of time approval	Data unavailable	Slow processing of final accounts	Data unavailable
7	Submission of claims with calculation mistakes.	Data unavailable	Refusal to pay interest on late payment	inapplicable

8	Contractor’s experience in governmental projects.	Data is available	Delay in issuance of payment certificate process.	Data available
9	Inappropriate implementation of projects program.	Data available	Lack of decision making during construction	Intangible factor
10	Delays of documentation required to fulfill payments.	Data unavailable	Inaccurate bill of quantities	Intangible factor
11	Inability to follow MoW procedures.	Intangible factor	Inappropriate implementation of projects program.	Data available
12	Ministry of Finance processes	Data available	Changes in rules and regulations	Didn’t occur
13	Failure to understand the contract agreement	Intangible factor	Economic changes	Didn’t occur
14	Accuracy of estimation	Intangible factor	Unavailability of funds	Didn’t occur
15	Slow processing of final accounts	Data unavailable	Incomplete documents for variation claims.	Data unavailable

16	Slow processing of variations orders.	Data available	Delays of documentation required to fulfill payments.	Data unavailable
17	Lack of decision making during construction	Intangible factor	Lack of periodical meetings to address payment problems	Exists in all cases
18	Accuracy of payment scheduling program	Intangible factor	Consultant’s experience	Data available
19	Inadequate financial resource	Data unavailable	Duplication of work	Data unavailable
20	Lack of periodical meetings to address payment problems.	Exists in all cases	Submission of claims with calculation mistakes.	Data unavailable

Table 6-2 Interim Payment Factors Used for Model I

	Factors	Value
1	Delay in submitting valuation or claim by contractor	Days
2	Valuation review	Days
3	Payment processed by owner	Days
4	Variations occurrence	Binary expression
5	Extension of time occurrence	Binary expression
6	Contractor experience	Bahraini Dinar.
7	Consultant experience	Years
8	External funding entity	Years
9	Local funding entity	Binary expression
10	Work progress	Binary expression
11	Payment amount	Days

Table 6-3 Variation Order Payment Factors Used for Model V

	Factors	Value
1	Valuation review	Days
2	Payment process by owner	Days
3	Variation orders evaluation and approval	Days
4	Amount paid for variation	Bahraini Dinar
5	Balance of contingency	Bahraini Dinar
6	Available contingency in the contract	Binary expression
7	Extension of time	Bahraini Dinar.
8	Contractor experience	Years
9	Consultant experience	Years
10	Work progress	Days

6.3 Historical Data Collection and Types

The payment delay models are designed using historical data for actual governmental projects. One hundred and fourteen interim payment cases for building projects are used for the development of Model I, while 91 variation payment cases for building projects are used for Model V development. The chosen cases are all for school projects constructed in the years between 2014-2016. The values of the models' factors are extracted from the cases and organized in an Excel sheet for the design purpose as shown in Appendix (3). The values of the payment delay factors, which are used as the inputs to the models, are defined in two ways: first, as a numerical input; and secondly as binary input (0, 1) where (1) expresses the positive reaction as the availability of the factor in each case, and (0) expresses the negative reaction like unavailability of the factor in each of the payment cases. After defining the input factors, the historical data needed for the development of Model I and Model V are expressed as follows.

6.3.1 Factors used in interim payment delay model (Model I)

For interim payment delay model development, eleven factors are chosen and expressed as shown in Table (6-2). They are illustrated below:

1- Delay in submitting valuation by the contractor: This factor is expressed by the number of days the submission of payment notice is delayed by the contractor at the end of each month as per payment schedule.

2- Claim review by the consultant: This factor is expressed by the total number of days of evaluation and issuance of payment certificate by summing the following: -

- Total number of days from receiving the claim by the project manager until it is forwarded to CED.

- The total number of days spent by CED for the evaluation and issuance of payment certificate and forwarding it to FRD.
- Total number of days for FRD to check and forward payment certificate to MoF in case of governmental funded projects and to the funding entity in case of externally funded projects.

3- Payment processing by owner: This factor is expressed by the number of days spent by the owner to make full payment to the contractor.

4- Variations orders occurrence: This factor is expressed by binary expression: 1 in case of the existence of variation within each payment case, and expressed by 0 if there is not.

5- Extension of time occurrence: This factor is expressed by binary expression: 1 in case the payment is affected by extension of time based on expert's opinion and expressed by 0 in case it is not.

6- Payment amount: It is expressed by the due amount of payment certificate in Bahraini Dinar.

7- Contractor experience: This factor is expressed by the total number of years of experience of the contractor's engineer who processes the claim.

8- Consultant experience: This factor is expressed by the total number of years of experience of the consultant's (MoW) engineer who processes the claim.

9- Externally funded projects: This factor is expressed by binary expression: 1 in case it is an externally funded project, and expressed by 0 in case it is not.

10- Locally funded projects by government of Bahrain: This factor is expressed by binary expression: 1 in case it is locally funded project, and expressed by 0 in case it is not.

11- Work Progress: It is the total number of time delay of the project at the time of each payment.

The actual total payment delay in days (dependent variable) for Model I is calculated in two stages: the first stage includes valuation of the following factors:

1- The delay in submitting payment valuation by the contractor: This factor is calculated by subtracting the planned date of submitting the payment valuation by the contractor from the actual date of submitting the payment valuation by the contractor.
2- Number of days for payment claim to be reviewed and approved by consultant: This factor is calculated by subtracting the date of claim receival from the contractor from the date of final approval by MoW.
3- Number of days for payment to be paid by owner: This factor is calculated by subtracting the date of receival of payment final approval by MoW from the date of payment deposit in contractor bank account.

Second stage: After valuation of the above factors, the actual total payment delay is calculated using Equation (6-1) developed in excel sheet. It is established with the help of experts' engineers using "IF condition" to recognize the payment factors causing the occurrence of delay, and those complying with the payment period allowed by MoW clauses. This is being done for each of the historical cases. The equation starts by subtracting the maximum allowed 42 days as per MoW clauses from the number of days for payment to be paid by owner, and to subtract the maximum allowed 14 days as per MoW clauses from the number of days of claim review and approval, then these two factors are summed up together. If the summation results in delay, then the number of delayed days in payment deposit is added to the number of delayed days in submitting payment valuation by the contractor. On the other hand, if payment delay did not occur, then payment delay will be expressed as zero.

Total payment delay (days) = **IF [**(Payment by owner - 42days) + **(**IF (Claim review<14days, 0, Claim review)**) +** Delay in submitting valuation by the contractor <0, **0**, (Payment by owner - 42days) + **(**IF (Claim review<14days, 0, Claim review)**)** + Delay in submitting valuation by the contractor**]** (6-1)

6.3.2 Factors used in variation payment delay model (Model V)

The variation payments process in MoW as explained in Chapter 3 is a long process and different than the interim payment process, especially for externally funded projects where it involves three stages: prior approval of variation from funding entity, formal approval of variation from funding entity, and finally certifying the payment. While for locally funded projects, the process includes only two stages: variation order approval, and payment certification stage. Table (6-3) shows the factors used in model V and their expressions as illustrated below: -

1- Variation evaluation and approval: This factor is expressed as follows:
   a) For locally funded projects, the factor is given by the total number of days for variation orders approval.
   b) For external funded projects, the factor is given by the total number of days for prior and formal approval of variation.
2- Claim review: as defined in Subsection 6.3.1.
3- Payment process by owner: as defined in Subsection 6.3.1.
4- Allocated contingency in the contract: It reflects the total amount of contingency (Bahraini Dinar) allocated for the project.
5- Balance of contingency: This factor is expressed by the amount of contingency balance (BD) in the contract at the time of the variation approval. The collected data has shown the effect of this factor on the approval decision of both the consultant and the client for each variation

case, where less number of variations are approved with the decrease of contingency balance during construction, where only the most important variation items are approved.

6- Extension of time occurrence: as defined in Subsection 6.3.1.

7- Payment Amount: It is expressed by the amount of variation claimed in Bahraini Dinar.

8- Contractor experience: as defined in Subsection 6.3.1.

9- Consultant experience: as defined in Subsection 6.3.1.

10- Work Progress: as defined in Subsection 6.3.1.

The actual payment delay in days (dependent variable) for Model V is calculated in two stages: first stage includes valuation of the following factors:

1- Number of days for Variation order evaluation and approval: This factor is calculated by subtracting the date of submission of variation order request by the contractor from the date of variation order final approval by consultant.
2- Number of days for payment claim to be reviewed and approved by consultant: as defined in Subsection 6.3.1.
3- Number of days for variation payment to be paid by owner: as defined in Subsection 6.3.1.

Second stage: After valuation of the above factors, the actual payment delay is calculated using Equation (6-2) developed in excel sheet. It is observed that a noticeable delay occurs in all the historical cases used for variation orders payment, therefore the extent of this delay was directly calculated by subtracting the maximum allowable limit from the number of days for each investigated factor mentioned above. The equation calculates the delay by subtracting the maximum allowed 14 days as per MoW clauses from the number of days for variation order to be evaluated

and approved by consultant, then to subtract the maximum allowed 42 days as per MoW clauses from the number of days for payment to be paid by owner, and to subtract the maximum allowed 14 days as per MoW clauses from the number of days of claim review and approval, after that these three factors are added together to obtain the actual payment delay in days.

Actual payment delay (days) = (Variation order evaluation and Approval - 14days) + (Claim review - 14days) + (Payment by owner - 42days) (6-2)

6.4 Chapter Summery

The data collection and analysis for Model I and Model V passed through quite a few steps, beginning by identifying the independent variables (input) used in the models' design based on the factors collected from the questionnaire results. Then 140 historical data instances and 91 historical data instances are collected, for the design of Model I and Model V, respictively. Each of the historical cases includes the values of the independent variables chosen for the models design. These values are clearly identified as per their expression type, whether it is days, years, or binary. Moreover, the collection of dependent variable (output) values are explained for each of the models along with calculation stages and the used equations.

CHAPTER 7
Modeling with Neural Networks and Regression

7.1 Introduction
7.2 Artificial Neural Networks
7.3 Regression Modeling
7.4 Design of Models
7.5 Building ANN Models
7.6 Chapter Summary

Chapter 7
Modeling with Neural Networks and Regression

7.1 Introduction

In this study two types of models are applied for the prediction of interim and variation payment delay which are: artificial neural network and regression. Each of the applied models has different software tools, architecture and features. These differences are explained further in order to get an apprehension of the most suitable model for the prediction of interim and variation payments delay. Below is an explanation of the models used in this study: -

7.2 Artificial Neural Networks

The artificial neural network (ANN) is inspired from the human brain system in which it contains elements called neurons, these elements work as the human biological nervous system. In which a neuron with (n) inputs calculates its output as shown in Equation (7-1) (NeuralDesigner, 2017)

$$\mathbf{ANN = F\ (\ \sum_{i=1}^{n} w_i p_i + b\ )} \qquad (7\text{-}1)$$

Where, (p_i) is the value of (*ith)* input, (w_i) is the weight of (ith*)* input, *b* is the bias, and *f* is an activation function of the neuron where this function is needed to establish nonlinearity into the network. The Architecture of ANN includes input, hidden and output layers as shown in Figure (7-1).

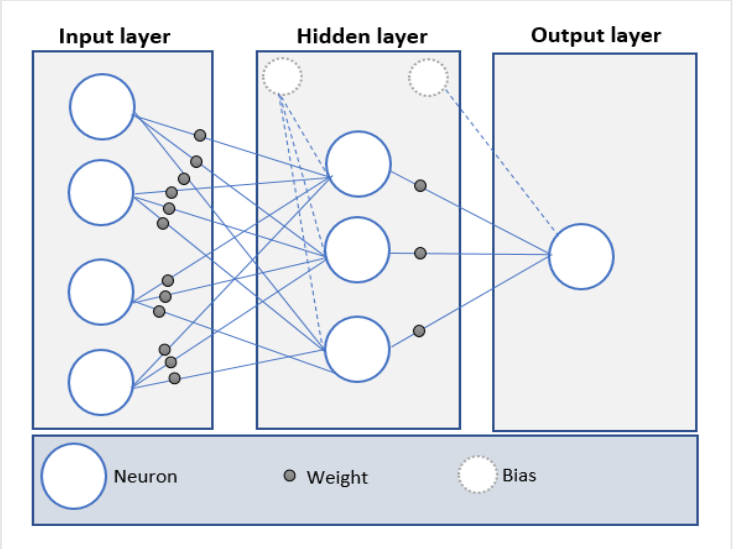


Figure 7-1 Architecture of Ann

A Network with only one output layer and no hidden layer is called a single layer perceptron network. In this type of network, the inputs are send right away to the output layer through a series of weights. On the other hand, networks with multiple layers are consisting of one or more hidden layers and one or more output layers, where each neuron in one layer is connected to the neurons in other layers and uses different techniques, algorithms and training as will be illustrated further below (Goyal and Goyal, 2012).

In the input layer, the number of neurons is the same as the number of input data (historical data) which are used to predict the required output. In output layer, the neurons determine the data to be predicted. The number of hidden layers depends on the complexity of the problem and the number of the neurons within these layers is decided by trial and error approach (Demuth et al., 2007). The Learning Algorithms are formulated to search the weight vector parameter with minimum loss function value at each iteration through the training stage of the network (NeuralDesigner, 2017).

The learning algorithms used in this study are three, the first one is Levenberg-Marquardt algorithm which requires more memory but less

time. The training of Levenberg stops automatically once generalization stops improving; this is shown by a rise in the mean square error of the validation samples. The second algorithm is Bayesian regularization algorithm, which requires more time, but can result in good generalization for difficult, small or noisy datasets. Training stops according to adaptive weight minimization (regularization). The third algorithm used is Scaled Conjugate gradient, this algorithm requires less memory. Training automatically stops when generalization stops improving, as indicated by an increase in the mean square error of the validation samples (Demuth et al., 2009).

The Forecasting of the output is performed through 3 stages which are training, validation and testing. To perform the training, large number of algorithms has been developed and most popular is backpropagation network which is implemented in this study. The learning step starts by discovering linear relationships between the inputs and the output data by assigning weight values to the links between the neurons. The second step is feed forward of the network, where the neurons are added to the hidden layer, and the input values in the first layer are multiplied by the weights and passed to the second (hidden) layer to create one iteration (Al-Sobiei et al., 2005). At each iteration, the weights are adjusted to minimize the calculated error measure between the output produced and the targeted output. The error minimization process is repeated until an acceptable result is reached (Iranmanesh and Zarezadeh, 2008). In case the predicted results do not meet the desired output, and this is measured by the validation stage where the performance (error) is calculated, then the back propagation of error signals takes place in which error is propagated back to all the elements in the prior layer and finally updating of the weights and biases based on the error signal (Amita et.al, 2015). Finally, the third stage

includes testing the model with an independent set of data that was not included in training in order to evaluate the performance of the model and its accuracy.

7.2.1 Software used for the design of neural network model

ANN can be developed through quite a few types of software, which are used to predict the future values based on the past data such as SPSS, MATLAB, Nonresolution, Minitab …etc (El-Sawalhi and Nasser, 2015). The neural models in this study are developed using Neural Networks Toolbox by MATLAB. MATLAB is a multi-numerical computing tool developed by MathWorks. It started developing in the late 1970 in the Computer Science Department at the University of New Mexico. The programme is built around the MATLAB scripting language and it is used by scientists, academics and wide range users across industry for numerical computing for various backgrounds including engineering in general and construction projects management in specific. MATLAB application practice comprises of working through Command Window as an interactive mathematical case or through performing text files comprising of MATLAB code (Matlab, 2017).

Each Neural network can be trained to perform a particular function by adjusting the values of the connections (weights) between neurons in a way that a particular input leads to a specific target output which proofs that simple neural network can fit any practical function. In MATLAB there are several neural networks tools that help the user to perform any kind of neural networks smoothly and easily such as using the Neural Network Fitting Tool (*nftool*) and (*nntool*), as described in "Graphical User Interface" (Demuth et al., 2009).

7.3 Regression Model

In statistical Modeling, regression analysis is "a set of statistical processes for estimating the relationships among variables" (Regression analysis, 2017). Fitting a curve for a specific data while minimizing the total squared error and maximizing the goodness of fit (R^2) is the core idea of a regression analysis. Regression models are used to describe a dependent variable (y_i) in terms of independent variables by using the least number of parameters. Regression model is called multiple linear regression when it has linear coefficients and a multiple number of independent variables. In most of the studies where regression analysis is applied, more than one independent variable is needed as in this study. For the case of *k* independent variables x_1, x_2, …, x_k, the predictable output is calculated using the multiple linear regression Equation (7-2), and the sum of squared error (*SSE*) is calculated using Equation (7-3):

$$y_i = b_0 + b_1 x_{1i} + b_2 x_{2i} + \ldots\ldots + b_k x_{ki} + e_i \quad (7\text{-}2)$$

$$SSE = \sum_{i=1}^{n} e_i^2 = \sum_{i=1}^{n} (y_i - b_0 - b_1 x_{1i} - b_2 x_{2i} - \ldots. - b_k x_{ki})^2 \quad (7\text{-}3)$$

Each regression coefficient ($b_1 \ldots\ldots b_k$) is estimated from the sample data using the least squares method by minimizing the expression showed in Equation (7-3) (Karanci, 2010). The error captures the amount of variation not predicted by the slope and intercept terms. Correlation determines the strength of the relationship between variables, while regression attempts to describe that relationship between these variables in more detail (Campell and Campell, 2008).

7.3.1 Software used for the design of regression model

Regression analysis can be performed by all the major statistical software packages. Different software packages perform different approaches; also, each method with a specific name might be implemented differently in each package (Regression analysis, 2017). Regression can be implemented in a wide variety of software packages which are accessible to anyone with a laptop/microcomputer. Microsoft Excel is a popular spreadsheet package, SAS, SCA, RATS, and EViews can do simple or multiple regressions. In this Study Microsoft Excel is used for building regression models (Guerard, 2013), specifically Microsoft Excel (Data analysis toolpak) version 2016 is used to develop regression models. Data analysis tool by Excel is used to develop different engineering analyses. Excel can be used as a spreadsheet, for data entry and manipulation. Moreover, it provides a collection of statistical analysis functions and further tools that can be used to accomplish several different and useful statistical tests that are widely used in business and management research. The Data Analysis ToolPak is an Excel add-in tool. It contains more widespread functions, including some useful inferential statistical tests for example regression that can provide single and multiple linear regression (Rose et al., 2014).

7.4 Design of Models

The models that are used in this study are presented in Figure (6-2) and are tested for both Interim payment delay model (Model I) and Variation payment delay model (Model V). Both MATLAB programme and Microsoft Excel are used for the development of the neural network and regression model, respectively.

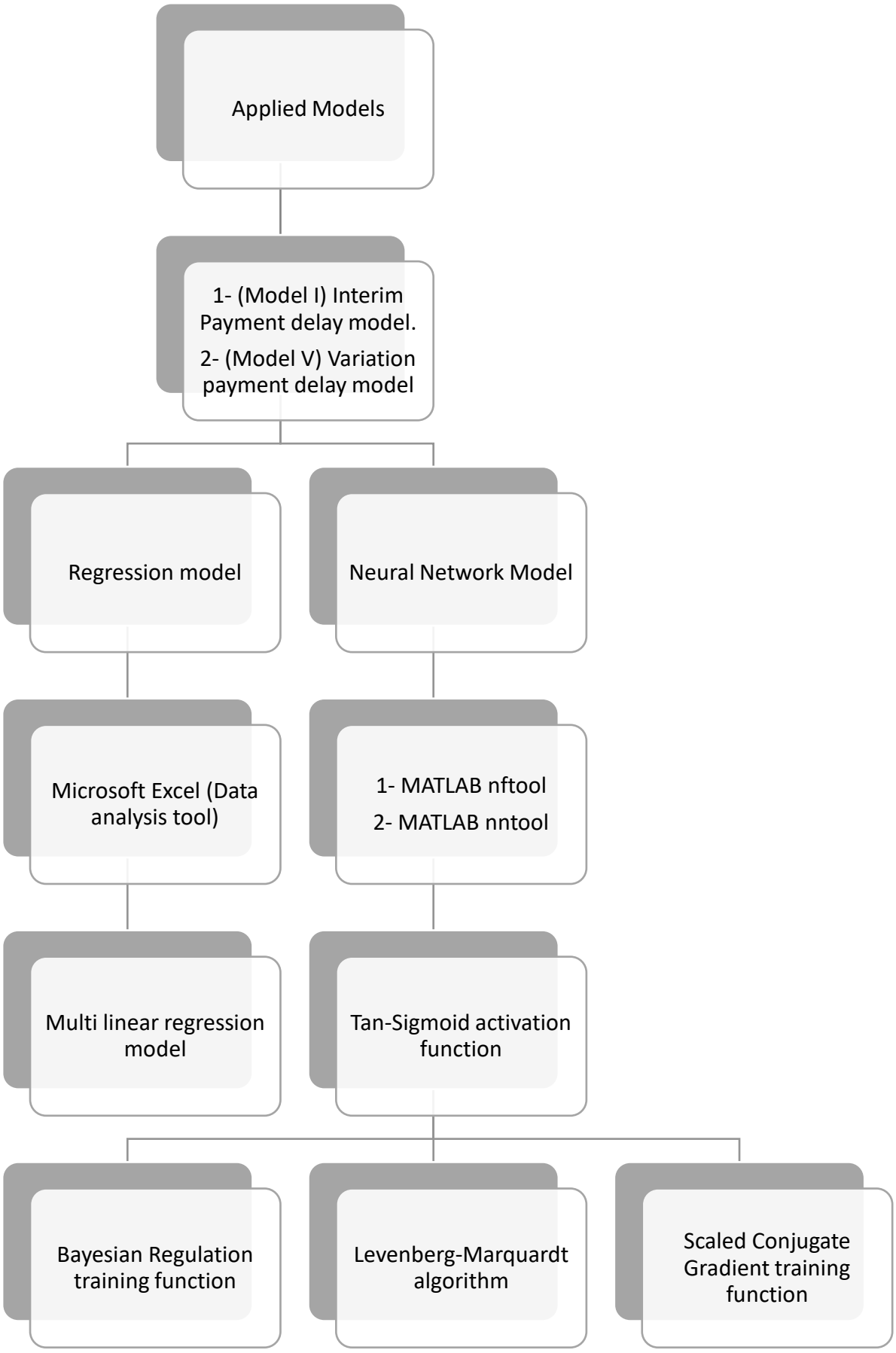


Figure 7-2 Approaches Adopted for Models Development

7.5 Building ANN Models

Two models are developed using ANN Toolbox by MATLAB, while the preparation of the input data and statistical computations had been performed by applying Microsoft Excel. The first model is build based on historical data for 114 interim payments data points taken from real governmental building construction projects, while the second model is build based on historical data for 91 variation orders payments taken from other governmental building construction projects. The development of the models includes the steps shown in Figure (7-3): starting from identifying the input factors and collecting historical data as defined previously in Chapter 6 (Section 6.2); to the model development, calculation of performance; and finally comparision of different resullts.

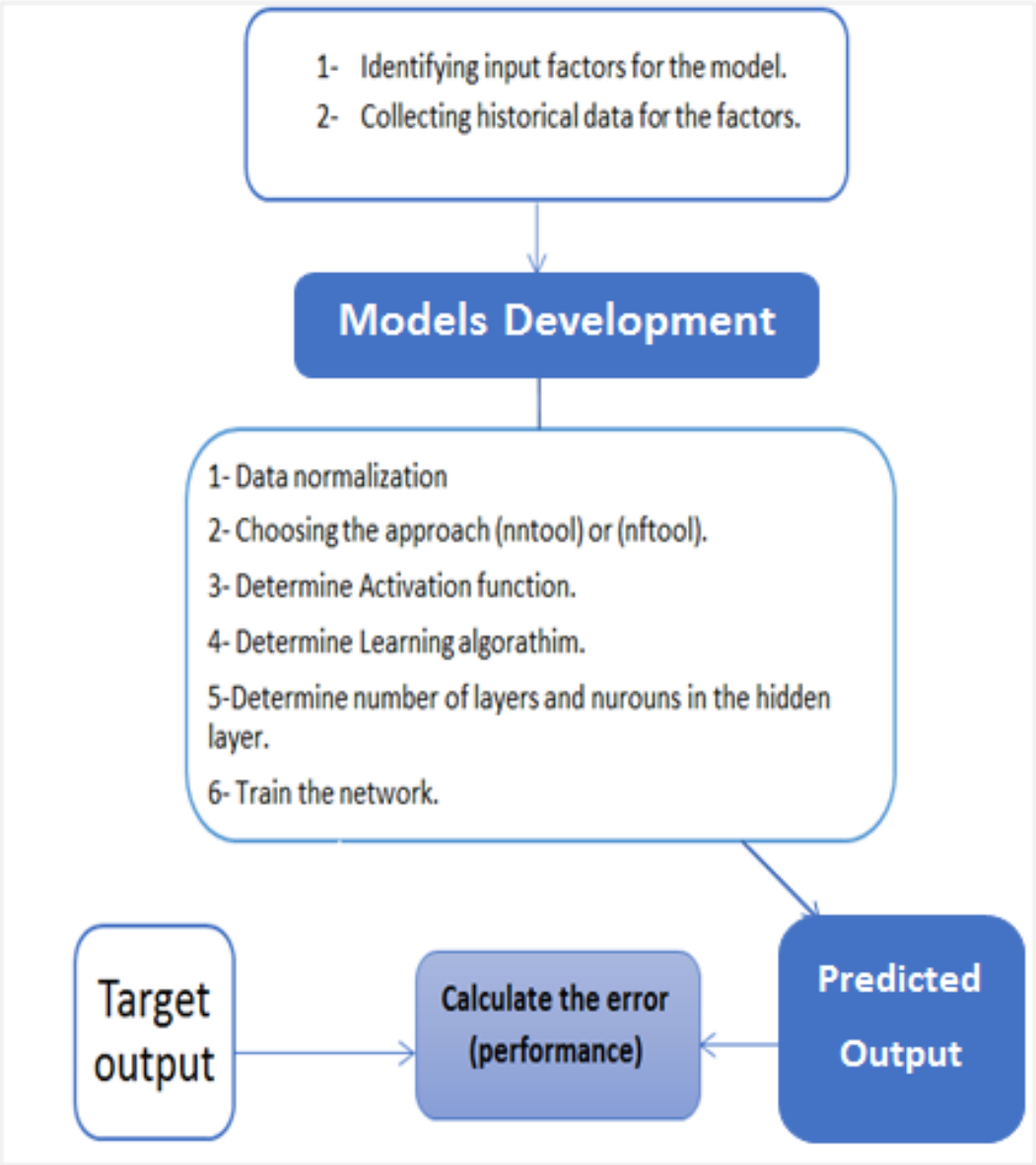


Figure 7-3 ANN Models Development

The Payment delay models are developed using the 114 actual interim payment cases for Model I and 91 actual variation payment cases for Model V. The data used in building each of the two models are divided into 3 subsets, (70%) used for training the network, (15%) for validation, and (15%) for testing as shown in the MATLAB window of Figure (7-4). The program accepts up to two layers including 1 hidden layer and 1 output layer which are approved to be enough for most engineering problems.

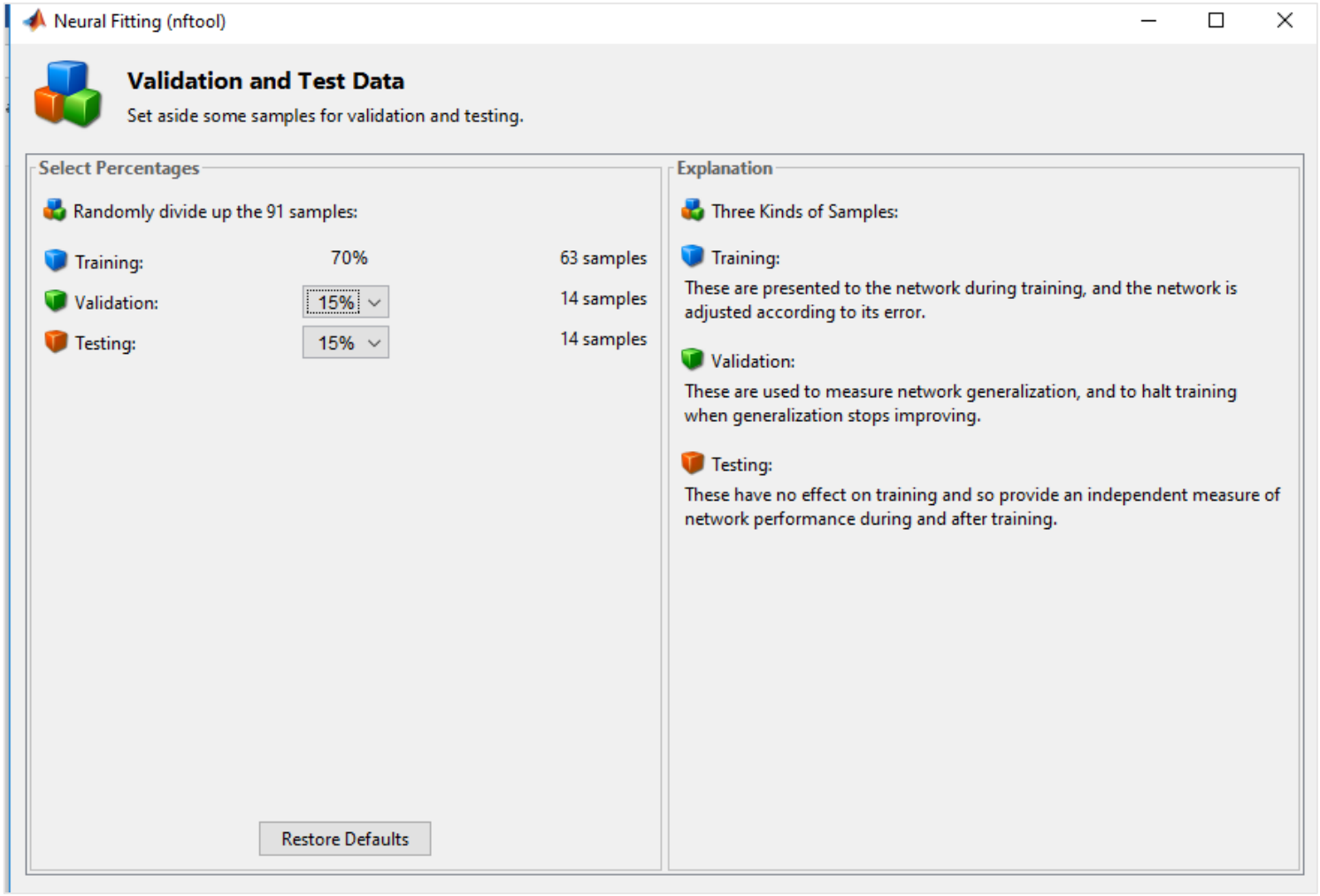


Figure 7-4 Validation and Test Data Window in MATLAB

Multi-layers ANN models are developed and compared with each other using 2 approaches: 1) nftool (Neural Network Fitting Tool); and 2) nntool (in Network/Data Manager window) from MATLAB software. Hit and trial method is used to test different combinations of training algorithms and hidden neurons to train the models. Three chosen algorithms are used: *Bayesian regularization, Levenberg Marquardt algorithm and Scaled conjugate algorithm*. These algorithms are all tested along with a tan-sigmoid activation function as shown in Figure (7-5) to work best with the normalized factors of a range [-1,1]. The tan-sigmoid function is also defined by Equation (7-3). In this study the frequently used "backpropagation" network was implemented. The evaluation approaches used to test the models for the best number of neurons and training function are as follows: Mean Absolute Error (MAE), Mean Absolute Percentage Error (MAPE) and Root Mean Square Error (RMSE) for the nntool, and RMSE, MSE and (R) regression value for the nftool.

$$f(n) = \frac{1}{1 + e^{-n}} \tag{7-3}$$

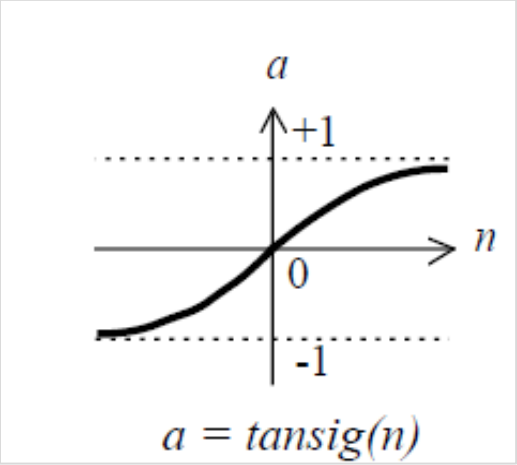


Figure 7-5 Tan-Sigmoid Activation Function
(Demuth et al., 2007, P. 2-4)

7.5.1 MATLAB nntool

In nntool approach a code was inserted in the command window in order to input and normalize the data using Min and Max command as shown in Appendix 4.

7.5.1.1 Data normalization in MATLAB

The algorithm works best when the network inputs and outputs are normalized roughly in the range [-1, 1] (Demuth et al., 2007). Normalization of the data improves the performance of the trained ANN. It brings all the variables within specific range (Naik and Radhika, 2015). The historical Data of this study are normalized to a range between (-1 to 1) using the command Min and Max (mapminmax) from MATLAB. This function scales all the inputs and targets in a range of [-1, 1]. The codes shown in Figure (7-6) are used in the MATLAB command window in order to perform the normalization of data; where (d) is the full data set; (p) is the independent data set; (t) is the dependent data set; and the normalized set will be saved in (pn) for the independent data set and in (tn) for the dependent data set. "The MATLAB normalized settings are used to perform the linear mappings of inputs and targets, which are returned as ps and ts" (Demuth et al., 2007). This command will produce predicted outputs from the network in the range between [-1, 1], and to convert these outputs back into the same units, the code shown in Figure (7-7) is used also in MATLAB for de-normalization of the predicted data where (net) is the developed network, (a) is the network output after denormalization and (an) is the normalized network output.

```
t = d(:,12)';
p = d(:,1:11)';
[pn,ps] = mapminmax(p);[tn,ts] = mapminmax(t);
```

Figure7-6 Mapminmax Normalization Command in MATLAB

```
Command Window
an = sim(net,pn);
a = mapminmax('reverse',an,ts);
```

Figure 7-7 De-Normalization Command in MATLAB

7.5.1.2 Network properties

Thereafter in the nntool window the network properties are defined by entering the following [as shown in Figure (7-8):

1- The inputs and targets
2- Number of hidden neurons.
3- Type of transfer function.
4- Type of learning function.

After the network is created using nntool approach the training and validation step is run inside the programme where the validation set is used to pause the training when the generalization of the network stops improving. After that a totally different set of data are used for testing of the network as shown in Figure (6-9). The results of the testing samples are presented and compared using some performance parameters in order to choose the best network that is able to generate the best estimation.

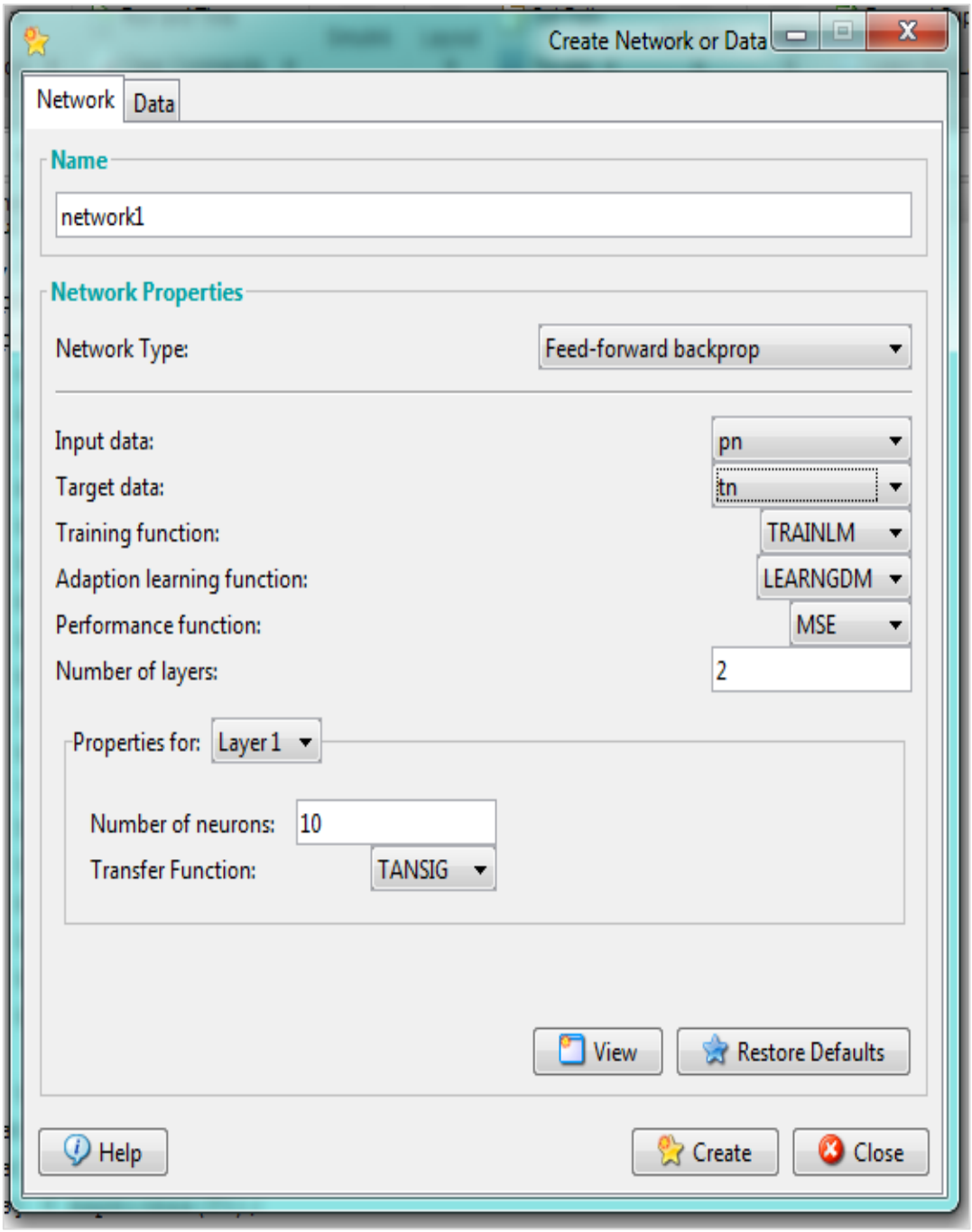


Figure 7-8 New Network Creation Using nntool

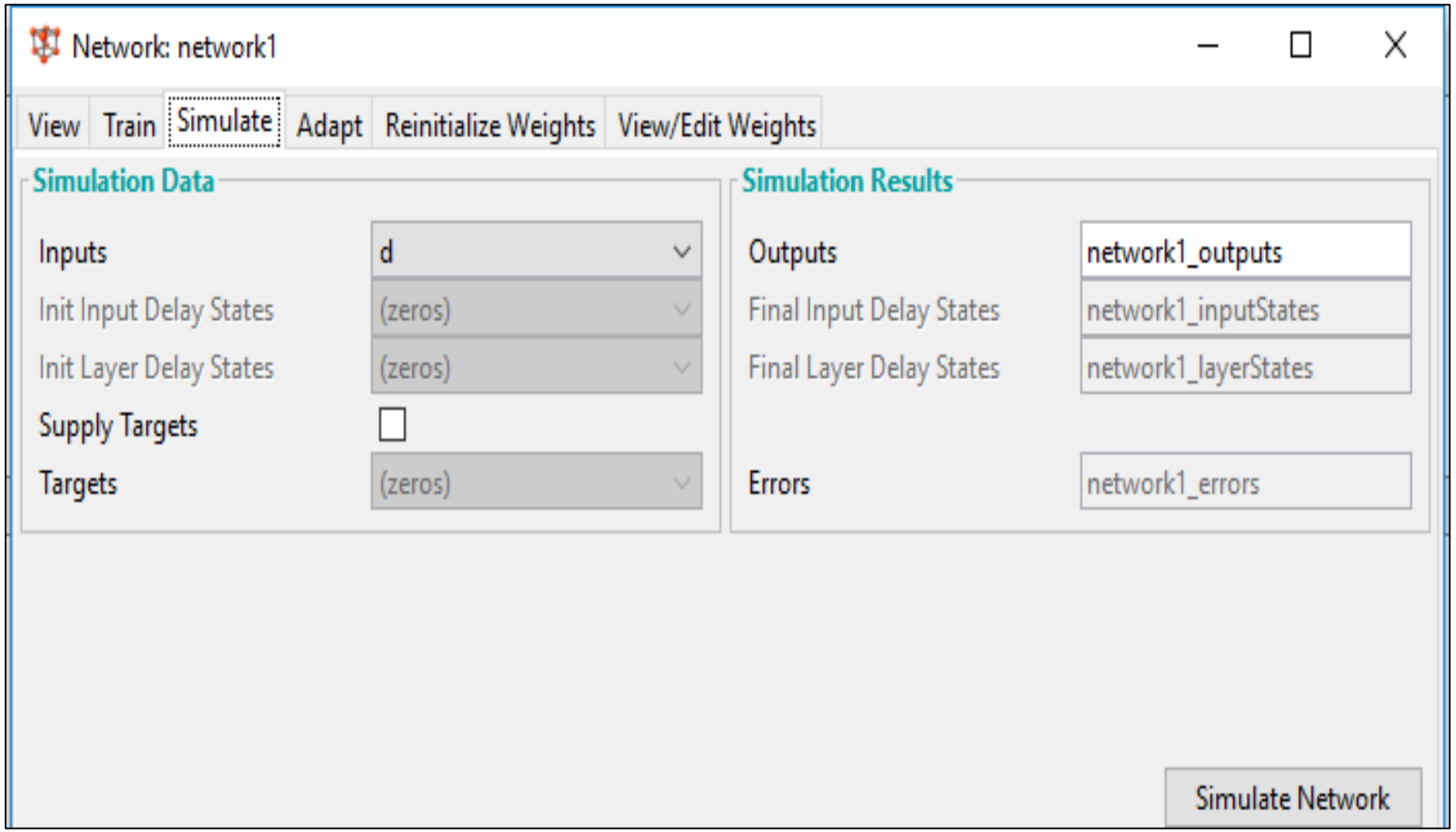


Figure 7-9 Testing the Network

7.5.2 MATLAB **nftool**

The nftool (Neural Network Fitting Tool) creates a two-layer feed-forward network trained with Levenberg-Marquardt algorithm, Bayesian regulation backpropagation and Scaled Conjugate Gradient training function. The approach starts by selecting the input data and target data as shown in Figure (7-10), and percentage of the training, validation and testing data sets as shown in Figure (7-11). After that it proceeds by choosing the number of hidden neurons as shown in MATLAB window in Figure (7-12), and finally choosing training algorithm and training the network as shown in Figure (7-13). The approach applies a built-in normalization tool to all data to be ranged between [-1,1] and is using tan-sigmoid training function. The predicted output is compared with the target by evaluating the performance through calculating the mean square error and regression result by the MATLAB.

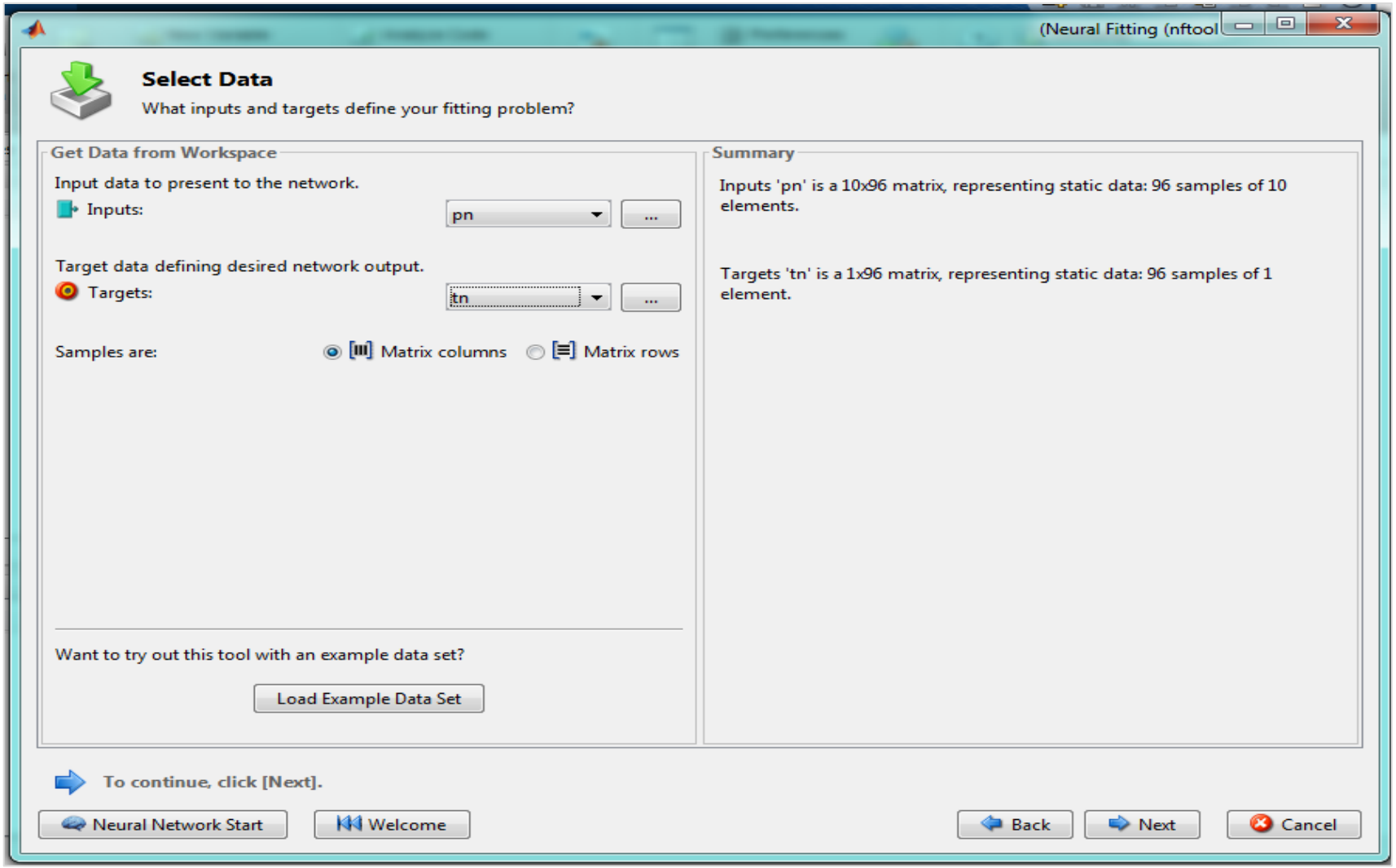


Figure 7-10 nftool Data Selection

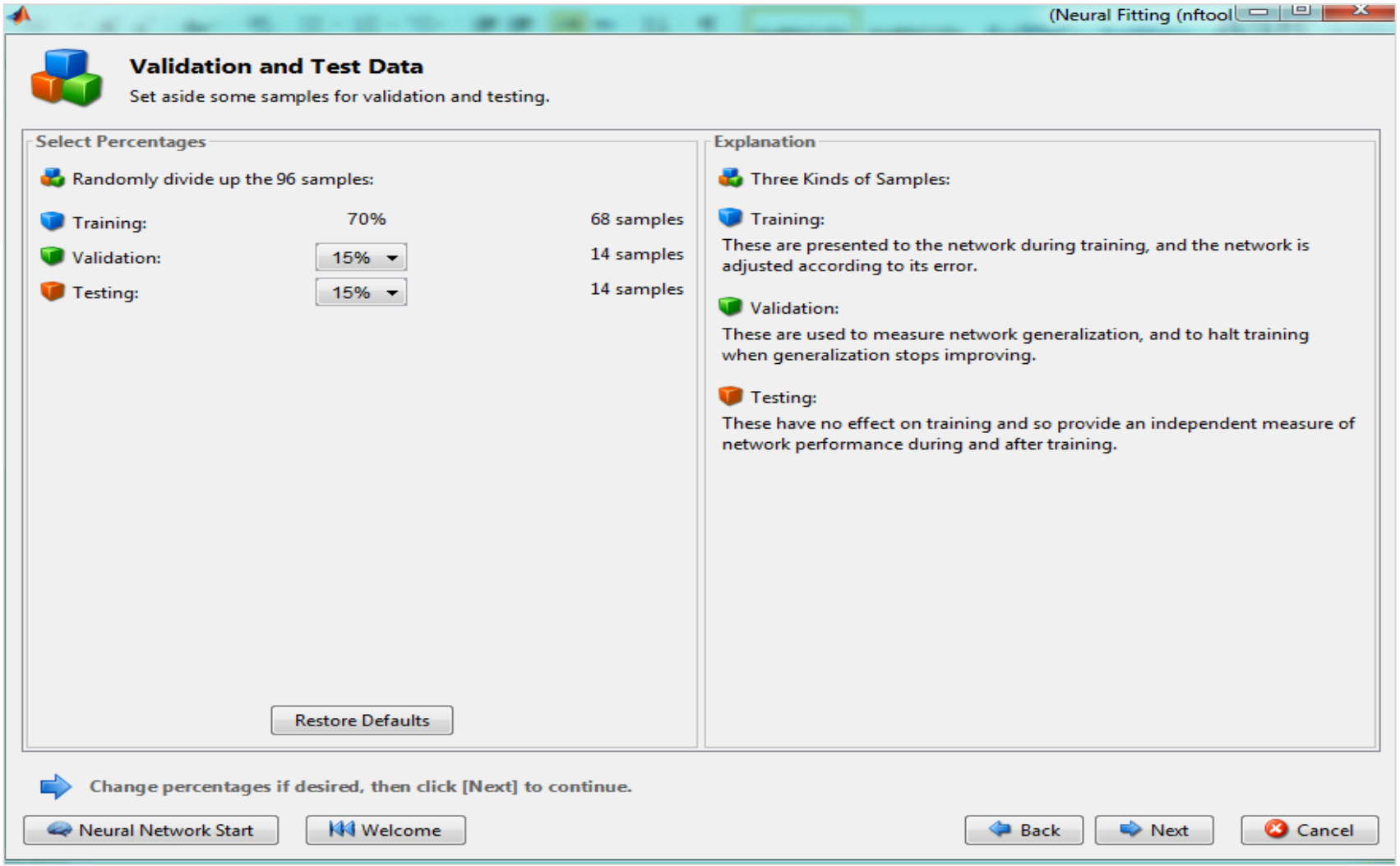


Figure 7-11 nftool Validation and Test Data Percentages

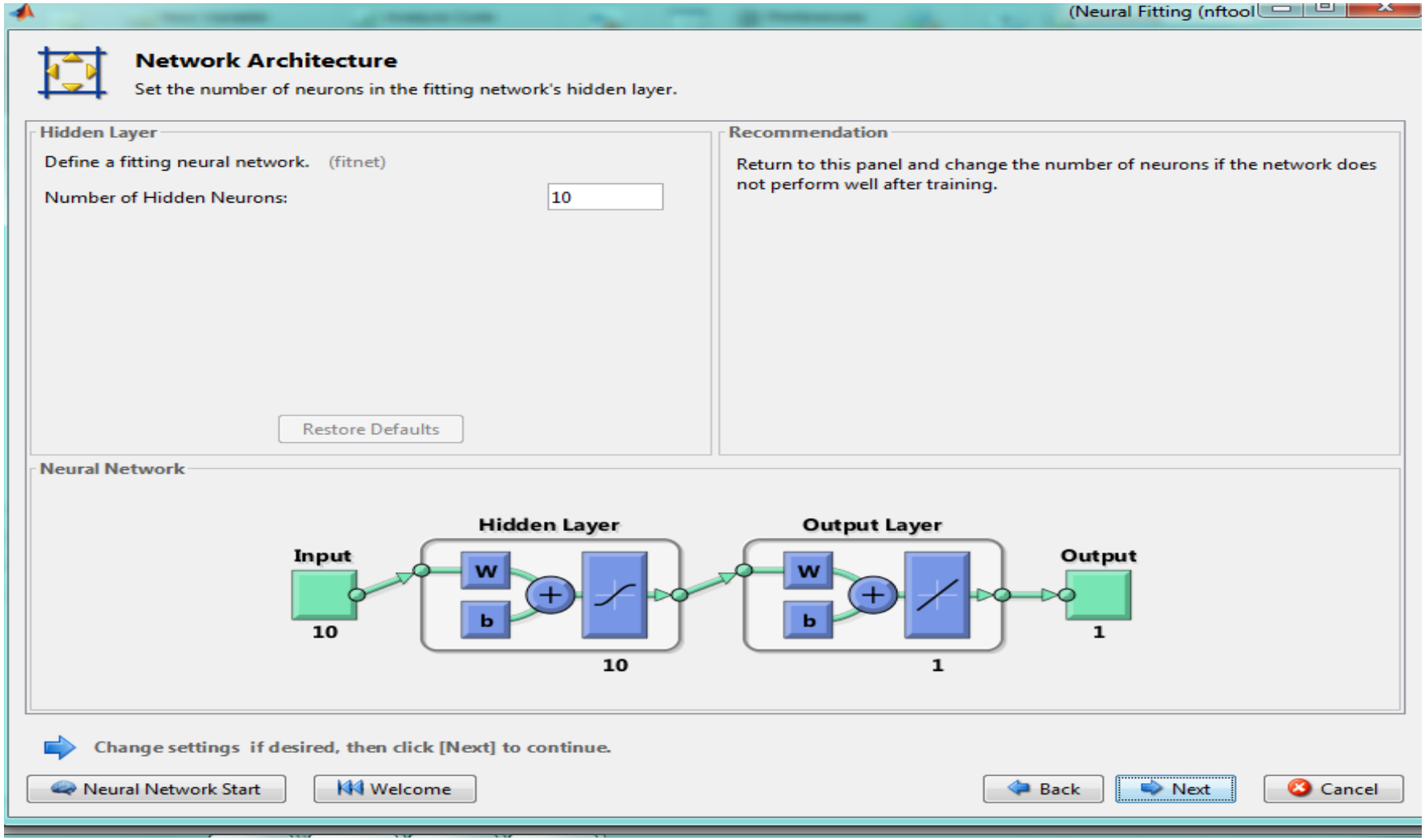


Figure 7-7-12 Number of Hidden Neurons Selection

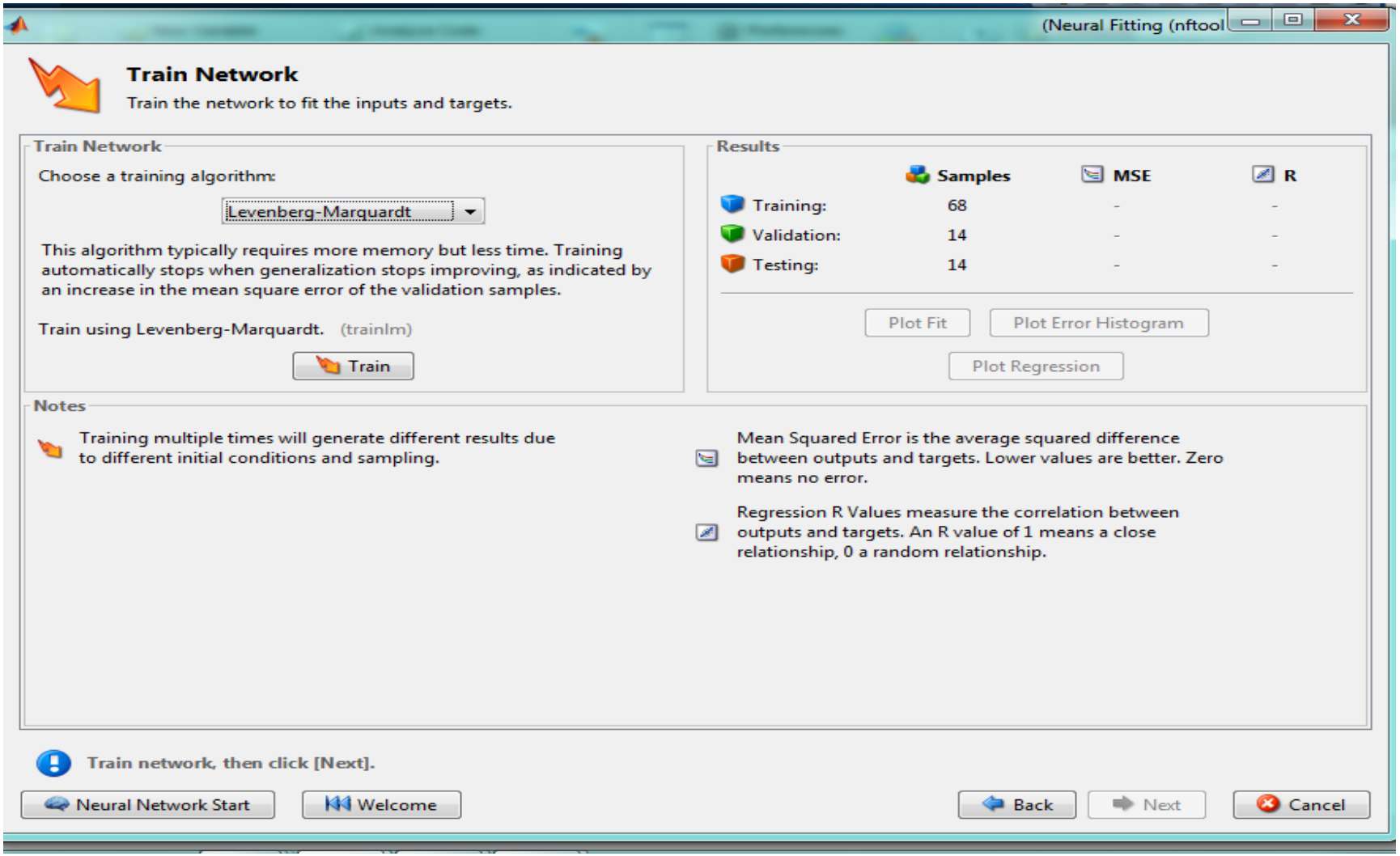


Figure 7-13 Training Algorithm Selection

7.5.3 Building regression models

The significant factors used in the development of the regression models for interim payment delay (Model I) and variation payment delay model (Model V) are the same as the factors used in the development of the neural model as defined in Chapter 6, Section 6.2. These factors are working as the independent variables for the regression model. All the independent variables data are known from historical data as explained previously in Section 7.5. Multiple regression models were created using Microsoft Excel (Data analysis tool) through the following steps: first by entering the data into the working spreadsheet, then opening the data analysis tool and choosing regression analysis as shown in Figure (7-14), after that defining the input y range and the input x range and the confidence level as shown in Figure (7-15), and finally the results is displayed as shown in Figure (7-16).

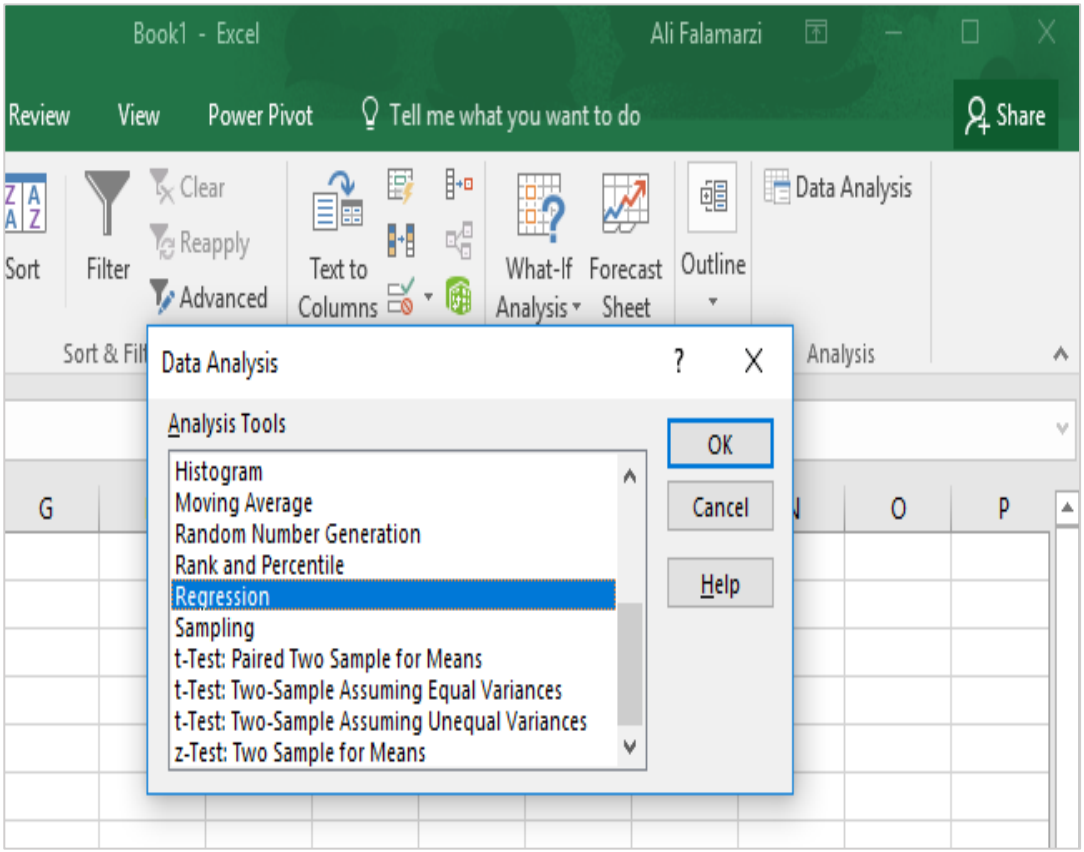


Figure 7-14 Opening the Data Analysis Tool

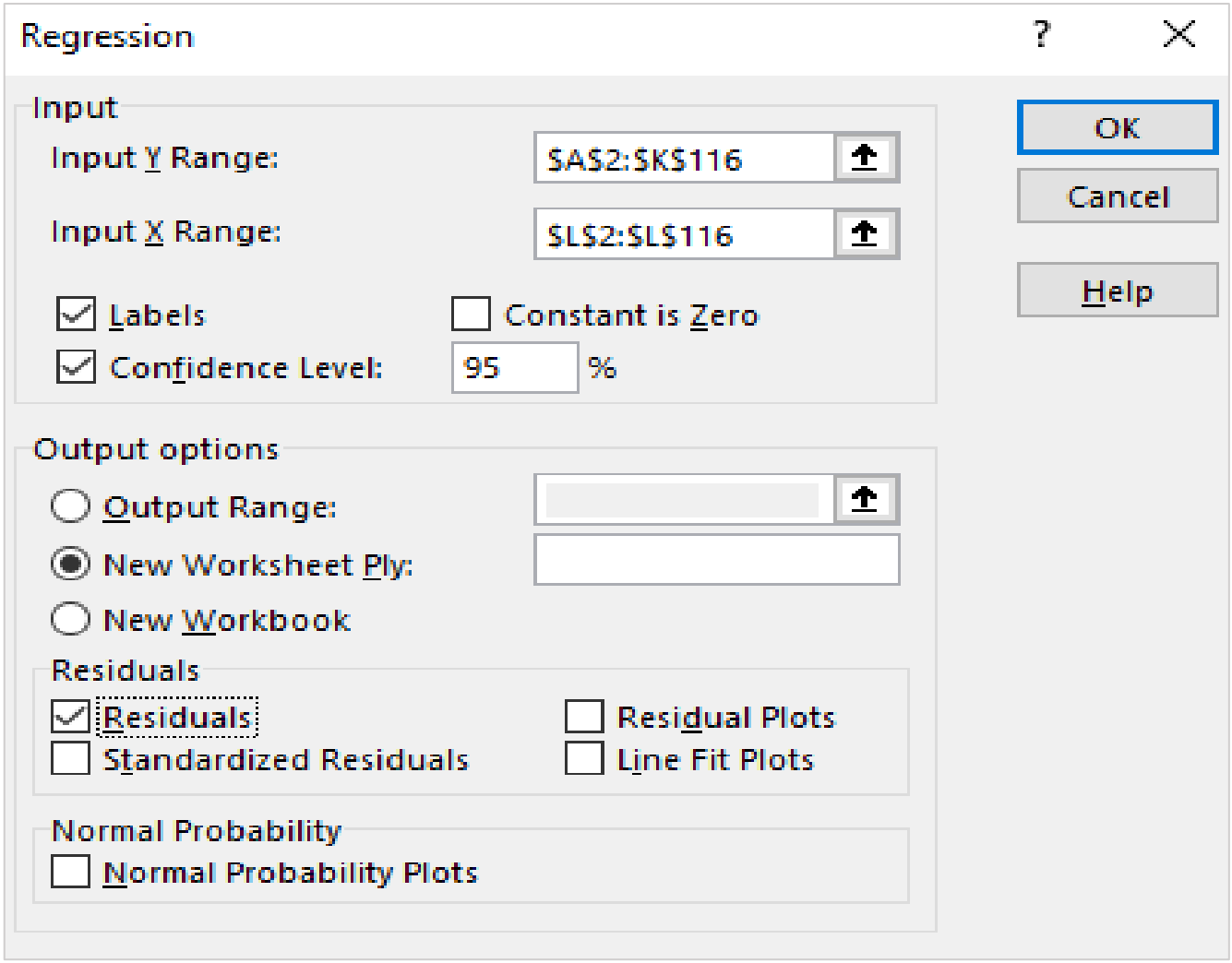


Figure 7-15 Defining the Input Y Range and the Input X Range

SUMMARY OUTPUT		Force Constant to Zero						
		FALSE						
Regression Statistics								
Multiple R	0.999							
R Square	0.998	Goodness of Fit >= 0.80						
Adjusted R Square	0.997							
Standard Error	2.963							
Observations	91							
							Confidence Level	
						0.95		0.99
	Coefficients	*Standard Error*	*t Stat*	*P-value*	*Lower 95%*	*Upper 95%*	*Lower 99%*	*Upper 99%*
Intercept	-68.82508982	7.248522413	-9.495050978	0.000	-83.25010914	-54.40007051	-87.9517	-49.6985
Claim review(days)	0.92033487	0.043673377	21.07313286	0.000	0.833422081	1.00724766	0.805094	1.035575
Payment by employer(days)	0.9515619	0.021178386	44.93080305	0.000	0.909415568	0.993708232	0.895679	1.007445
VO evaluation & Approval (days)	0.984292421	0.005970957	164.8466721	0.000	0.972409838	0.996175005	0.968537	1.000048
Amount	-4.67388E-06	1.93835E-05	-0.241127037	0.810	-4.32482E-05	3.39004E-05	-5.6E-05	4.65E-05
Balance of contingincy	8.39251E-06	1.01915E-05	0.823481889	0.413	-1.18892E-05	2.86742E-05	-1.8E-05	3.53E-05
Available contingency in the contract	1.92796E-05	4.00641E-05	0.481220137	0.632	-6.04504E-05	9.90097E-05	-8.6E-05	0.000125
Extension of time	-1.192719672	1.610043755	-0.740799539	0.461	-4.396808856	2.011369512	-5.44113	3.055688
Contractor Experience (years)	0.13687064	0.204736287	0.668521649	0.506	-0.270567555	0.544308836	-0.40337	0.677106
Cunsultant Experience (years)	0.094843967	0.376833595	0.251686603	0.802	-0.655078786	0.844766721	-0.8995	1.089191
Work Progress (Delay in days)	-0.020308009	0.017250089	-1.177269775	0.243	-0.054636781	0.014020763	-0.06583	0.02521

Figure 7-16 Regression Analysis Results

7.5.4 Models' Performance Evaluation

The performance of the models was recognized through comparing their predicted output over a test sample. The test sample consists of dataset of 18 historical interim payment cases for Model I and 14 historical variation payments cases for Model V. The evaluation approaches that have been used to test the models are as follows:

1- Mean Absolute Error (MAE).
2- Mean Absolute Percentage Error (MAPE).
3- Root Mean Square Error (RMSE).
4- Coefficient of Determination R-squared Values.

7.5.4.1 Mean Absolute Error (MAE)

MAE is calculated by the summation of the (absolute values) of the errors in order to have the total absolute errors and to divide it thereafter by the number of observations (predicted data) (Willmott and Matsuura, 2005). Equation (7-4) is used to calculate the MAE values:

$$\mathbf{MAE} = \frac{\sum \left| \mathbf{target\ output} - \mathbf{predicted\ output} \right|}{\mathbf{number\ of\ predicted\ output}} \qquad (7\text{-}4)$$

7.5.4.2 Mean Absolute Percentage Error (MAPE)

MAPE is based on percentage unit and is one of the famous techniques used for predicting measures. MAPE calculates the mean of absolute percentage error using Equation (7-5) (Jassal, 2011).

$$\mathrm{MAPE} = \frac{\sum \frac{\left| \mathbf{Target\ Output} - \mathbf{Predicted\ Output} \right|}{\mathbf{Target\ Output}}}{\mathbf{Number\ Of\ Predicted\ Output}} \times \mathbf{100} \qquad (7\text{-}5)$$

7.5.4.3 Root Mean Square Error (RMSE)

RMSE is a widely used metric for indicating model's performance. It is calculated by measuring the average squared error between the targeted and predicted values which helps in cancelling the problem of negative and positive errors, and finally by taking the square root of these average errors. Higher RMSE value reflects a weaker prediction (Jassal, 2011). The RMSE is calculated using Equation (7-6).

$$\textbf{RMSE}= \sqrt{\frac{\sum(\text{target output} - \text{predicted output})^2}{\text{number of predicted output}}} \qquad (7\text{-}6)$$

7.5.4.4 Coefficient of Determination (R squared values)

Which measures the amount of the total discrepancy showing how strong the linear relationship and the goodness of fit between predicted outputs and targets. The R-squared value ranges from 0 to 1. An R squared value near to 1 means a close relationship, near to 0 a random relationship (Legates and McCabe, 1999).

7.6 Chapter Summary

Model I and Model V formulations pass through several steps started with choosing the input factors (independent variables) for Model I which are: Delay in submitting valuation or Claim by the contractor (days), Claim review (days), Payment process by employer (days), Variations orders occurrence, Extension of time occurrence, Contractor experience (years), Consultant experience (years), Externally funded, Locally funded, Work progress (Delay in days) and Payment amount (BD). The model is used to predict the output factor (dependent variable), which is Interim payment delay (days). Secondly, choosing the input factors (independent variables) for Model V which are: Claim review (days), Payment processed by owner (days), Variations' orders evaluation and approval (days), Extension of time occurrence (binary), Payment amount (BD), Balance of contingency in the contract (BD), Available contingency in the contract (BD), Contractor experience (years), Consultant experience (years), Work progress (Delay in days). The model is used to predict the output factor: (dependent variable) which is variation payment delay (days).

The technique of data collection is through historical data collection from real payment cases for building construction governmental projects and by taking experts opinion. One hundred and fourteen case studies for interim payment delay and 91 case studies for variation payment delay are used in building the models. MATLAB (nntool), MATLAB (nftool) and Excel (Analysisi toolpak) are selected to formulate the models.

In order to ensure the validity of the models in measuring the effect of payment delay, many statistical performance measures are conducted, namely, Mean Absolute Error (MAE)), Mean Absolute Percentage Error (MAPE), Root Mean Square Error (RMSE) and Coefficient of Determination (R^2).

CHAPTER 8
Development of Interim Payment Delay Model (Model I)

8.1 Introduction
8.2 Developing Model I Using MATLAB nntool
8.3 Developing Model I using MATLAB nftool
8.4 Developing Model I using Regression Excel Tool
8.5 Comparison and Discussion of Model I Results
8.6 Chapter Summary

Chapter 8
Development of Interim Payment Delay Model (Model I)

8.1 Introduction

The interim payment delay model (Model I) is developed for the prediction of interim payment delay in days using 114 actual historical cases of MoW building projects. The model is developed as neural network model using MATLAB nntool and MATLAB nftool approaches, and as a multiple linear regression model using Excel data analysis tool pack approach. A total of seventy (70) trial Models were created to come out with best prediction model for interim payments delay.

8.2 Developing Model I Using MATLAB nntool

A total of thirty-three ANN models are trained, validated and tested for model I with different number of hidden neurons and training algorithms using MATLAB nntool. The one hundred and fourteen cases are divided into three sets: the training set consisting of 79 cases; the validation set consisting of 17 cases; and the testing set consisting of 18 cases. The below subsections show the performance of the test samples for multilayer (2 layers) feed-forward network with tan-sigmoid transfer function in the hidden layer and linear transfer function in the output layer for predicting interim payment delay. The training algorithms used are Levenberg-Marquardt algorithm, Bayesian Regulation and Scaled Conjugate Gradient. The performance of the training and validation samples for the thirty-three trial models are presented in Appendix 5. These samples are not involved in the evaluation of models to eliminate the risk of misevaluation, because during the training and learning some models may accomplish good results during the training and validation data set, but

very poor on new data which is the test set. Therefore, the evaluation of the models' performance is done by comparing their predicted output over an independent test sample as explained in Chapter six.

8.2.1 Model I performance using Levenberg-Marquardt

The best ANN observed using Levenberg-Marquardt algorithm is Model I-8 with 60 neurons in the hidden layer as per Table (8-1) and Figure (8-1). Model I-8 has a minimum value for RMSE of 13.557, MAE of 10.698 and MAPE of 29.252%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model I-8 are shown in Table (8-2). Table (8-2) shows that fourteen out of the eighteen predicted results are low biased, which is (78%) of the total results. Figure (8-2) shows the performance for the targeted interim payment delay (days) and the estimated interim payment delay (days) of the selected model, i.e. Model I-8. It is noticed that there isn't a noticeable matching between the two curves and they are rarley conciding in some points which is not reflecting very good performance for the network. The details of the predicted output for the eleven models' trials are shown in Appendix 6.

Table 8-1 Performance of Test Sample Model I Using (nntool and Levenberg-Marquardt)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Levenberg-Marquardt algorithm		
					RMSE	MAE	MAPE%
I-1	11	1	1	1	53.993	51.389	205.458
I-2	11	1	1	5	13.810	11.468	31.4104
I-3	11	1	1	10	31.130	22.862	50.303
I-4	11	1	1	20	20.482	16.309	48.511
I-5	11	1	1	30	26.828	18.928	81.978
I-6	11	1	1	40	45.812	36.039	82.666
I-7	11	1	1	50	20.506	17.906	49.333
I-8	11	1	1	60	13.557	10.698	29.251
I-9	11	1	1	70	18.902	14.863	42.434
I-10	11	1	1	80	20.792	15.832	41.699
I-11	11	1	1	100	41.708	31.921	66.497

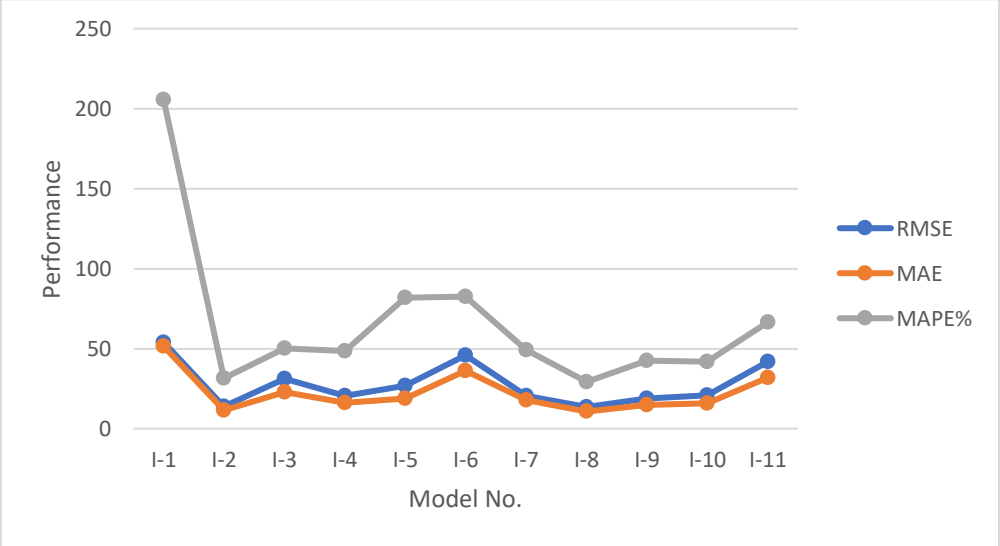


Figure 8-1 Performance of Model I Using (nntool and Levenberg-Marquardt)

Table 8-2 Test Sample and Predicted Results for Model I-8 (nntool)

Case No.	Target output (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24	23.12735	0.762	0.873	3.636
2	64	61.102	8.398	2.898	4.528
3	115	92.929	487.106	22.070	19.192
4	26	16.891	82.971	9.109	35.034
5	9	15.090	37.093	6.090	67.671
6	62	39.711	496.781	22.289	35.949
7	23	13.769	85.213	9.231	40.135
8	30	17.058	167.492	12.942	43.140
9	21	11.876	83.240	9.124	43.446
10	67	85.708	349.975	18.708	27.922
11	19	11.526	55.866	7.474	39.339
12	60	26.630	1113.552	33.370	55.617
13	19	18.099	0.812	0.901	4.744
14	90	97.386	54.554	7.386	8.207
15	27	15.074	142.233	11.926	44.171
16	40	29.401	112.330	10.599	26.496
17	25	28.015	9.088	3.015	12.059
18	30	25.425	20.935	4.575	15.252
Performance			RMSE	MAE	MAPE (%)
			13.557	10.699	29.252

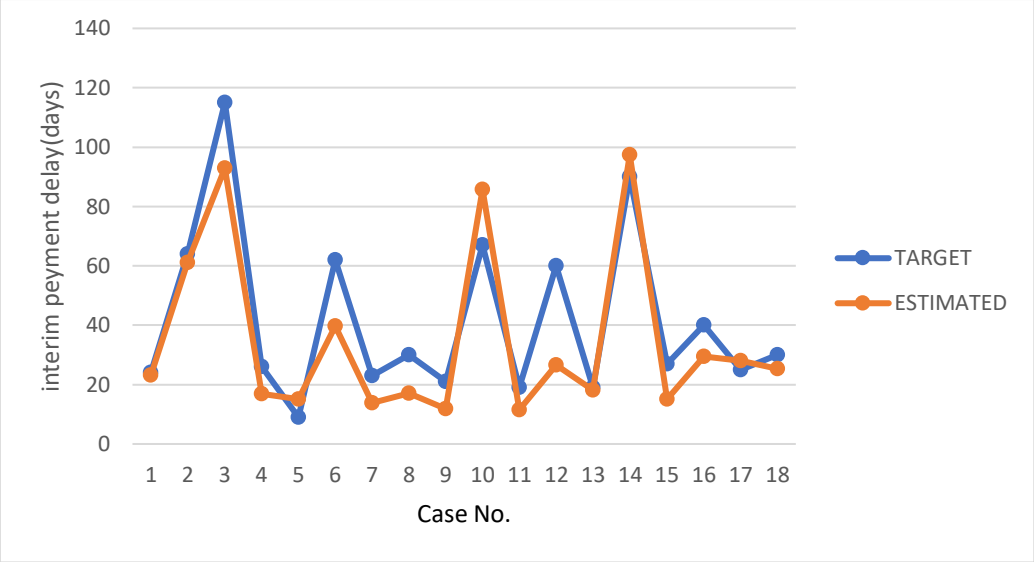


Figure 8-2 Test Sample and Predicted Results for Model I-8 (nntool)

8.2.2 Model I performance using Bayesian Regulation

The best ANN observed using Bayesian regulation algorithm is Model I-12 with 1 neuron in hidden layer as per Table (8-3) and Figure (8-3). Model I-12 has a value for RMSE of 11.370, MAE of 8.947 and MAPE% of 23.266%. Model I-12 was compared to Model I-22 which is the second best model using Bayesian regulation algorithm. Model I-22 has a value for RMSE of 12.105, MAE of 8.748 and MAPE% of 20.971%. RMSE and the MAE are more sensitive error measures than MAPE because they measure the errors with the same unit as the predicted data, while MAPE measures the error in percentage term. The best observed RMSE value is for Model I-12 with a difference of (12.105 - 11.370 = 0.735). On the other hand, the best observed MAE value is for Model-22 with a difference of (8.974 - 8.748 = 0.199). Therefore, Model I-12 is chosen to be the best ANN using Bayesian regulation algorithm because it has better RMSE results with a higher difference reflecting a better performance. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model I-12 are shown in Table (8-4). Table (8-4) shows that eleven out of the eighteen predicted results are low biased,

which is (61.1%) of the total results. Figure (8-4) shows the performance for the targeted interim payment delay (days) and the estimated interim payment delay (days) of the selected model, i.e. Model I-12. It is noticed that there isn't a noticeable matching between the two curves showing high error. The details of the predicted output for the eleven models' trials are is shown in Appendix 6.

Table 8-3 Performance of Test Sample Model I Using (nntool and Bayesian Regulation)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Bayesian regulation		
					RMSE	MAE	MAPE%
I-12	11	1	1	1	11.370	8.947	23.266
I-13	11	1	1	5	14.410	11.314	30.338
I-14	11	1	1	10	14.737	12.138	31.552
I-15	11	1	1	20	15.626	11.702	30.222
I-16	11	1	1	30	12.367	9.098	21.641
I-17	11	1	1	40	18.609	13.722	33.271
I-18	11	1	1	50	14.828	10.812	28.205
I-19	11	1	1	60	15.952	12.911	34.039
I-20	11	1	1	70	13.565	11.052	28.431
I-21	11	1	1	80	12.034	9.241	23.076
I-22	11	1	1	100	12.105	8.748	20.971

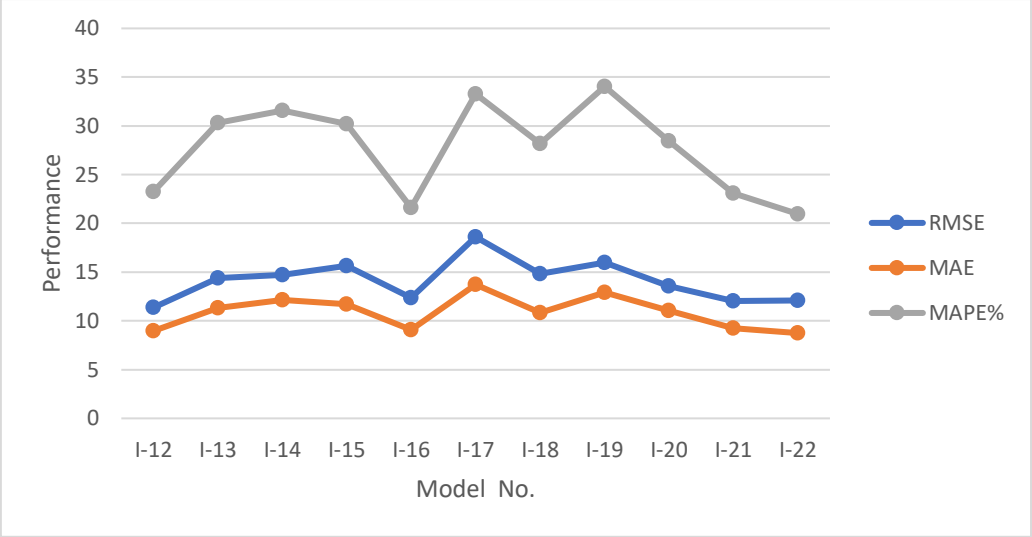


Figure 8-3 Performance of Test Sample Model I Using (nntool and Bayesian Regulation)

Table 8-4 Test Sample and Predicted Results for Model I-12 (nntool)

Case No.	Target Output (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24	25.050	1.101	1.050	4.373
2	64	76.232	149.616	12.232	19.112
3	115	89.302	660.409	25.698	22.346
4	26	19.825	38.132	6.175	23.750
5	9	15.448	41.579	6.448	71.646
6	62	42.727	371.461	19.273	31.086
7	23	19.643	11.269	3.357	14.595
8	30	24.349	31.937	5.651	18.837
9	21	14.585	41.153	6.415	30.548
10	67	89.108	488.773	22.108	32.997
11	19	16.325	7.156	2.675	14.079
12	60	45.082	222.557	14.918	24.864
13	19	20.027	1.056	1.027	5.408
14	90	93.144	9.884	3.144	3.493
15	27	18.219	77.102	8.781	32.521
16	40	50.062	101.237	10.062	25.154
17	25	19.217	33.443	5.783	23.132
18	30	23.748	39.085	6.252	20.839
Performance			RMSE	MAE	MAPE (%)
			11.370	8.947	23.266

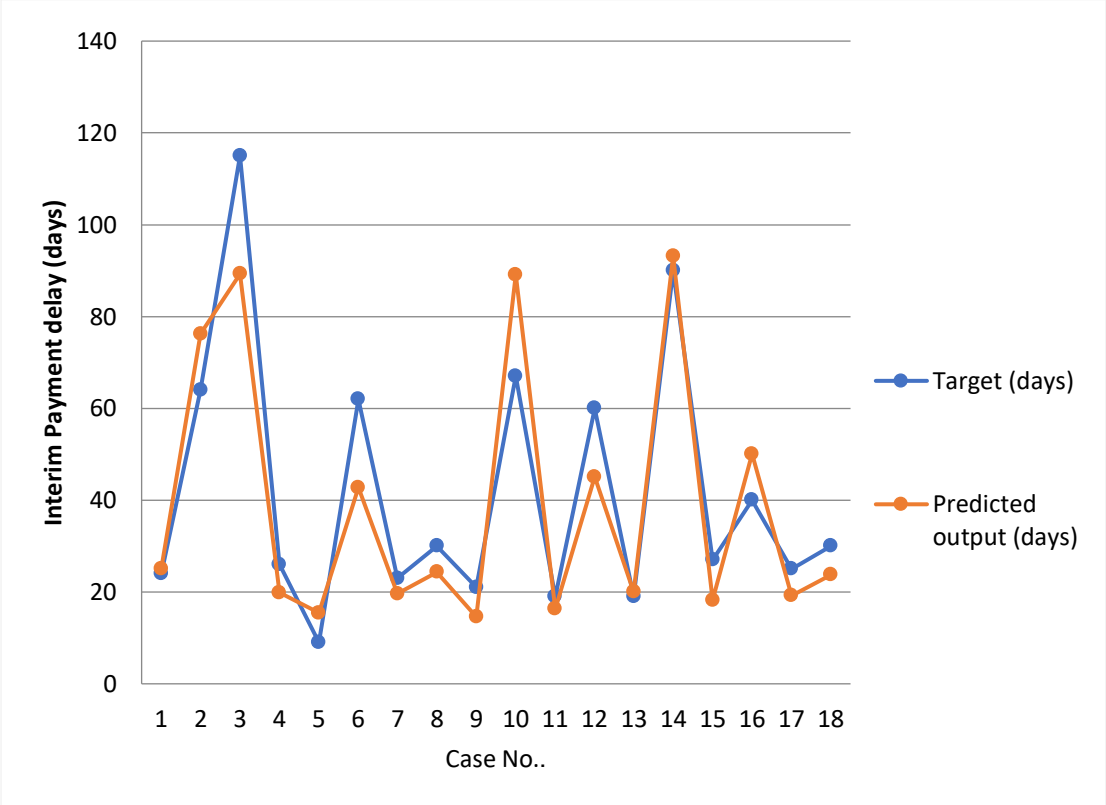


Figure 8-4 Test Sample and Predicted Results for Model I-22 (nntool)

8.2.3 Model I performance using Scaled Gradient

The best ANN observed using Scaled Conjugate Gradient is Model I-33 with 100 neurons in hidden layer as per Table (8-5) and Figure (8-5). Model I-33 has a minimum value for RMSE of 16.567, MAE of 13.113 and MAPE% of 33.69%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model I-33 are shown in Table (8-6). Table (8-6) shows that nine out of the eighteen predicted results are low biased which is (50%) of the total results. Figure (8-6) shows the performance for the targeted interim payment delay (days) and the estimated interim payment delay (days) of the selected model, i.e. Model I-33. It is noticed that there isn't a noticeable matching between the two curves showing high error. The details of the predicted output for the eleven models' trials are shown in Appendix 6.

Table 8-5 Performance of Test Sample for Model I Using (nntool and Scaled Conjugate Gradient)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Scaled Conjugate Gradient		
					RMSE	MAE	MAPE%
I-23	11	1	1	1	33.684	22.288	45.54
I-24	11	1	1	5	30.397	19.164	51.64
I-25	11	1	1	10	25.715	21.194	77.94
I-26	11	1	1	20	27.605	19.653	46.40
I-27	11	1	1	30	42.864	32.722	68.02
I-28	11	1	1	40	16.717	13.811	37.62
I-29	11	1	1	50	29.028	21.723	44.85
I-30	11	1	1	60	23.195	18.633	45.05
I-31	11	1	1	70	17.000	14.243	38.21
I-32	11	1	1	80	40.456	30.886	65.93
I-33	11	1	1	100	16.567	13.113	33.69

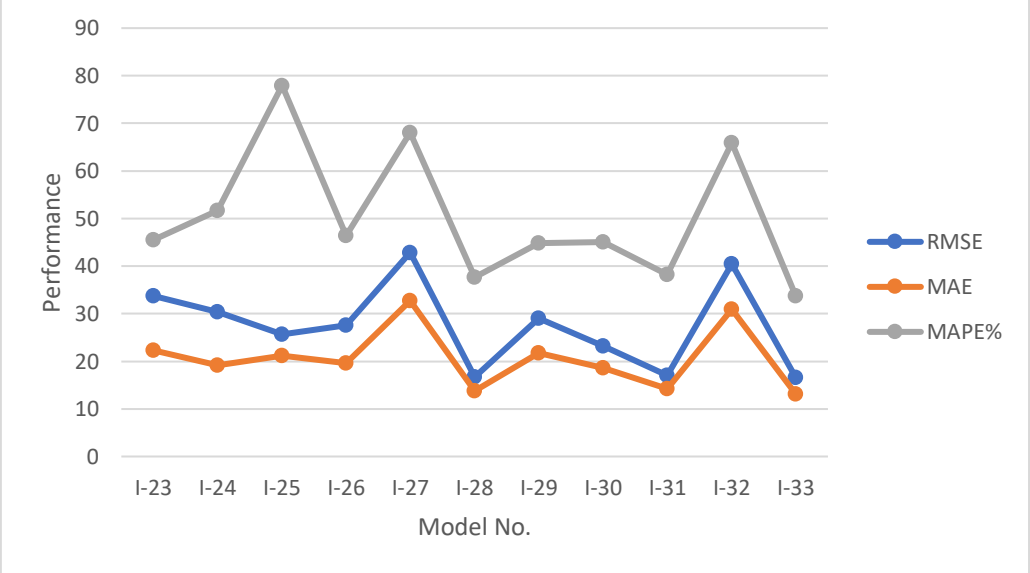


Figure 8-5 Performance of Test Sample Model I Using (nntool and Scaled Conjugate Gradient)

Table 8-6 Test Sample and Predicted Results for Model I-33 (nntool)

Case No.	Target output (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24	17.107	47.513	6.893	28.721
2	64	77.222	174.830	13.222	20.660
3	115	91.380	557.896	23.620	20.539
4	26	18.825	51.484	7.175	27.597
5	9	12.634	13.203	3.634	40.373
6	62	23.561	1477.583	38.439	61.999
7	23	24.668	2.782	1.668	7.252
8	30	61.278	978.339	31.278	104.261
9	21	12.622	70.192	8.378	39.896
10	67	92.479	649.185	25.479	38.029
11	19	14.976	16.196	4.024	21.181
12	60	73.410	179.840	13.410	22.351
13	19	23.409	19.442	4.409	23.207
14	90	101.353	128.885	11.353	12.614
15	27	17.842	83.873	9.158	33.919
16	40	53.418	180.054	13.418	33.546
17	25	21.831	10.040	3.169	12.674
18	30	12.698	299.365	17.302	57.674
Performance			RMSE	MAE	MAPE (%)
			16.568	13.113	33.694

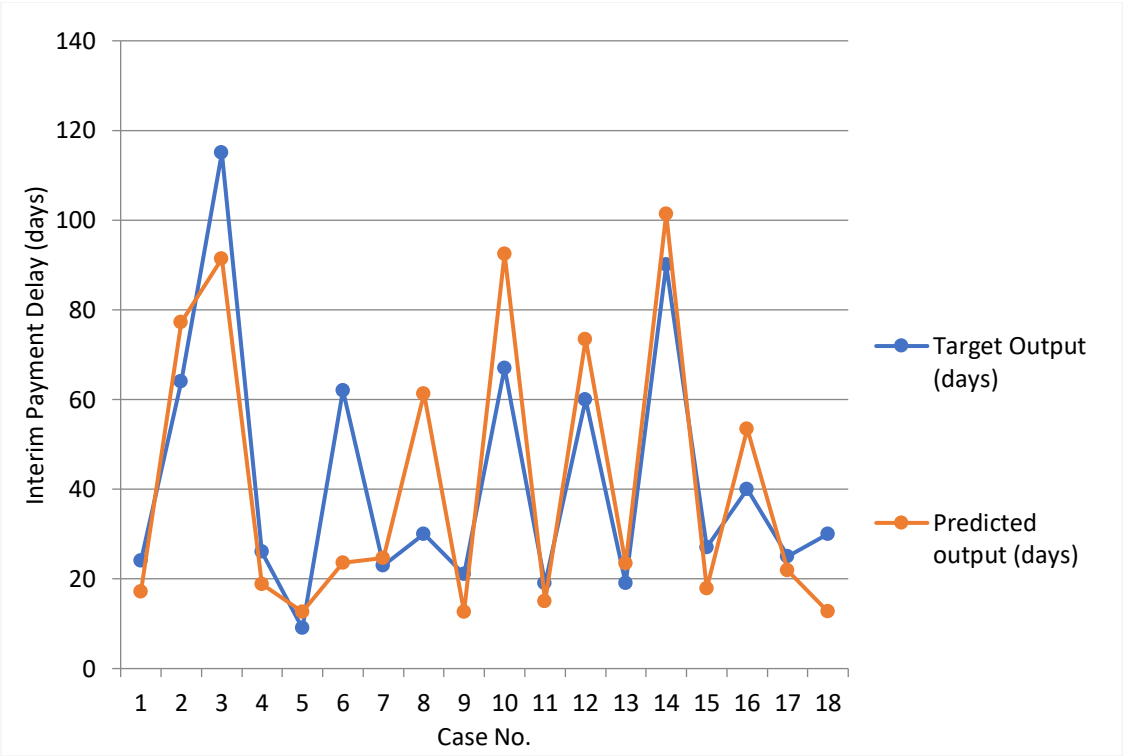


Figure 8-6 Test Sample and Predicted Results for Model I-33 (nntool)

8.2.4 Comparison of MATLAB nntool results

By comparing the computed results for each of the three selected models using MATLAB (nntool), Model I-12 with 1 neuron in hidden layer based on Bayesian Regulation algorithm and tan-sigmoid function has been chosen. It has the lowest error values for interim payment prediction with RMSE of 11.370, MAE of 8.947and MAPE value of 23.266% as shown in Table (8-7) and Figure (8-7). The ANN structure of the model chosen is shown in Figure (8-8). The best performance for the training sample of this model is at 29 epochs with MSE of 0.0033 as shown in Figure (8-9), and R value of 0.984 as shown in Figure (8-10) and Appendix 5. The validation sample performance is not available because the MATLAB Programme sets the validation parameter for Bayesian Regulation as zero.

Table 8-7 Selected Models for Model I Using MATLAB (nntool)

Model No	RMSE	MAE	MAPE (%)	Training Algorithm
Model I-8	13.557	10.699	29.252	Levenberg
Model I-12	11.370	8.947	23.266	**Bayesian**
Model I-33	16.567	13.113	33.694	Scaled

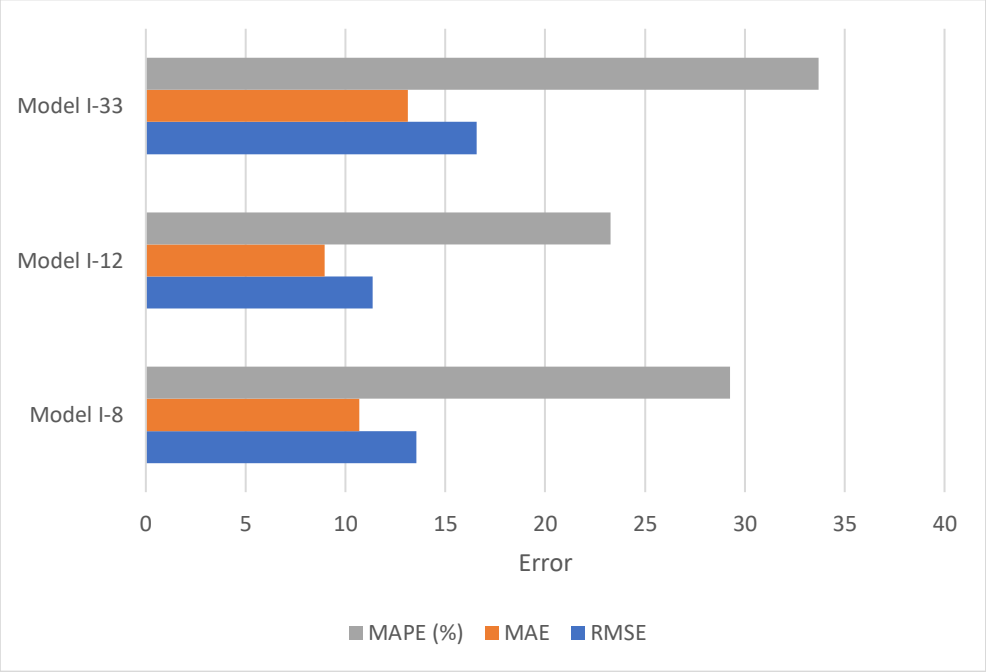


Figure 8-7 Selected Models for Model I from MATLAB (nntool)

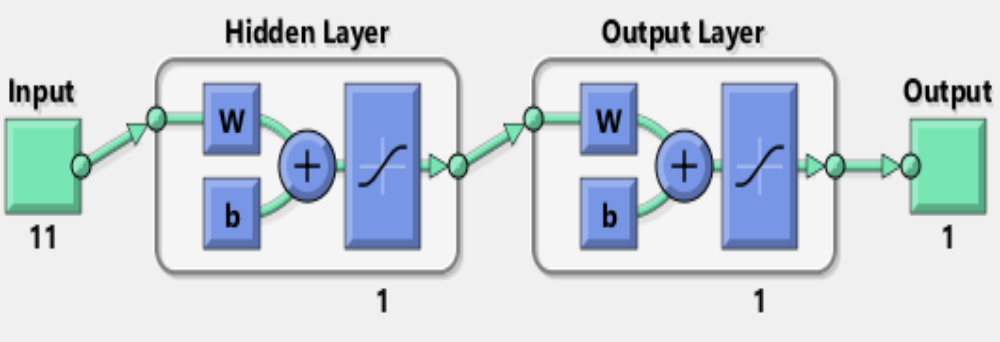


Figure 8-8 ANN Diagram for Model I-12

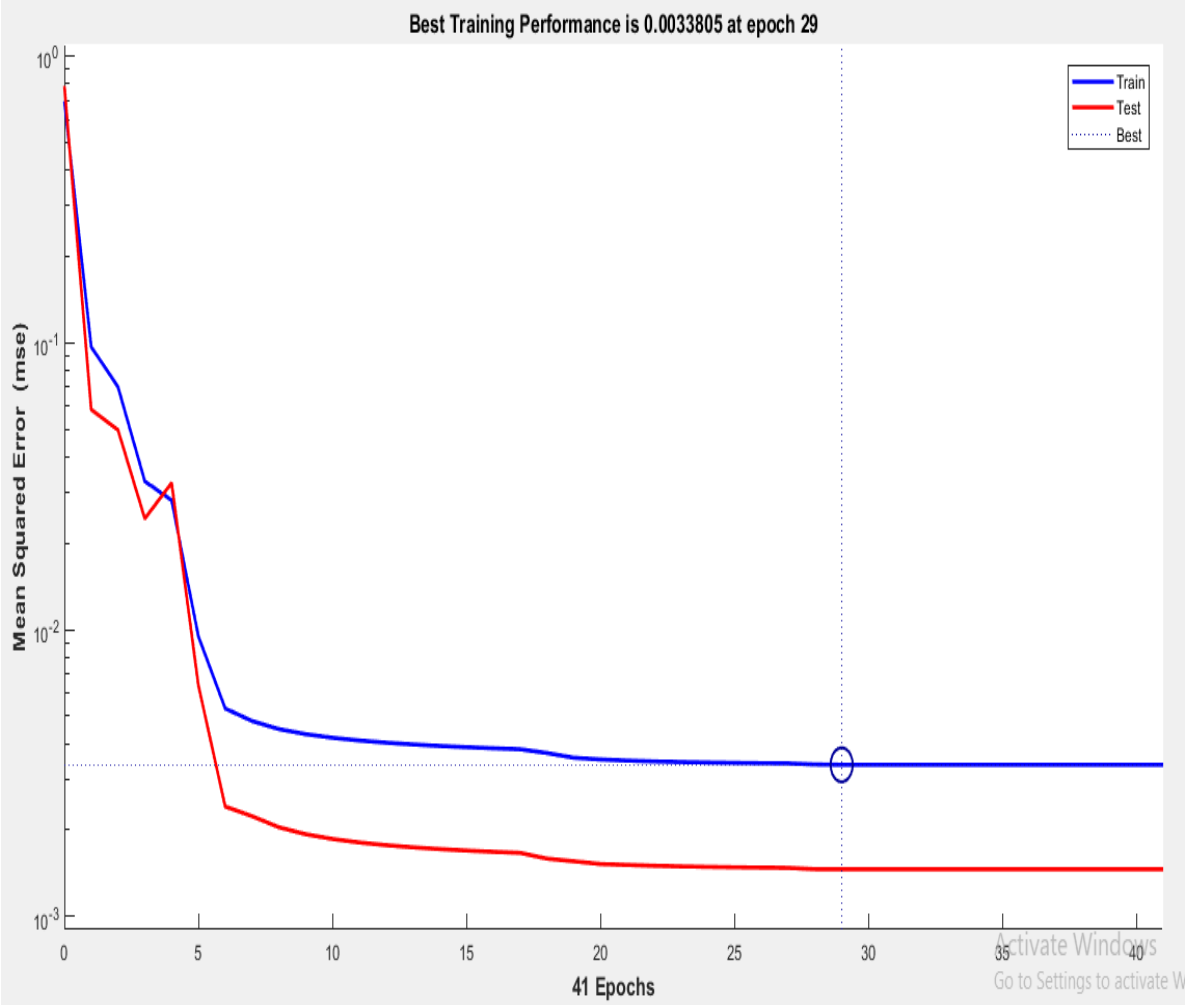


Figure 8-9 Training Performance for Model I-12

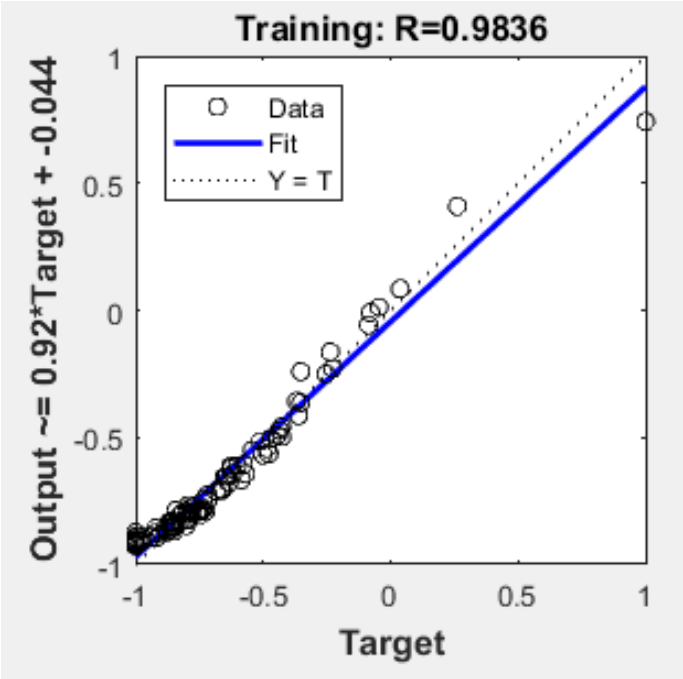


Figure 8-10 Training Sample R-Value Result for Model I-12

8.3 Developing Model I Using MATLAB nftool

A total of thirty-six ANN models are trained, validated and tested for model I using MATLAB nftool. The cases are divided into three sets: training set of 79 cases; the validation set of 17 cases; and the testing set of 18 cases. The below subsections along with Tables (8-8), (8-10), and (8-12) show the performance of the test samples for multilayer (2 layers) feed-forward network with different number of hidden neurons, tan-sigmoid transfer function in the hidden layer and linear transfer function in the output layer for predicting interim payment delay. The training algorithms used are Levenberg-Marquardt algorithm, Bayesian Regulation and Scaled Conjugate Gradient. The performance of the training and validation samples for the thirty-six trial models are presented in Appendix 7. These samples are not involved in the evaluation of models to eliminate the risk of misevaluation, because during the training and learning some models may accomplish good results during the training and validation data set, but very poor on new data which is the test set. Therefore, the evaluation of the models' performance is done by comparing their predicted output over an independent test sample as explained in Chapter 6.

8.3.1 Model I performance using Levenberg-Marquardt

The best ANN observed using Levenberg-Marquardt algorithm is Model I-38 with 30 neurons in the hidden layer as per Table (8-8) and Figure (8-11). Model I-38 has a minimum value for RMSE of 1.970, MAE of 0.916 and MAPE% of 3.657%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model I-38 are shown in Table (8-9). Table (8-9) shows that three out of eighteen predicted results are low biased which is (16%) of the total results. Figure (8-12) shows the performance for the targeted interim payment delay (days) and

the estimated interim payment delay (days) of the selected model, i.e. Model I-38. It is noticed that there is a noticeable matching between the two curves, which is showing very high performance for the network. The details of the predicted output for the twelve models' trials are shown in Appendix 8.

Table 8-8 Performance of Test Sample for Model I Using (nftool and Levenberg Algorithm)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Levenberg-Marquardt algorithm		
					RMSE	MAE	MAPE
I-34	11	1	1	1	3.719	3.371	12.031
I-35	11	1	1	5	3.410	2.890	11.641
I-36	11	1	1	10	3.744	3.118	10.899
I-37	11	1	1	20	3.679	1.539	6.183
I-38	11	1	1	30	1.970	0.916	3.657
I-39	11	1	1	40	8.424	6.998	23.501
I-40	11	1	1	50	7.898	3.966	12.236
I-41	11	1	1	60	8.872	4.238	11.156
I-42	11	1	1	70	13.865	6.615	19.561
I-43	11	1	1	80	21.536	11.482	34.086
I-44	11	1	1	90	15.645	10.126	23.205
I-45	11	1	1	100	12.139	5.369	16.890

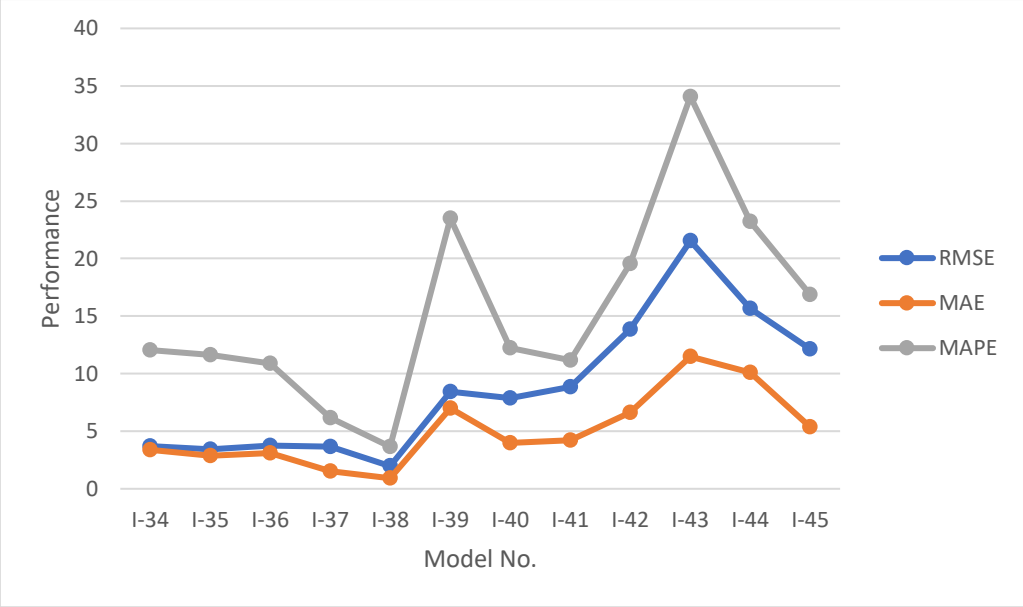


Figure 8-11 Performance of Test Sample for Model I Using (nftool and Levenberg Algorithm)

Table 8-9 Test Sample and Predicted Results for Model I-38 (nftool)

Case No.	Target output	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24	24.001	7.91E-07	8.90E-04	3.71E-03
2	64	61.526	6.12E+00	2.47E+00	3.87E+00
3	115	115.001	1.25E-06	1.12E-03	9.74E-04
4	26	26.001	1.01E-06	1.01E-03	3.87E-03
5	9	9.001	3.43E-07	5.86E-04	6.51E-03
6	62	62.001	1.38E-06	1.17E-03	1.89E-03
7	23	23.979	9.58E-01	9.79E-01	4.25E+00
8	30	30.002	5.68E-06	2.38E-03	7.94E-03
9	21	15.544	2.98E+01	5.46E+00	2.60E+01
10	67	66.999	3.34E-07	5.78E-04	8.62E-04
11	19	19.001	5.75E-07	7.59E-04	3.99E-03
12	60	60.001	4.92E-07	7.02E-04	1.17E-03
13	19	21.324	5.40E+00	2.32E+00	1.22E+01
14	90	90.001	5.22E-07	7.23E-04	8.03E-04
15	27	32.251	2.76E+01	5.25E+00	1.94E+01
16	40	40.001	9.79E-07	9.90E-04	2.47E-03
17	25	25.001	1.18E-06	1.09E-03	4.34E-03
18	30	30.000	3.82E-09	6.18E-05	2.06E-04
Performance			RMSE	MAE	MAPE (%)
			1.970	0.916	3.657

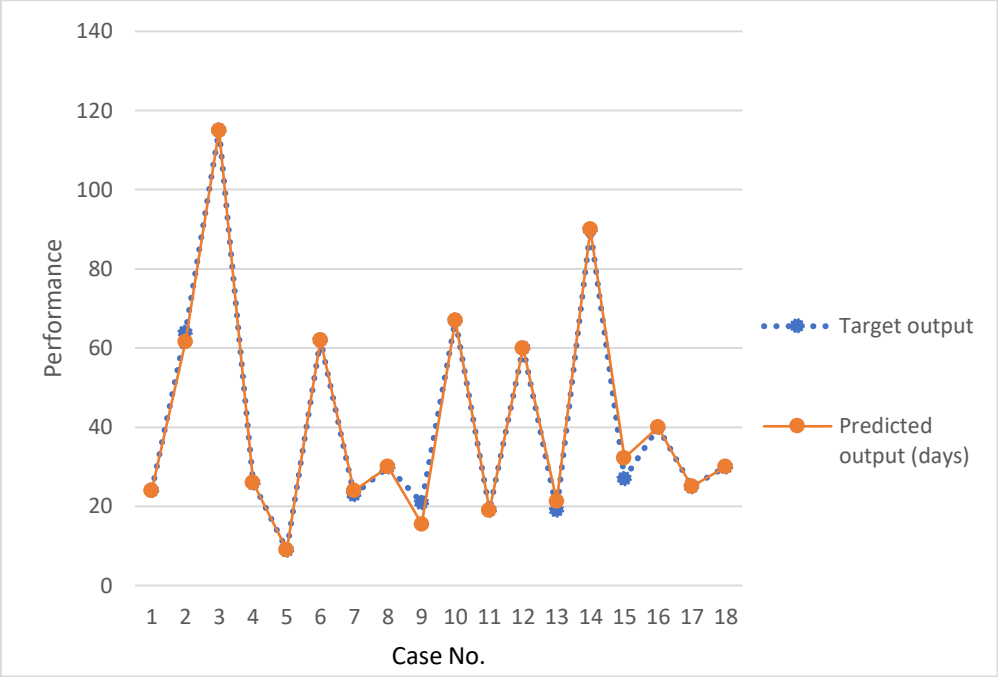


Figure 8-12 Test Sample and Predicted Results for Model I-38 (nftool)

8.3.2 Model I performance using Bayesian Regulation

The best ANN observed using Bayesian regulation algorithm is Model I-48 with 10 neurons in hidden layer as per Table (8-10) and Figure (8-13). Model I-48 has a minimum value for RMSE of 1.520, MAE of 0.969 and MAPE of 3.767%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model I-48 are shown in Table (8-11). Table (8-11) shows that nine out of eighteen predicted results are slightly low biased which is (50%) of the total results. Figure (8-14) shows the performance for the targeted interim payment delay (days) and the estimated interim payment delay (days) of the selected model, i.e. Model I-48. It is noticed that there is a noticeable matching between the two curves, which is showing very high performance for the network. The details of the predicted output for the twelve models' trials are shown in Appendix 8.

Table 8-10 Performance of Test Sample for Model I Using (nftool and Bayesian Regulation)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Bayesian regulation		
					RMSE	MAE	MAPE
I-46	11	1	1	1	3.871	3.519	12.442
I-47	11	1	1	5	2.469	2.044	7.388
I-48	11	1	1	10	1.520	0.969	3.767
I-49	11	1	1	20	2.770	1.822	5.535
I-50	11	1	1	30	2.469	1.822	7.078
I-51	11	1	1	40	2.746	1.007	4.089
I-52	11	1	1	50	3.631	2.379	8.221
I-53	11	1	1	60	5.512	2.832	10.460
I-54	11	1	1	70	3.110	1.216	5.714
I-55	11	1	1	80	21.536	11.482	34.086
I-56	11	1	1	90	5.373	2.795	8.426
I-57	11	1	1	100	5.252	2.332	8.108

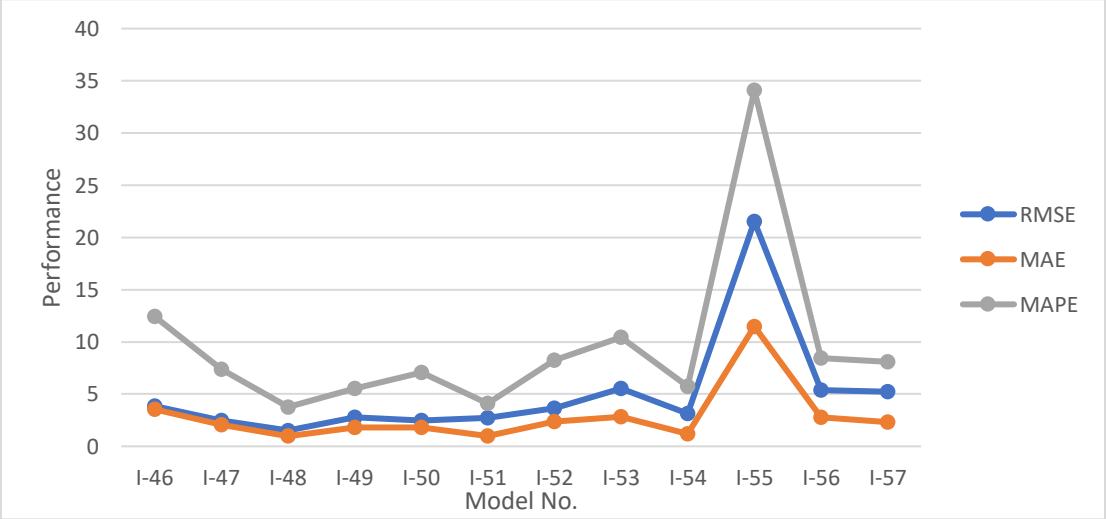


Figure 8-13 Performance of Test Sample for Model I Using (nntool and Bayesian Regulation)

Table 8-11 Test Sample and Predicted Results for Model I-48 (nftool)

Case No.	Target output	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24	24.308	0.095	0.308	1.285
2	64	63.592	0.166	0.408	0.637
3	115	115.238	0.057	0.238	0.207
4	26	25.258	0.551	0.742	2.856
5	9	9.386	0.149	0.386	4.288
6	62	61.349	0.424	0.651	1.051
7	23	26.534	12.486	3.534	15.363
8	30	29.170	0.688	0.830	2.765
9	21	16.505	20.209	4.495	21.407
10	67	67.269	0.073	0.269	0.402
11	19	18.840	0.026	0.160	0.843
12	60	57.974	4.104	2.026	3.376
13	19	20.108	1.227	1.108	5.829
14	90	89.674	0.106	0.326	0.362
15	27	27.672	0.452	0.672	2.490
16	40	40.054	0.003	0.054	0.135
17	25	25.576	0.331	0.576	2.303
18	30	29.338	0.439	0.662	2.208
Performance			RMSE	MAE	MAPE (%)
			1.520	0.969	3.767

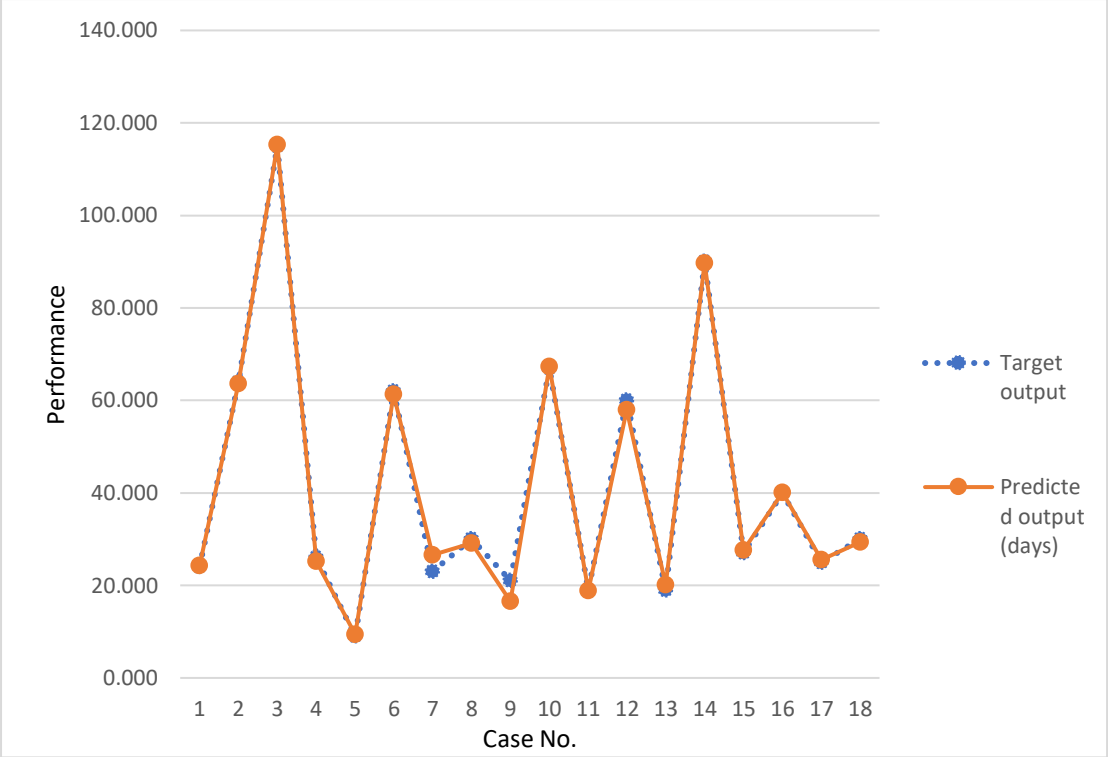


Figure 8-14 Test Sample and Predicted Results for Model I-48 (nftool)

8.3.3 Model I performance using Scaled Gradient

The best neural network observed using Scaled Conjugate Gradient is Model I-61 with 20 neurons in hidden layer as per Table (8-12) and Figure (8-15). Model I-61 has a minimum value for RMSE of 4.453, MAE of 2.573 and MAPE of 6.522%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model I-61 are shown in Table (8-13). Table (8-13) shows that eight out of eighteen predicted results are low biased which is (44%) of the total results. Figure (8-16) shows the performance for the targeted interim payment delay (days) and the estimated interim payment delay (days) of the selected model, i.e. Model I-61. It is noticed that there is a modest matching between the two curves which may reflect acceptable results. The details of the predicted output for the twelve models' trials are shown in Appendix 8.

Table 8-12 Performance of Test Sample for Model I Using (nftool and Scaled Conjugate Gradient)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Scaled Conjugate Gradient		
					RMSE	MAE	MAPE
I-58	11	1	1	1	16.008	12.037	36.611
I-59	11	1	1	5	6.547	5.640	16.810
I-60	11	1	1	10	6.425	4.396	16.702
I-61	11	1	1	20	4.453	2.573	6.522
I-62	11	1	1	30	6.074	3.878	11.112
I-63	11	1	1	40	11.144	7.160	25.718
I-64	11	1	1	50	14.371	10.766	34.679
I-65	11	1	1	60	9.657	6.443	28.003
I-66	11	1	1	70	19.257	16.932	64.145
I-67	11	1	1	80	14.214	12.025	53.859
I-68	11	1	1	90	22.936	14.821	52.962
I-69	11	1	1	100	31.920	20.594	63.630

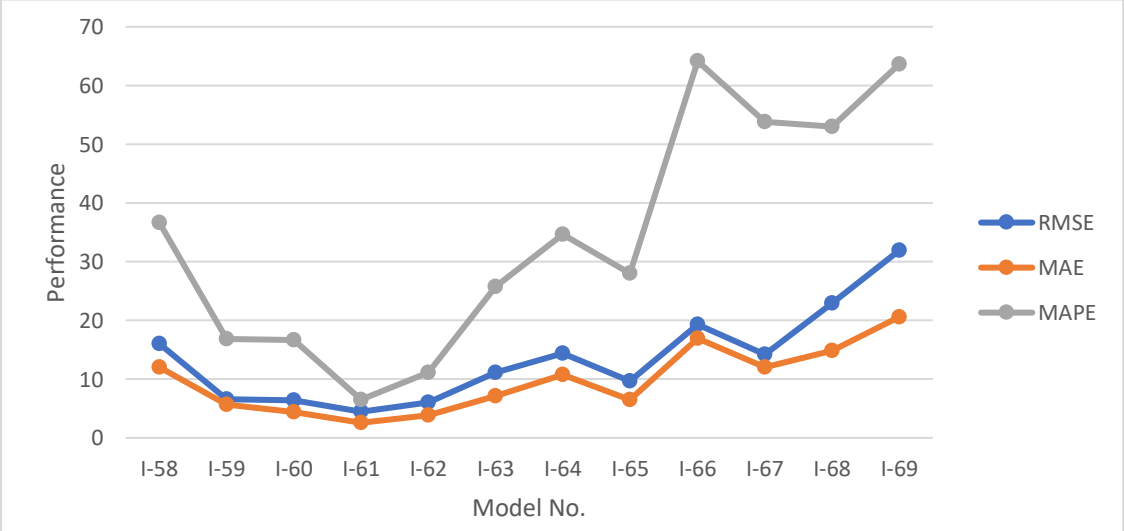


Figure 8-15 Performance of Test Sample for Model I Using (nftool and Scaled Conjugate Gradient)

Table 8-13 Test Sample and Predicted Results for Model I-61 (nftool)

Case No.	Target output	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24.000	25.095	1.200	1.095	4.564
2	64.000	77.050	170.298	13.050	20.390
3	115.000	115.567	0.321	0.567	0.493
4	26.000	26.872	0.760	0.872	3.353
5	9.000	8.918	0.007	0.082	0.911
6	62.000	60.525	2.177	1.475	2.380
7	23.000	27.362	19.023	4.362	18.963
8	30.000	28.682	1.738	1.318	4.395
9	21.000	16.488	20.360	4.512	21.487
10	67.000	78.401	129.977	11.401	17.016
11	19.000	18.510	0.240	0.490	2.577
12	60.000	57.694	5.320	2.306	3.844
13	19.000	20.831	3.352	1.831	9.636
14	90.000	88.869	1.279	1.131	1.257
15	27.000	27.493	0.243	0.493	1.825
16	40.000	40.610	0.372	0.610	1.524
17	25.000	25.530	0.281	0.530	2.121
18	30.000	29.802	0.039	0.198	0.661
Performance			RMSE	MAE	MAPE (%)
			4.453	2.573	6.522

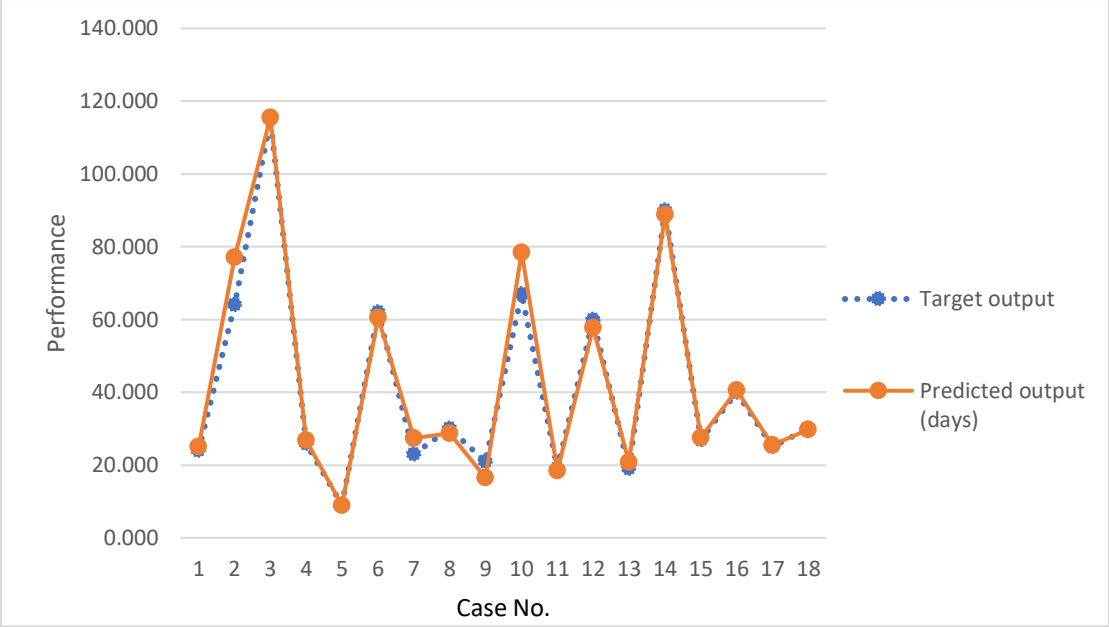


Figure 8-16 Test Sample and Predicted Results for Model I-61 (nftool)

8.3.4 Comparison of MATLAB nftool results

By comparing the computed results for each of the selected models using MATLAB (nftool), Model I-48 with 10 neurons in hidden layer based on Bayesian Regulation algorithm and tan-sigmoid function has been chosen as it has the lowest error values for interim payment prediction with RMSE of 1.520, MAE of 0.969 and MAPE value of 3.767% as shown in Table (8-14) and Figure (8-17). The ANN structure of the model chosen is shown in Figure (8-18). The best performance for the training sample of this model is at 120 epochs with MSE of 1.547 as shown in Figure (8-19), and R value of 0.999 which is reflecting a good fit of results and high predictive power of the network as shown in Figure (8-20) and Appendix 7. The validation sample performance is not available because the MATLAB Programme sets the validation parameter for Bayesian Regulation as zero.

Table 8-14 Selected Models for Model I Using MATLAB (nftool)

Model No	MAE	RMSE	MAPE (%)	Training Algorithm
Model I-38	1.970	0.916	3.657	Levenberg
Model I-48	**0.969**	**1.520**	**3.767**	**Bayesian**
Model I-61	2.573	4.453	6.522	Scaled

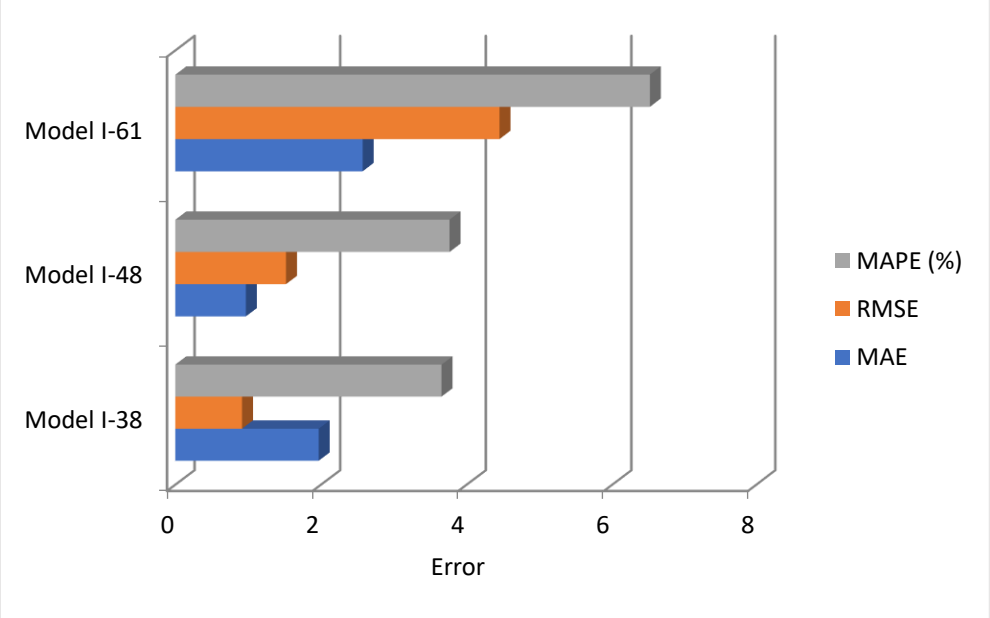


Figure 8-17 Selected Models for Model I from MATLAB (nftool)

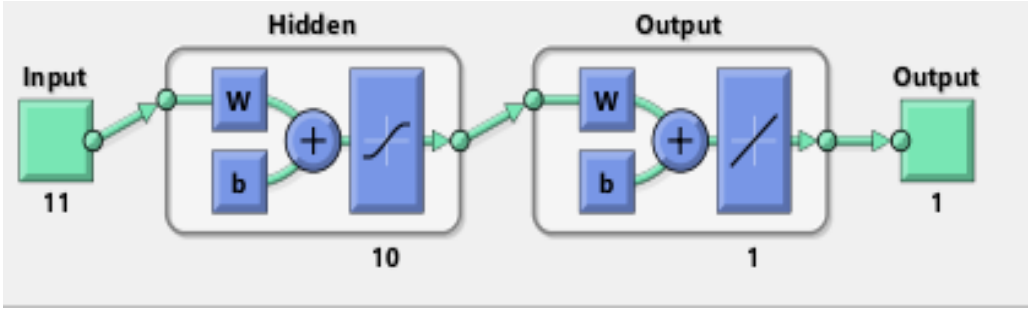


Figure 8-18 ANN Diagram for Model I-48

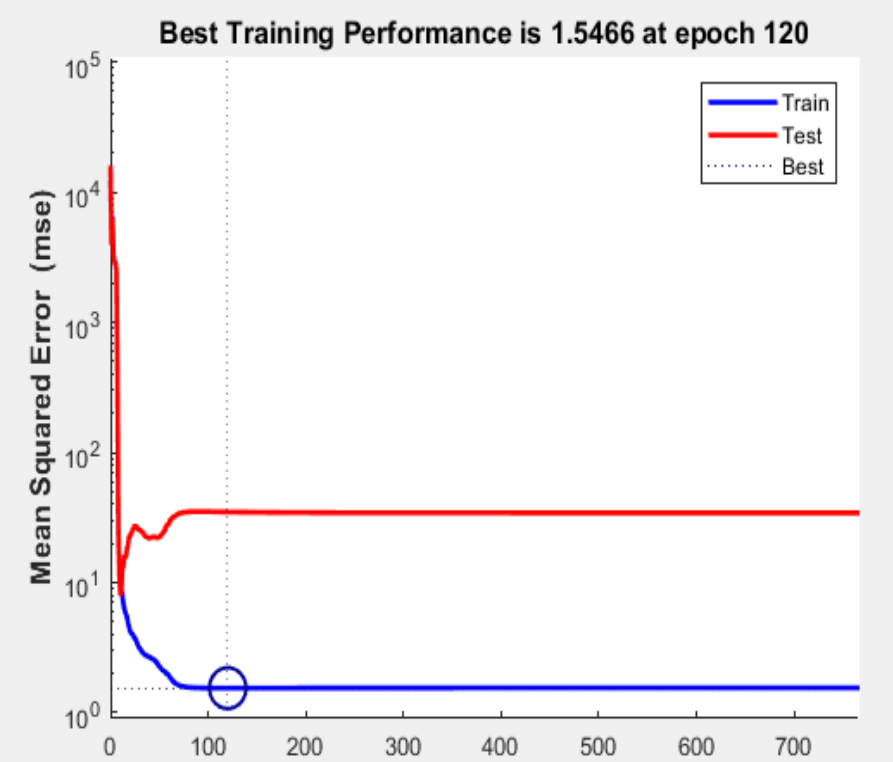


Figure 8-19 Training Performance for Model I-48

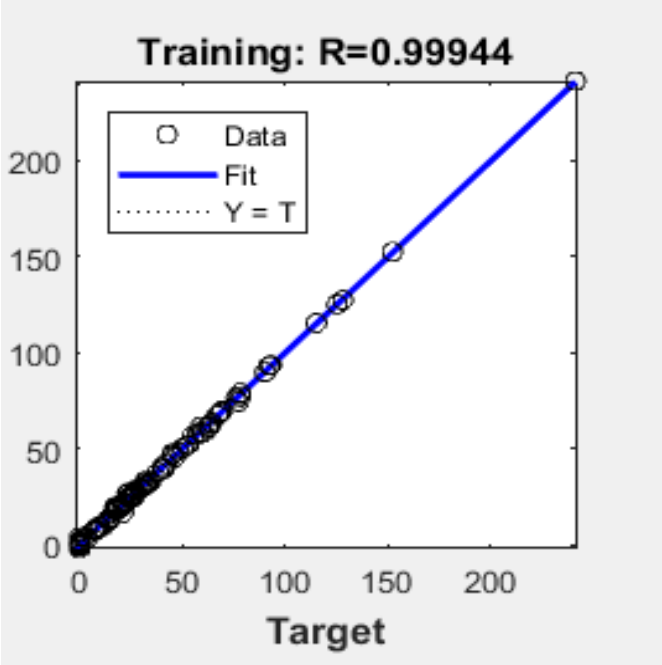


Figure 8-20 Training and Test Samples R-Value Result for Model I-48

8.4 Developing of Model I Using Regression Excel Tool

Linear regression model is used to statistically estimate the relationships among independent and dependent variables. The model is developed using Microsoft Excel (data analysis toolpak) in order to predict the payment delay for interim payment using 114 historical cases. Ninety-six cases are used for development and 18 cases are used for testing the model. Linear regression analysis is used to predict the output of dependent variable interim payment delay (Y) on the basis of the independent variables which are: Delay in the submission of payment evaluation (X1); Claim review (X2); Payment process by owner (X3); Variation orders occurrence (X4); Extension of time occurrence (X5); Contractor experience (X6); Consultant experience (X7); Externally funded projects (X8); Locally funded projects (X9); Work progress (X10); Payment amount (X11). The linear regression output (Model I-70) is as presented by Equation (8-1), this equation is a result of the outputs shown in Table (8-17):

$$Y = -48.56 +1.005*X1 +1.022*X2 +0.981*X3 +1.185*X4 -0.268*X5 -0.180*X6 +0.766*X7 +0*X8 +1.484*X9 +0.002*X10 +0*X11 \quad (8\text{-}1)$$

The goodness of fit for the Regression Model is shown in Table (8-15) based on 95% confidence intervals. The Multiple R value represents the correlation coefficient of determination with a value of 0.996 showing a strong linear relationship between the predicted output and targets. The calculated R-squared value of 99.2% is representing the goodness of fit for the above equation. This means that 99.2% of the variance in the dependent variable (payment delay) is explained by the model indicating a high predictive power of the model. The adjusted R square is equal to 0.991 and

it represents R square value in term of the number of variables in the model. As shown both values are very close to each other. The computed standard error is equal to 3.453%, this tells that the average distance for the predicted points falls about 3.453% from the regression line, this result asses a high precision of the prediction by the model. The obtained P-value of 2.054×10^{-103}(considered extremely significant) and reflecting the probability for obtaining an R squared value of 99.2%.

Table 8-15 Goodness of Fit of Model I-70 Using Equation (8-1)

Goodness of Fit >= 0.80	
Regression Statistics	
Multiple R	0.996
R Square	0.992
Adjusted R Square	0.991
Standard Error	3.453
P-Value	2.054E-103
Observations	114

Table (8-16) shows the variables codes, coefficients, the standard error along with the lower and upper bounds of the confidence interval of each variable. The table shows that seven out of twelve variables (58.3%) have a positive biased coefficient, three out of twelve (25%) have negative biased coefficients and two out of twelve (16.6%) have zero value coefficients. As shown in the table for a 95% confidence prediction interval, about 95% of the observations should fall within coefficient value ± 2*Standard error from the regression line, these ranges of confidence intervals are expected to comprise the right value of the coefficient for each variable of the regression model.

Table 8-16 Regression Coefficients for Model I-70 Using Equation (8-1)

Code	Variables	Coefficients	Standard Error	Lower 95%	Upper 95%
C	Constant	-48.56	2.791	-54.1	-43.0
X1	Delay in the submission of payment evaluation (days)	1.005	0.036	0.93	1.08
X2	Claim review(days)	1.022	0.012	0.99	1.05
X3	Payment process by owner (days)	0.981	0.013	0.96	1.01
X4	Variation orders occurrence (binary)	1.185	0.709	-0.22	2.59
X5	Extension of time occurrence (binary)	-0.268	1.049	-2.35	1.81
X6	Contractor Experience (years)	-0.180	0.148	-0.47	0.11
X7	Consultant's experience (years)	0.766	0.350	0.07	1.46
X8	Externally funded project (binary)	0.000	0.000	0.00	0.00
X9	Locally funded project (binary)	1.484	1.327	-1.14	4.12
X10	Work progress (delay in days)	0.002	0.007	-0.01	0.02
X11	Payment amount (BD)	0.000	2.72E-06	-4.49E-06	6.29E-06

Table (8-17) shows the P-values of the regression model which examine the effect of each independent variable on the dependent variable and its significance to the model. For a 95% confidence level a P-value of more than or equal to 0.05 is considered not significant, while P-value of less than 0.05 is considered significant. The results show that seven variables are considered as not significant, four out of these seven are binary (0,1) variables which are: externally funded projects, locally funded project, Variation orders occurrence (binary), and Extension of time occurrence (binary). This indicates that the model considers all the binary (0, 1) input data as not significant. The other non-significant factors are: Work progress (delay in days), Payment amount (BD), and Contractor experience. This is apparent because these three factors do not have a direct effect on the payment delay as shown in Figure (8-21) and Figure (8-22) below. The Model consederation of "Extension of time" and "Variation" as non-significant factors can be explained by their non-direct relations with payment delay. These relationships can be expressed as shown in Figure (8-21). Where a delay in the approval of extension of time and variation orders by the consultant cause a delay in issuance of payment certificate and as a result a delay in MoF process which results eventually in a payment delay to contractor. On the other hand, the non-direct relation of work progress to payment delay is shown in Figure (8-22). Where the delay in progress of work of a project might cause: 1) a delay in the documentations required to support payment and/or 2) a delay in payment evaluation, and/or 3) the occurrence of extension of time. These three might lead to delay in payment evaluation and review, a delay in issuance of payment certificate, a delay in MoF process, and eventually a delay in payment to contractor.

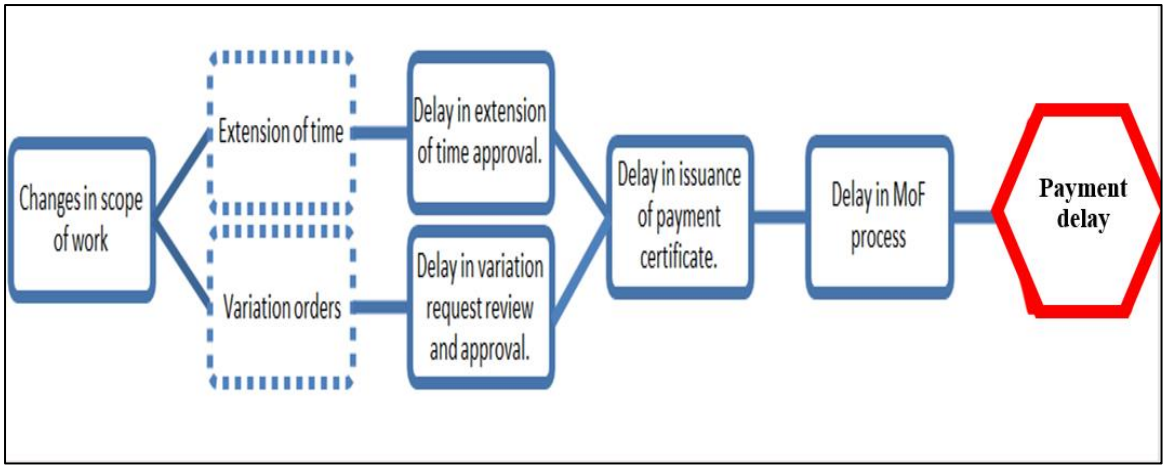


Figure 8-21 Extension of Time and Variation Orders Effect on Payment Delay

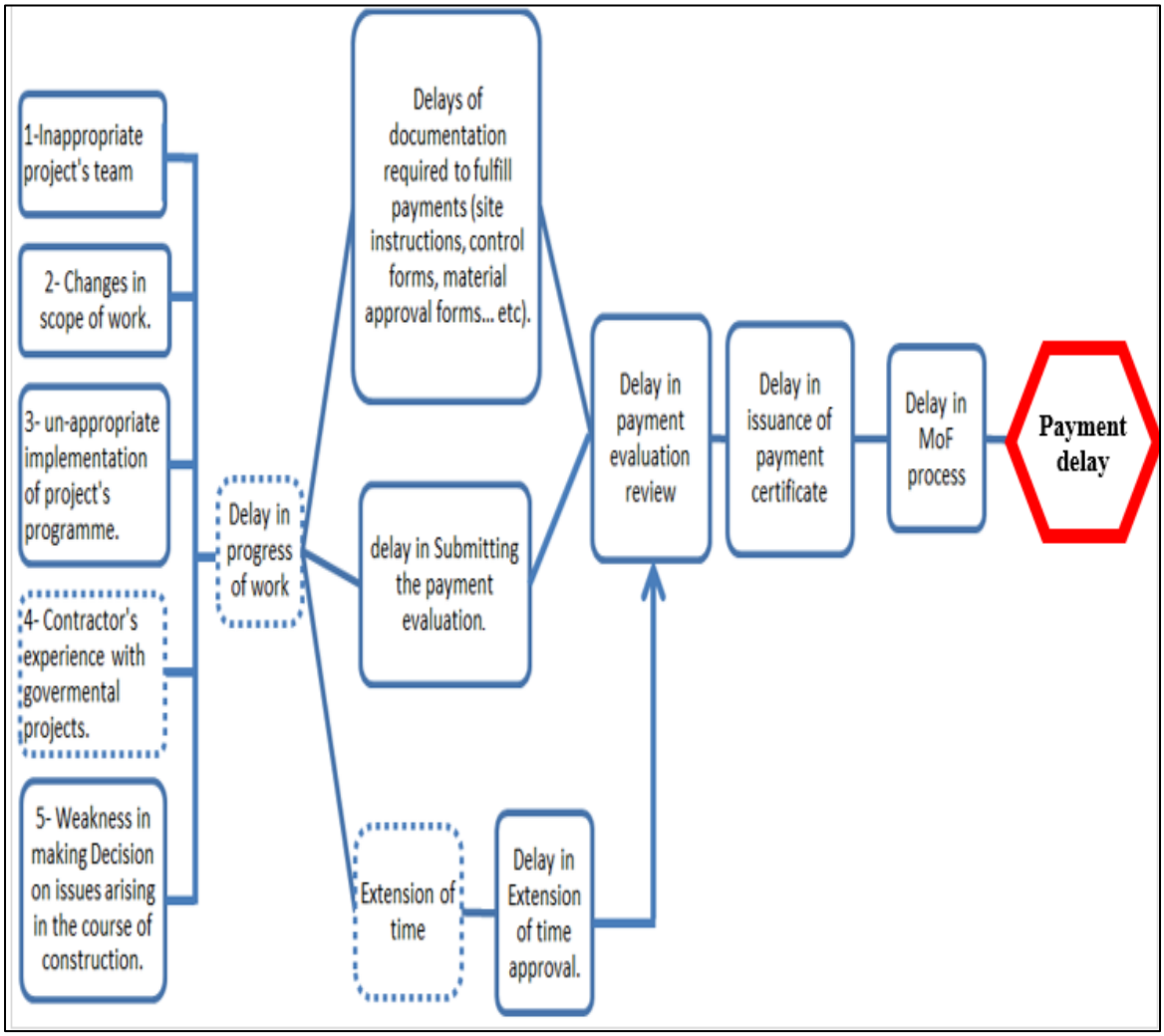


Figure 8-22 Effect of Nonsignificant Factors on Payment Delay

Table 8-17 Significant and Non-Significant Variables Model I-70 Using Equation (8-1)

Code	Variables	t Stat	P-value	Significance
C	Constant	-17.40	1.406E-32	Significant
X1	Delay in the submission of payment evaluation (days)	27.78	6.399E-50	Significant
X2	Claim review (days)	83.94	2.288E-97	Significant
X3	Payment process by owner (days)	75.63	9.819E-93	Significant
X4	Variation orders occurrence (binary)	1.67	0.097	Not Significant
X5	Extension of time occurrence (binary)	-0.26	0.79	Not Significant
X6	Contractor experience (years)	-1.22	0.22	Not Significant
X7	Consultant's experience (years)	2.19	0.031	Significant
X8	Externally funded project (binary)	0	1.00	Not Significant
X9	Locally funded project (binary)	1.12	0.26	Not Significant
X10	Work progress (delay in days)	0.28	0.78	Not Significant
X11	Payment amount (BD)	0.33	0.74	Not Significant

Accordingly, the model is modified by eliminating the non-significant factors and including only the significant independent factors as per the result of Table (8-17), which are: Delay in the submission of payment evaluation (X1), Claim review (X2), Payment process by owner (X3) and Consultant's Experience (X7), as presented in Equation (8-2).

$$Y = -48.96 + 0.997*X1 + 1.023*X2 + 0.978*X3 + 0.820*X7 \quad (8\text{-}2)$$

The goodness of fit for the regression model of equation (8-2) is shown in Table (8-18) based on 95% confidence intervals. The Multiple R value is equal to 0.996 showing a very good linear relationship between the predicted output and targets. The calculated R-squared value is equal to 99.1% which is indicating a great predictive power of the model. The computed standard error is equal to 3.453, this result asses a high precision of the prediction by the model. The obtained P-value of 3.699×10^{-112}(considered extremely significant) and reflecting the probability for obtaining an R squared value of 99.1%.

Table 8-18 Goodness of Fit of Model I-70 Using Equation (8-2)

Regression Statistics	
Multiple R	0.996
R Square	0.991
Adjusted R Square	0.991
Standard Error	3.450
P-Value	3.699E-112
Observations	114

Table 8-19 Regression Coefficients for Model I-70 Using Equation (8-2)

Code	**Variables**	**Coefficients**	**Standard Error**	**Lower 95%**	**Upper 95%**
C	Constant	-48.961	1.882	-52.691	-45.230
X1	Delay in the submission of payment evaluation (claim)	0.997	0.035	0.927	1.067
X2	Claim review(days)	1.023	0.011	1.001	1.046
X3	Payment process by owner (days)	0.978	0.013	0.953	1.003
X7	Consultant's experience (years)	0.820	0.252	0.321	1.319

Table (8-19) shows the variables codes, coefficients, the standard error along with the lower and upper bounds of the confidence interval of each variable. The table shows that four out of five variables (80%) have a positive biased coefficient, and one out of five (20%) has negative biased coefficient. As shown in the table for a 95% confidence prediction interval, about 95% of the observations should fall within coefficient value ± 2*Standard error from the regression line, these ranges of confidence intervals are expected to imply the right value of the coefficient for each variable of the regression model with the stipulated confidence.

8.4.1 Test sample of the regression model

The test sample cases (18 cases) are used to validate the regression models of Equation (8-1) and Equation (8-2) for comparison purpose. The test sample along with the estimated output and the performance errors are shown in Tables (8-20) and (8-21) for Equations (8-1) and (8-2), respectively. As shown in Table (8-20) and Figure (8-23), the performance error values for Equation (8-1) are: RMSE of 15.507, MAE of 3.655, and MAPE of 12.291%. While Table (8-21) and Figure (8-24) show the performance error values for Equation (8-2) as follows: RMSE of 3.928, MAE of 3.655 and MAPE of 11.944%. Figure (8-23) and Figure (8-24) show the targeted interim payment delay (days) and estimated interim payment delay (days) of the regression model for Equation (8-1) and Equation (8-2), respectively. It is noticed that there is a remarkable matching between the two curves for Equation (8-2) results, which is reflecting very good performance for the regression model. On the other hand, Equation (8-1) results has slightly less matching between the two curves that can be shown more clearly by the predicted output values and error values in Table (8-20). Therefore, it is recommended to choose Equation (8-2) for the regression model (Model I-70).

Table 8-20 Performance of Test Sample of Regression Model (Model I-70) Using Equation (8-1)

Case No.	Target output (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24	22.303	0.400	0.094	0.004
2	64	59.595	1.038	0.245	0.004
3	115	109.260	1.353	0.319	0.003
4	26	27.601	0.377	0.089	0.003
5	9	11.058	0.485	0.114	0.013
6	62	57.986	0.946	0.223	0.004
7	23	28.291	1.247	0.294	0.013
8	30	25.844	0.979	0.231	0.008
9	21	19.074	0.454	0.107	0.005
10	67	64.933	0.487	0.115	0.002
11	19	14.359	1.094	0.258	0.014
12	60	54.905	1.201	0.283	0.005
13	19	25.457	1.522	0.359	0.019
14	90	87.311	0.634	0.149	0.002
15	27	30.790	0.893	0.211	0.008
16	40	37.489	0.592	0.139	0.003
17	25	22.044	0.697	0.164	0.007
18	30	25.302	1.107	0.261	0.009
Performance			RMSE	MAE	MAPE (%)
			15.507	3.655	12.291

Table 8-21 Performance of Test Sample of Regression Model (Model I-70) Using Equation (8-2)

Case No.	Target output (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	24	22.338	2.763	1.662	6.926
2	64	59.930	16.565	4.070	6.359
3	115	109.079	35.063	5.921	5.149
4	26	27.515	2.295	1.515	5.827
5	9	10.930	3.725	1.930	21.446
6	62	56.650	28.620	5.350	8.629
7	23	28.149	26.512	5.149	22.387
8	30	25.690	18.579	4.310	14.368
9	21	18.991	4.035	2.009	9.565
10	67	64.142	8.169	2.858	4.266
11	19	14.726	18.268	4.274	22.496
12	60	54.865	26.371	5.135	8.559
13	19	24.295	28.032	5.295	27.866
14	90	88.514	2.208	1.486	1.651
15	27	30.999	15.992	3.999	14.811
16	40	36.234	14.180	3.766	9.414
17	25	22.352	7.013	2.648	10.593
18	30	25.595	19.403	4.405	14.683
Performance			RMSE	MAE	MAPE (%)
			3.928	3.655	11.944

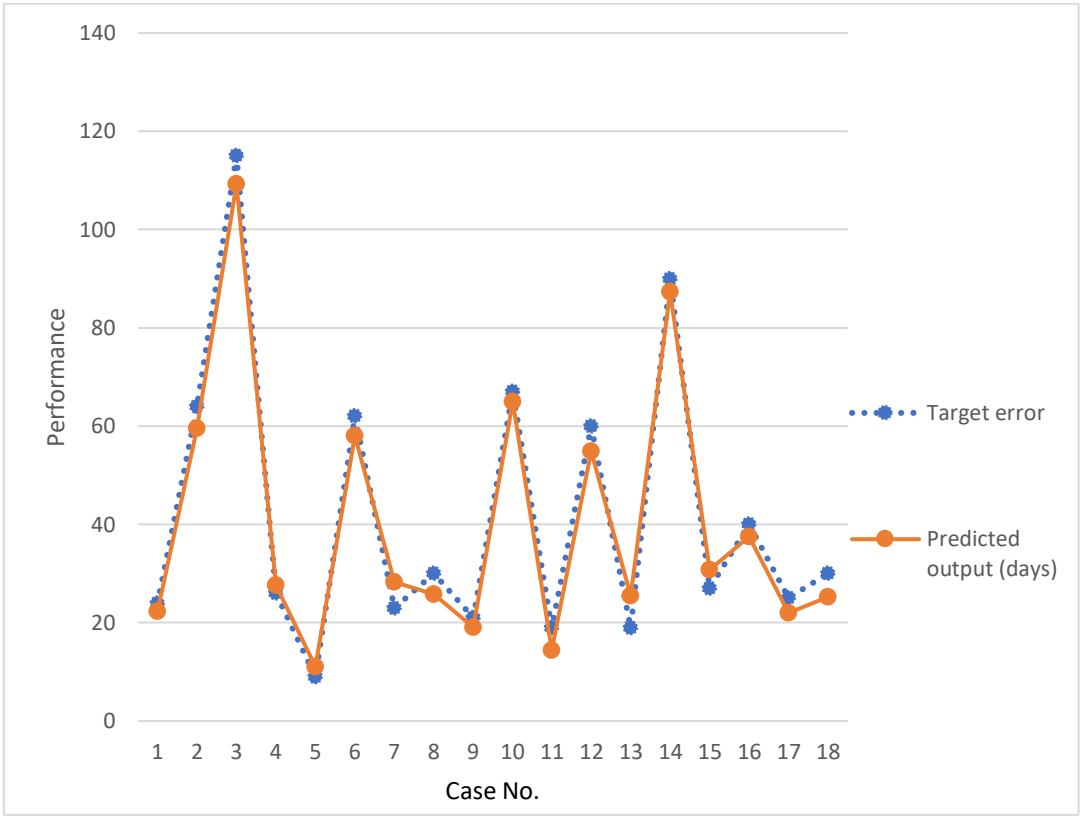


Figure 8-23 Performance of Test Sample of Regression Model (Model I-70) Using Equation (8-1)

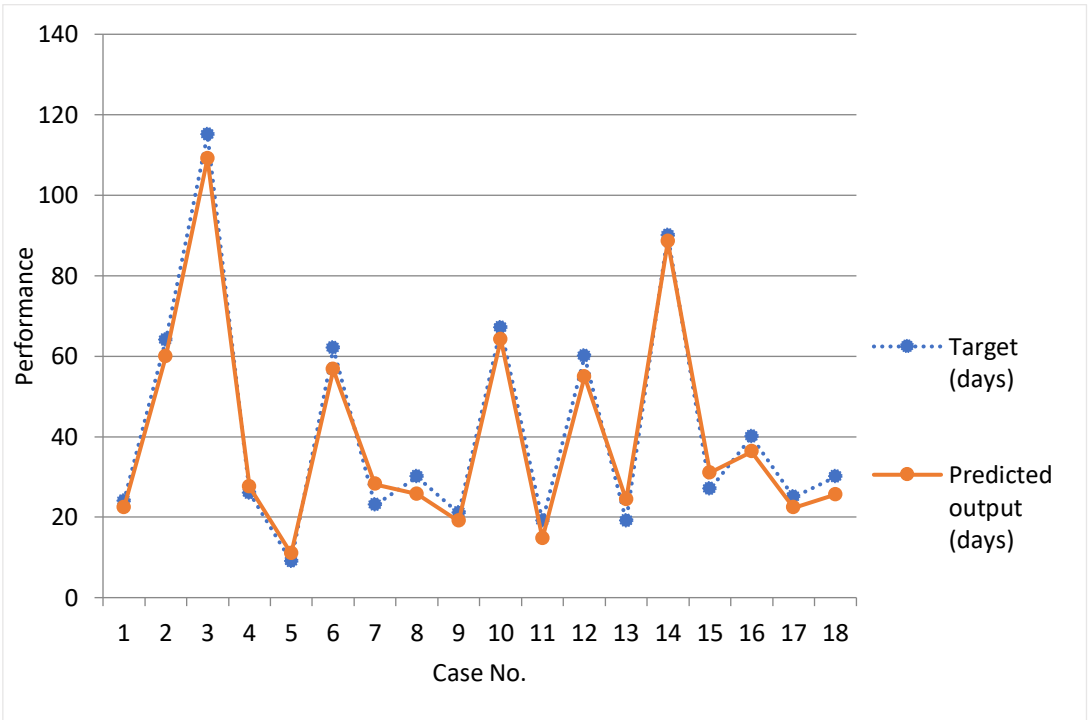


Figure 8-24 Performance of Test Sample of Regression Model (Model I-70) Using Equation (8-2)

8.5 Comparison and Discussion of Model I Results

Table (8-22) and Figure (8-25) show the comparison between the selected models created for interim payment delay using MATLAB (nntool), MATLAB (nftool) and Excel Regression analysis tool. As per the computed results the best performance model is the neural network Model I-48 with 10 neurons in hidden layer as shown in Figure (8-16) based on Bayesian Regulation algorithm and tan-sigmoid function. Model I-48 has error values for RMSE of 1.520, MAE of 0.969, and MAPE of 3.767%. In the second place comes the regression model (Model I-70) with RMSE of 3.928, MAE of 3.655 and MAPE of 11.944%.. Finally, in the third place the neural network Model I-12 with 1 neuron in hidden layer as shown in Figure (8-8) based on Bayesian Regulation algorithm and tan-sigmoid function. The ANN using MATLAB nftool shows relatively better results than the regression model. Although, on the basis of simplicity and ease of implementation of regression models, it will still give fairly good results for predicting of interim payment delay. The most significant factors for regression analysis model are: Delay in the submission of payment evaluation by contractor (days), Claim review (days), Payment process by owner (days), and Consultant's experience (years). Three out of these four significant factors represent the main steps in MoW interim payment process explained previously in Chapter 3, starting with submittion of the evaluation by the contractor, then claim review and approval, and finally, the payment process by owner. The fourth significant factor is consultant experience, which is not a part of the interim payment process. However, it is an essential factor to assure the speed and accuracy of payment approval process. On the other hand, the most significant factors for neural network model are not defined by MATLAB program, the only way for defining the significant factors is by removing different factors from the

network input, then re-train and re-test the network performance. Removing the most significant factors will result in a major decline in the performance. Although, this method is not precise because removing inputs will change the NN architecture, and thus its properties.

The results of this chapter show that Bayesian Regulation algorithm always produces better results than Levenberg algorithm and Scaled Conjugate algorithm. This can be justified as defined previously in Chapter 7 (Section 7.2) where it was mentioned that Bayesian regulation algorithm requires more time but can result in good generalization for difficult, small or noisy datasets. This is why most scientists prefer to use Bayesian regulation because it can work with different components and different complication levels of data sets. Moreover, by comparing with previous studies, Kayri (2016) concluded that "the Bayesian regulation training algorithm shows better performance than the Levenberg–Marquardt algorithm. The advantage of a Bayesian regulation artificial neural network is its ability to reveal potentially complex relationships, thus, it can be used in quantitative studies to provide a robust model". This chapter also shows that MATLAB (nftool) always gives better results than MATLAB (nntool), the justification of this may be because MATLAB (nfool) generates all the weights, data normalizations and dividing of data set automatically. This requires less human interference which means less human errors in contrast of MATLAB (nntool) as shown in the process of each tool previously in Chapter 7, Subsections 7.5.1 and 7.5.2.

Table 8-22 Comparison of the Selected Models for (Model I)

Model No	RMSE	MAE	MAPE (%)	R-squared	Type	Tool
Model I-12	11.370	8.947	23.266	0.984	Neural Network	MATLAB nntool
Model I-48	1.520	0.969	3.767	0.999	Neural Network	MATLAB nftool
Model I-70	3.928	3.655	11.944	0.991	Regression Model	Excel ATP

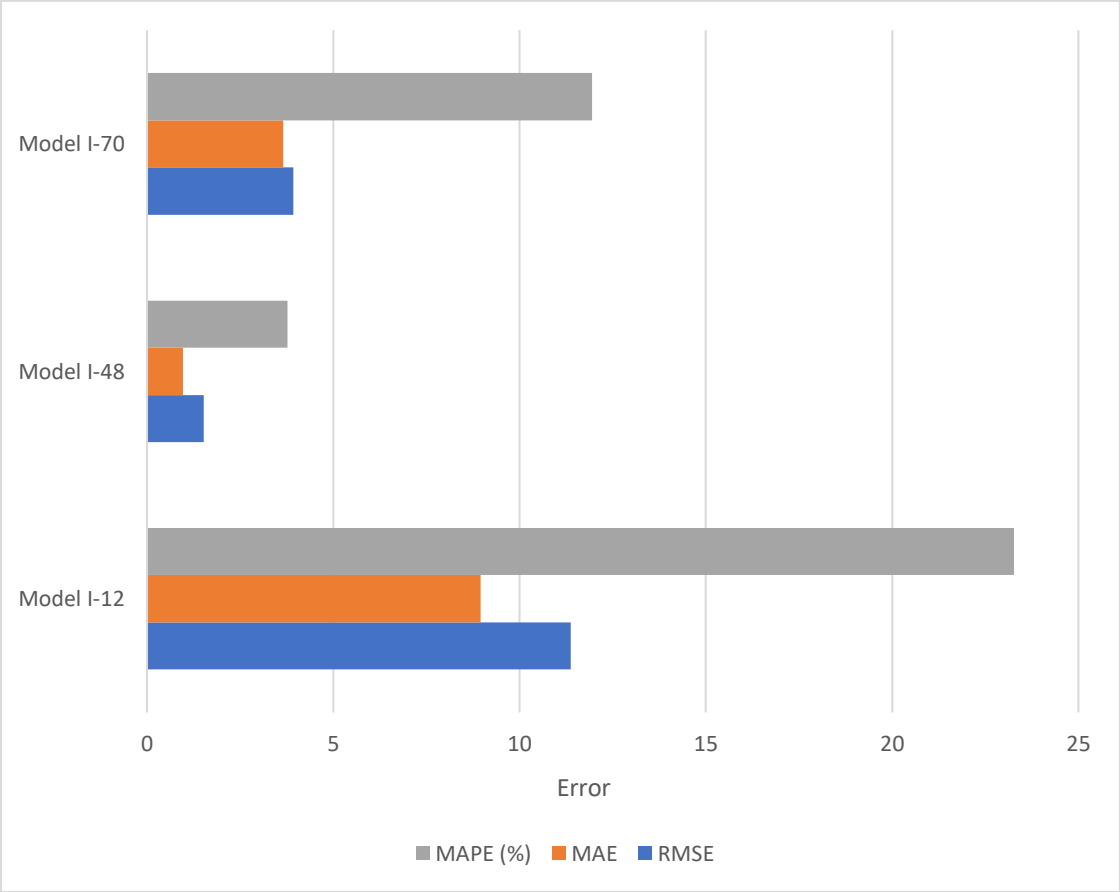


Figure 8-25 Comparison of the Selected Models for (Model I)

8.6 Chapter Summary:

The interim payment delay model (model I) development passed through several steps started by choosing the type of model, dividing the data set, choosing the software used to build the model, entering the dependent and independent variables, choosing the different parameters for each type of model, and finally training and testing the models to choose the best model for interim payment delay prediction. A total of seventy (70) models were trained, validated and tested for Model I. The best performance model proved to be neural network Model I-48 developed using MATLAB nfool. This model has 10 neurons in the hidden layer, and based on Bayesian Regulation algorithm and tan-sigmoid function. It has shown the minimum error results with RMSE of 1.520, MAE of 0.969 and MAPE of 3.767%

CHAPTER 9
Development of Variation Payment Delay Model (Model V)

9.1 Introduction
9.2 Developing Model V using MATLAB nntool
9.3 Developing Model V using MATLAB nftool
9.4 Developing Model V using Regression Excel tool
9.5 Comparison and Discussion of Model V Results
9.6 Chapter Summary

Chapter 9
Development of Variation Payment Delay Model (Model V)

9.1 Introduction

The variation payment delay model (Model V) is developed for the prediction of variation payment delay using 91 actual historical cases for MoW building projects. The model is developed as neural network model using MATLAB nntool and MATLAB nftool approaches, and as a multiple linear regression model using Excel data analysis tool pack approach. A total of seventy-sex (76) trial Models were created to come out with the best prediction model for variation payments delay.

9.2 Developing Model V Using MATLAB nntool

A total of thirty-six ANN models are trained, validated and tested for model V with different number of hidden neurons and training algorithms using MATLAB nntool. The ninety-one cases are divided into three sets: the training set consisting of 63 cases; the validation set consisting of 14 cases; and the testing set consisting of 14 cases. The below subsections show the performance of the test samples for multilayer (2 layers) feed-forward network with tan-sigmoid transfer function in the hidden layer and linear transfer function in the output layer for predicting variation payment delay. The training algorithms used are Levenberg-Marquardt algorithm, Bayesian Regulation and Scaled Conjugate Gradient. The performance of the training and validation samples for the thirty-six trial models are presented in Appendix (9). These samples were not involved in the evaluation of models to eliminate the risk of misevaluation, because during the training and learning some models may accomplish good results with

the training and validation data set, but very poor with new data, which is the test set. Therefore, the evaluation of the models' performance is done by comparing their predicted output over an independent test sample as explained in Chapter 6.

9.2.1 Model V performance using Levenberg-Marquardt

The best ANN observed using Levenberg-Marquardt algorithm is Model V-2 with 5 neurons in the hidden layer as per Table (9-1) and Figure (9-1). Model V-2 has a minimum value for RMSE of 1.292, MAE of 0.964 and MAPE of 2.295%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model V-2 are shown in Table (9-2). Table (9-2) shows that eight out of the fourteen predicted results are low biased, which is (57.1%) of the total results. Figure (9-2) shows the performance for the targeted variation payment delay (days) and the estimated variation payment delay (days) of the selected model, i.e. Model V-2. It is noticed that there is a good matching between the two curves which may reflect acceptable results. The details of the predicted output for the twelve models' trials are shown in Appendix 10.

Table 9-1 Performance of Test Sample Model V Using (nntool and Levenberg-Marquardt)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Levenberg-Marquardt algorithm		
					RMSE	MAE	MAPE
V-1	10	1	1	1	4.709	3.732	8.062
V-2	10	1	1	5	1.292	0.964	2.295
V-3	10	1	1	10	6.288	4.346	12.405
V-4	10	1	1	20	18.816	9.072	11.490
V-5	10	1	1	30	2.340	1.698	4.217
V-6	10	1	1	40	7.652	6.439	13.050
V-7	10	1	1	50	6.909	5.739	14.432
V-8	10	1	1	60	3.926	1.625	2.402
V-9	10	1	1	70	15.466	6.508	21.997
V-10	10	1	1	80	4.243	2.900	7.900
V-11	10	1	1	90	8.308	7.114	13.477
V-12	10	1	1	100	4.392	1.840	7.492

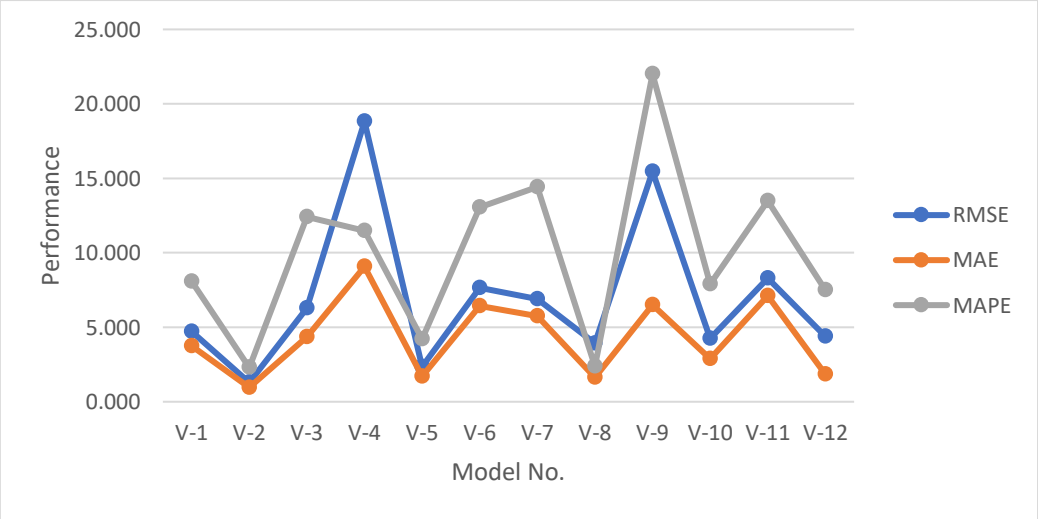


Figure 9-1 Performance of Test Sample Model V Using (nntool and Levenberg-Marquardt)

Table 9-2 Test Sample and Predicted Results for Model V-2 (nntool)

Case No.	Target (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83.000	82.993	0.000	0.000	0.000
2	70.000	70.983	0.966	0.070	0.001
3	30.000	29.235	0.585	0.055	0.002
4	25.000	25.325	0.106	0.023	0.001
5	21.000	19.324	2.809	0.120	0.006
6	32.000	32.141	0.020	0.010	0.000
7	142.000	142.571	0.326	0.041	0.000
8	63.000	62.735	0.070	0.019	0.000
9	83.000	84.138	1.294	0.081	0.001
10	36.000	35.595	0.164	0.029	0.001
11	83.000	82.489	0.261	0.037	0.000
12	68.000	64.906	9.574	0.221	0.003
13	69.000	66.618	5.673	0.170	0.002
14	19.000	20.238	1.533	0.088	0.005
Performance			RMSE	MAE	MAPE (%)
			1.292	0.964	2.295

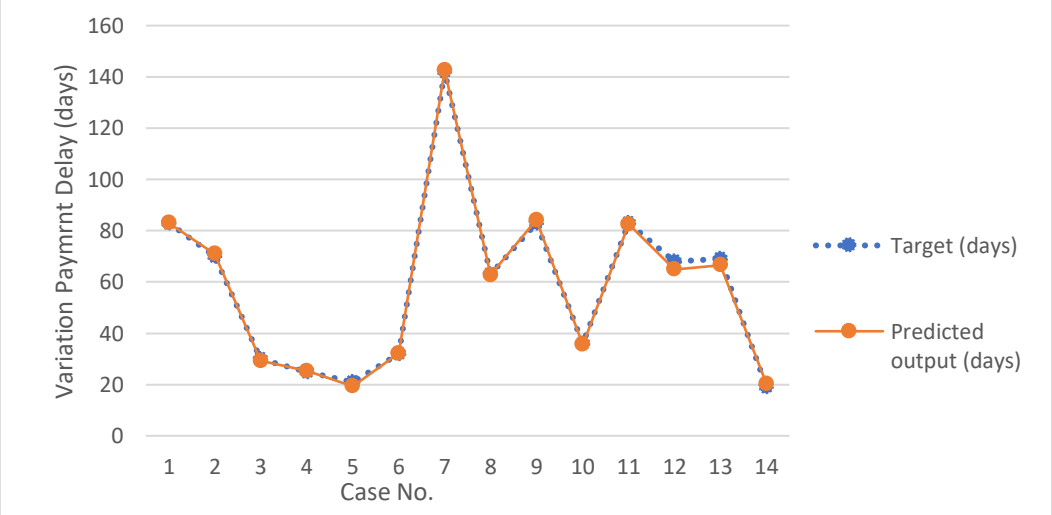


Figure 9-2 Test Sample and Predicted Results for Model V-6 (nntool)

9.2.2 Model V performance using Bayesian Regulation

The best ANN observed using Bayesian regulation algorithm is Model V-14 with 5 neurons in the hidden layer as per Table (9-2) and Figure (9-2). Model V-14 has a minimum value for RMSE of 0.304, MAE of 0.248 and MAPE of 0.586%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model V-14 are shown in Table (9-4). Table (9-4) shows that six out of fourteen predicted results are slightly low biased which is (42.9%) of the total results. Figure (9-4) shows the performance for the targeted variation payment delay (days) and the estimated variation payment delay (days) of the selected model, i.e. Model V-14. It is noticed that there is a noticeable matching between the two curves, which is showing very high performance of the network. The details of the predicted output for the twelve models' trials are shown in Appendix 10.

Table 9-3 Performance of Test Sample Model V Using (nntool and Bayesian Regulation)

Model No.	No. of input neurons	No. of output neurons	No. of hidden layers	No. of hidden neurons	Bayesian regulation		
					RMSE	MAE	MAPE%
V-13	10	1	1	1	5.260	4.178	9.138
V-14	10	1	1	5	**0.304**	**0.248**	**0.586**
V-15	10	1	1	10	14.828	12.225	25.067
V-16	10	1	1	20	2.213	0.960	2.165
V-17	10	1	1	30	2.539	0.930	2.491
V-18	10	1	1	40	1.132	0.390	0.620
V-19	10	1	1	50	0.433	0.372	0.999
V-20	10	1	1	60	6.101	2.457	4.747
V-21	10	1	1	70	1.298	0.498	0.839
V-22	10	1	1	80	3.659	1.335	1.512
V-23	10	1	1	90	4.475	3.829	10.392
V-24	10	1	1	100	0.424	0.255	0.464

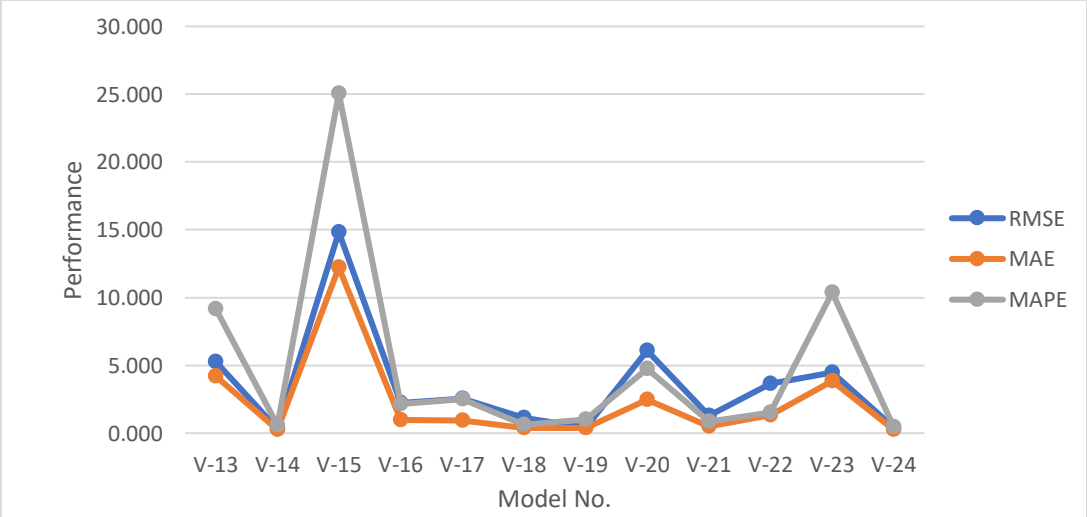


Figure 9-3 Performance of Test Sample Model V Using (nntool and Bayesian Regulation)

Table 9-4 Test Sample and Predicted Results for Model V-14 (nntool)

Case No.	Target (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83	82.778	0.049	0.016	1.91E-04
2	70	70.368	0.135	0.026	3.75E-04
3	30	30.407	0.166	0.029	9.69E-04
4	25	25.445	0.198	0.032	1.27E-03
5	21	21.176	0.031	0.013	6.00E-04
6	32	31.822	0.032	0.013	3.98E-04
7	142	142.036	0.001	0.003	1.80E-05
8	63	62.633	0.135	0.026	4.17E-04
9	83	83.064	0.004	0.005	5.47E-05
10	36	35.910	0.008	0.006	1.78E-04
11	83	82.642	0.128	0.026	3.08E-04
12	68	68.628	0.394	0.045	6.60E-04
13	69	68.969	0.001	0.002	3.21E-05
14	19	19.104	0.011	0.007	3.90E-04
Performance			RMSE	MAE	MAPE (%)
			0.304	0.248	0.586

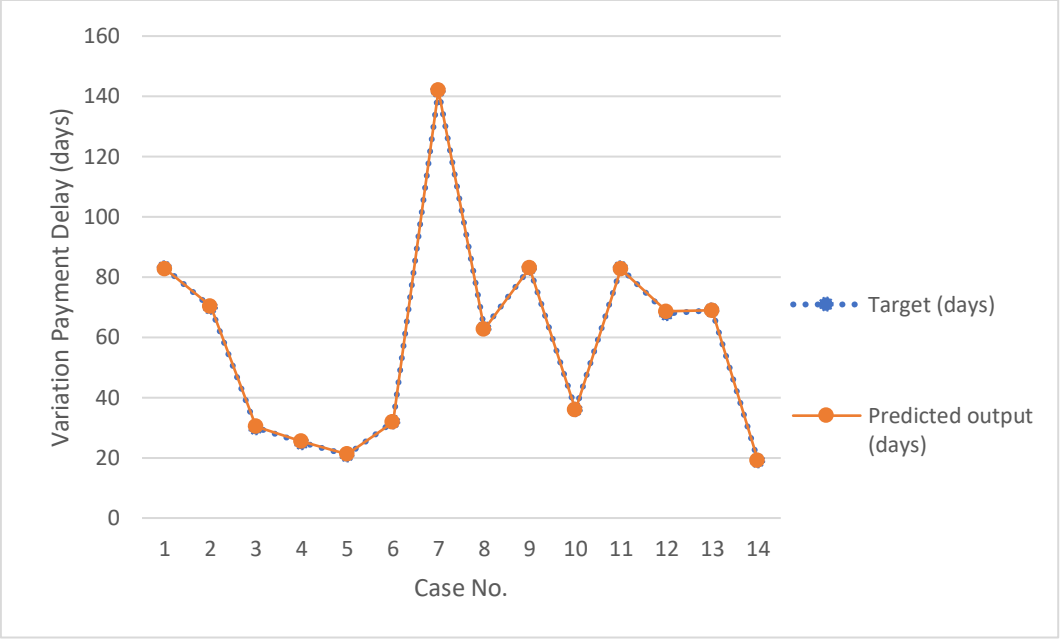


Figure 9-4 Test Sample and Predicted Results for Model V-14 (nntool)

9.2.3 Model V performance using Scaled Gradient

The best neural network observed using Scaled Conjugate Gradient is Model V-27 with 10 neurons in the hidden layer as per Table (9-5) and Figure (9-5). Model V-27 has a minimum value for RMSE of 6.367, MAE of 5.147 and MAPE of 13.160%. The calculation results for MAE, RMSE and MAPE of the test sample and the predicted results for Model V-27 are shown in Table (9-6). Table (9-6) shows that seven out of fourteen predicted results are low biased which is (50%) of the total results. Figure (9-6) shows the performance for the targeted variation payment delay (days) and the estimated variation payment delay (days) of the selected model, i.e. Model V-27. It is noticed that there is a noticeable difference between the two curves and they are rarely coinciding in some points which is not reflecting good performance of the network. The details of the predicted output for the twelve models' trials are shown in Appendix 10.

TABLE 9-5 Performance of Test Sample for Model V Using (nntool and Scaled Conjugate Gradient)

Model No.	No. of Input Neurons	No. of Output Neurons	No. of Hidden layers	No. of hidden Neurons	Scaled Conjugate Gradient		
					RMSE	MAE	MAPE%
V-25	10	1	1	1	8.192	7.472	17.518
V-26	10	1	1	5	14.828	12.225	25.067
V-27	10	1	1	10	**6.367**	**5.147**	**13.160**
V-28	10	1	1	20	8.675	7.324	18.501
V-29	10	1	1	30	8.088	6.699	18.819
V-30	10	1	1	40	6.591	5.656	15.532
V-31	10	1	1	50	7.559	6.914	17.576
V-32	10	1	1	60	7.736	6.357	17.147
V-33	10	1	1	70	8.133	6.790	21.120
V-34	10	1	1	80	8.952	6.132	10.407
V-35	10	1	1	90	11.785	11.185	25.540
V-36	10	1	1	100	12.413	10.425	27.862

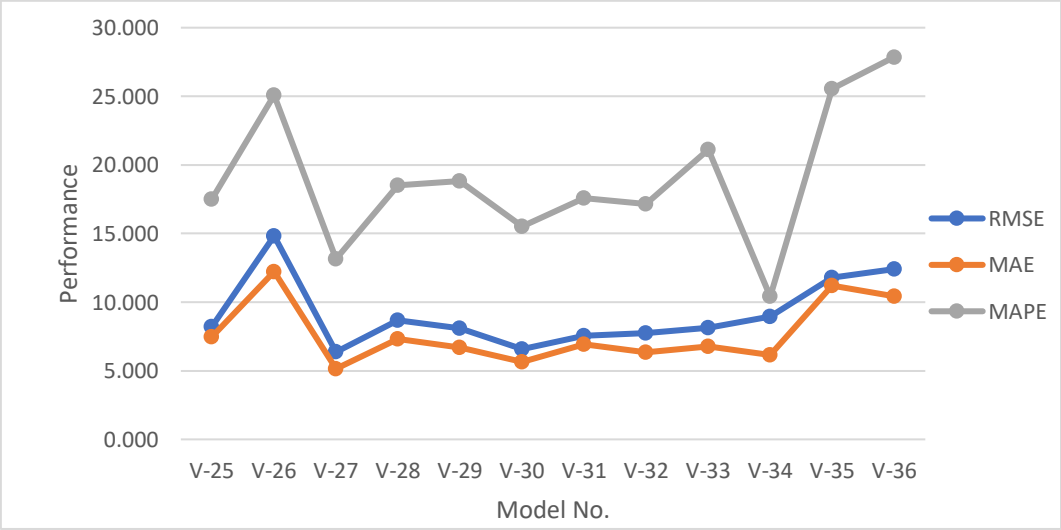


Figure 9-5 Performance of Test Sample for Model V Using (nntool and Scaled Conjugate Gradient)

Table 9-6 Test Sample and Predicted Results for Model V-27 (nntool)

Case No.	Target (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83	84.097	1.203	0.078	0.001
2	70	71.313	1.724	0.094	0.001
3	30	34.296	18.459	0.307	0.010
4	25	31.604	43.611	0.472	0.019
5	21	15.400	31.364	0.400	0.019
6	32	20.766	126.196	0.802	0.025
7	142	132.813	84.401	0.656	0.005
8	63	57.980	25.203	0.359	0.006
9	83	70.353	159.939	0.903	0.011
10	36	33.995	4.021	0.143	0.004
11	83	88.054	25.544	0.361	0.004
12	68	67.493	0.257	0.036	0.001
13	69	69.785	0.617	0.056	0.001
14	19	25.709	45.009	0.479	0.025
Performance			RMSE	MAE	MAPE (%)
			6.367	5.147	13.160

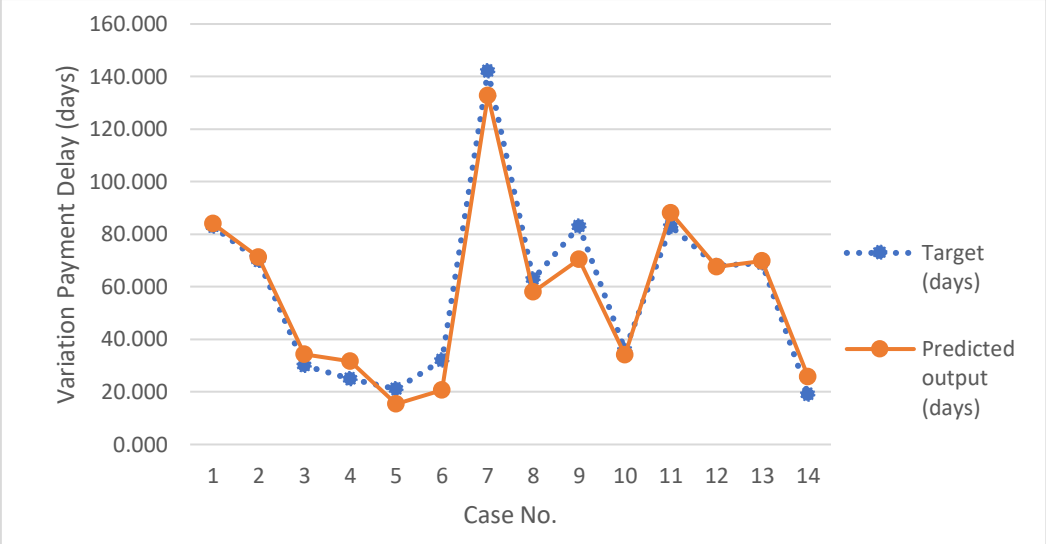


Figure 9-6 Test Sample and Predicted Results for Model V-27 (nntool)

9.2.4 Comparison of MATLAB nntool results

By comparing the computed results for each of the three selected models using MATLAB (nntool), Model V-14 with 5 neurons in hidden layer based on Bayesian Regulation algorithm and tan-sigmoid function has been chosen. It has the lowest error values for variation payment prediction with RMSE of 0.304, MAE of 0.248 and MAPE value of 0.586% as shown in Table (9-7) and Figure (9-7). The ANN structure of the model chosen is shown in Figure (9-8). The best performance for the training sample of this model is at 145 epochs with MSE of 1.50×10^{-5} as shown in Figure (9-9), and R value of 0.999 as shown in Figure (9-10) and Appendix 9. The validation sample performance is not available because the MATLAB Programme sets the validation parameter for Bayesian Regulation as zero.

Table 9-7 Selected Models for Model V Using MATLAB (nntool)

Model No	RMSE	MAE	MAPE (%)	Training Algorithm
Model V-2	1.292	0.964	2.295	Levenberg
Model V-14	**0.304**	**0.248**	**0.586**	**Bayesian**
Model V-27	6.367	5.147	13.160	Scaled

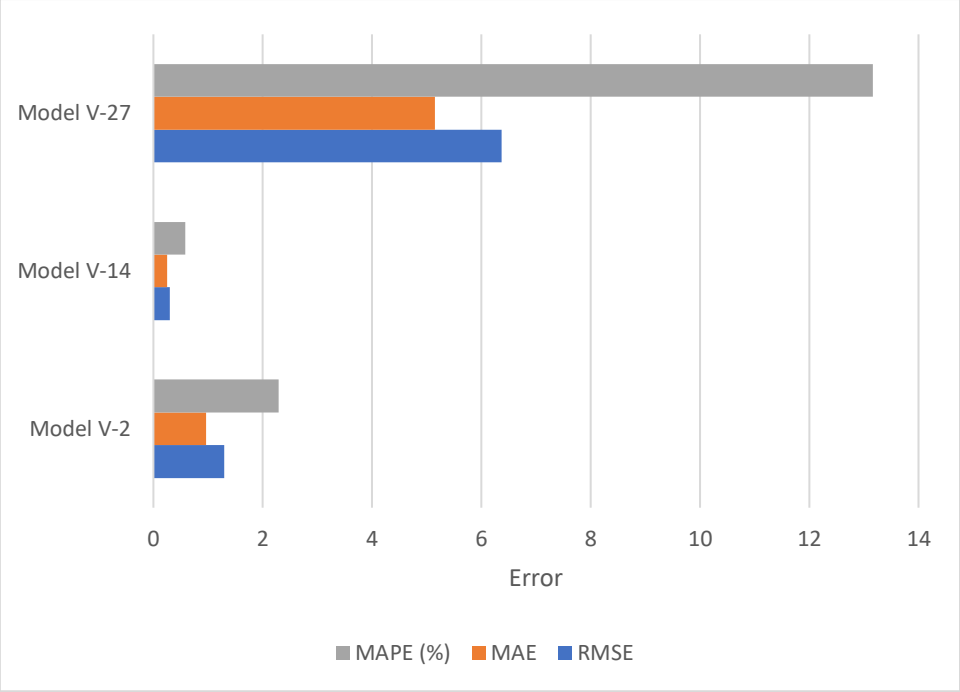


Figure 9-7 Selected Models for Model V Using MATLAB (nntool)

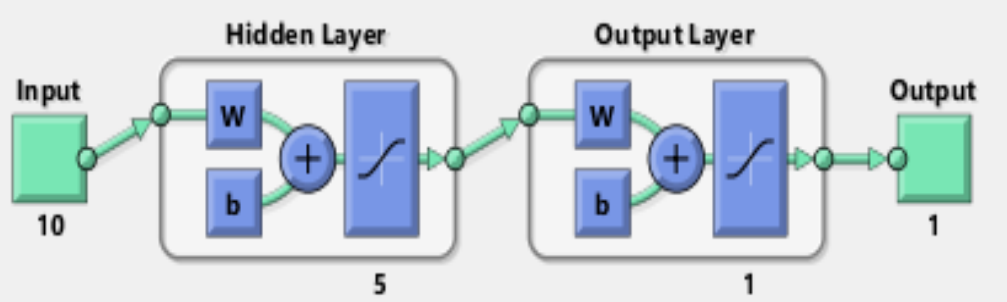


Figure 9-8 Selected Models for Model V from MATLAB (nntool)

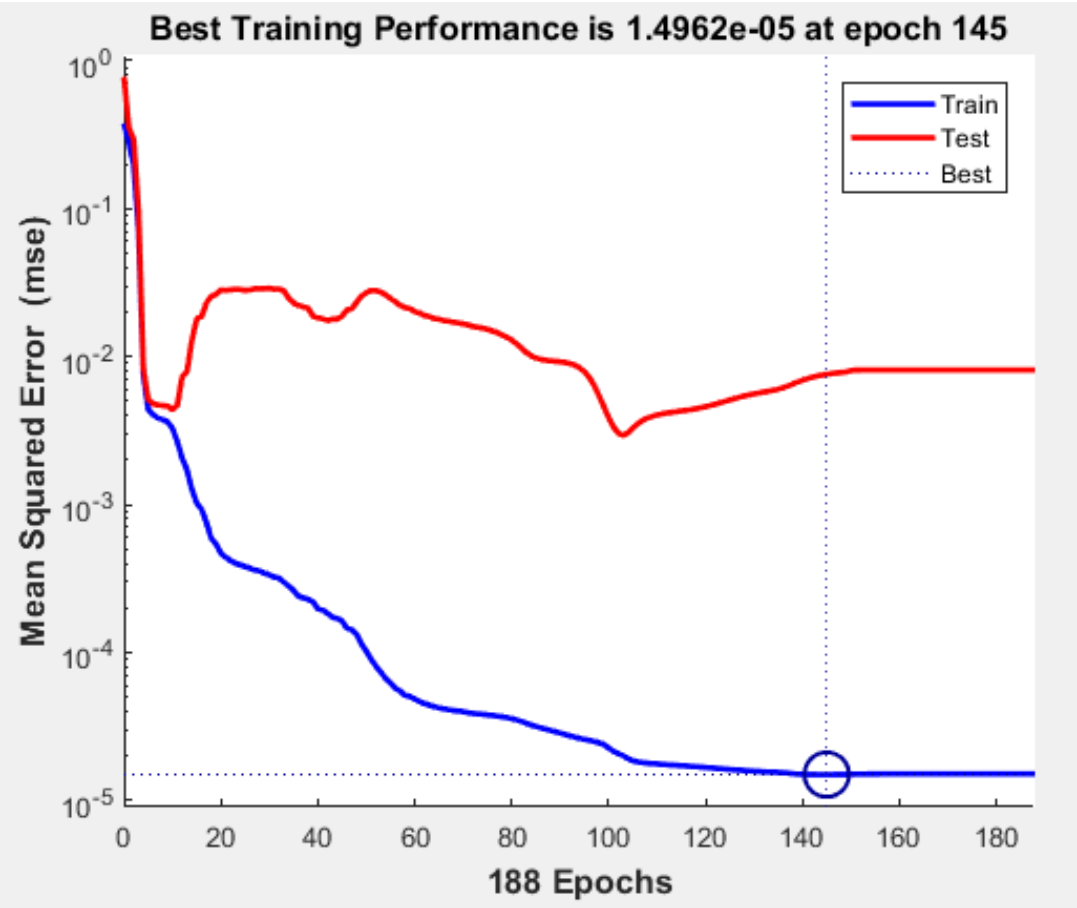


Figure 9-9 Training Performance for Model V-14

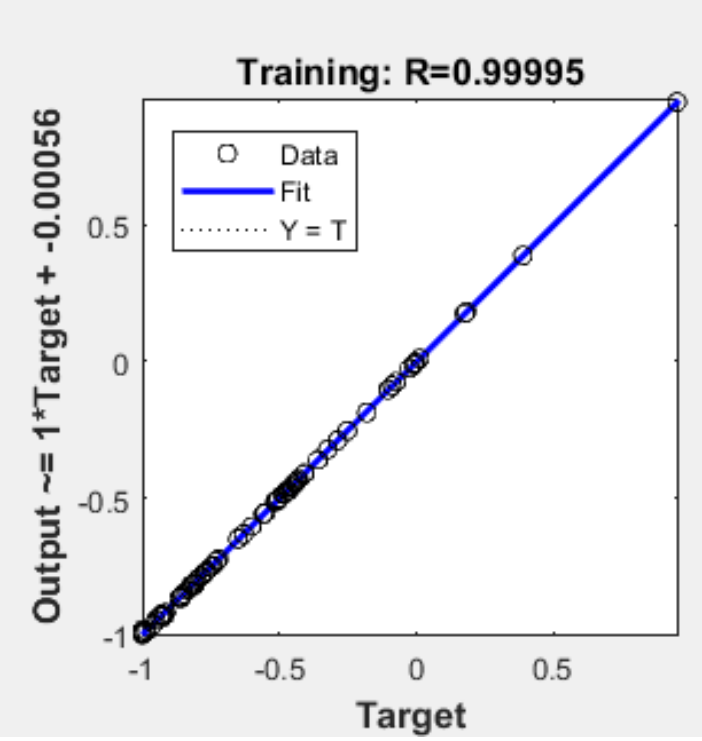


Figure 9-10 Training Sample R-Value Result for Model V-14

9.3 Developing Model V Using MATLAB nftool

A total of thirty-nine ANN models are trained, validated and tested for model V using MATLAB nftool. The below subsections along with Tables (9-8), (9-10), and (9-12) show the performance of the test samples for multilayer (2 layers) feed-forward network with different number of hidden neurons, tan-sigmoid transfer function in the hidden layer and linear transfer function in the output layer for predicting variation payment delay. The training algorithms used are Levenberg-Marquardt algorithm, Bayesian Regulation and Scaled Conjugate Gradient. The performance of the training and validation samples for the thirty-nine trial models are presented in Appendix 11. These samples were not involved in the evaluation of models to eliminate the risk of misevaluation, because during the training and learning some models may accomplish good results with the training and validation data set, but very poor with new data, which is the test set. Therefore, the evaluation of the models' performance is done by comparing their predicted output over an independent test sample as explained in Chapter 6.

9.3.1 Model V performance using Levenberg-Marquardt

The best ANN observed using Levenberg-Marquardt algorithm is Model V-37 with 1 neuron in the hidden layer as per Table (9-8) and Figure (9-11). Model V-37 has a minimum value for RMSE of 0.309, MAE of 0.183 and MAPE of 0.437%. The test sample is shown in Table (9-9) along with the estimated output by the selected network Model V-37 and their estimated performance (MAE, RMSE, MAPE (%)). Figure (9-9) shows the targeted variation payment delay (days) and estimated variation payment delay (days) of the selected model. It is noticed that there is a noticeable matching between the two curves showing very high performance of the

network. The calculation details for the predicted output for the thirteen models' trials are shown in Appendix 12.

Table 9-8 Performance of Test Sample for Model V Using (nftool and Levenberg Algorithm)

Model No.	No. of Input Neurons	No. of Output Neurons	No. of Hidden layers	No. of hidden Neurons	Levenberg-Marquardt algorithm		
					RMSE	MAE	MAPE
V-37	10	1	1	1	0.309	0.183	0.437
V-38	10	1	1	5	1.120	0.778	2.163
V-39	10	1	1	10	1.662	1.034	2.972
V-40	10	1	1	15	1.111	0.866	1.862
V-41	10	1	1	20	1.938	1.083	2.777
V-42	10	1	1	30	7.149	2.892	4.906
V-43	10	1	1	40	5.175	2.613	3.798
V-44	10	1	1	50	19.036	8.856	11.648
V-45	10	1	1	60	21.449	10.070	13.773
V-46	10	1	1	70	16.007	9.033	19.531
V-47	10	1	1	80	5.783	1.594	4.952
V-48	10	1	1	90	1.015	0.388	0.840
V-49	10	1	1	100	4.095	1.526	3.456

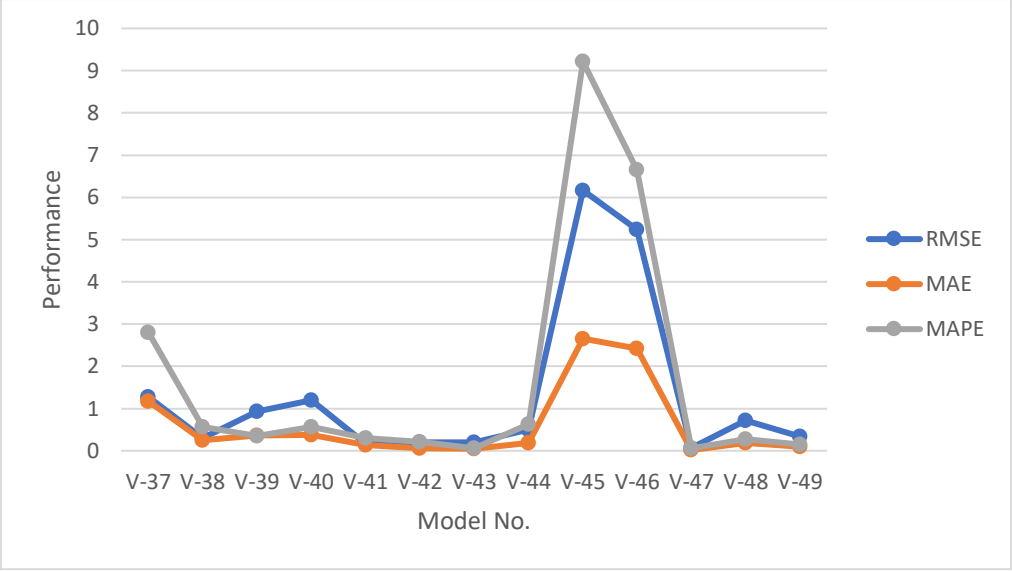


Figure 9-11 Performance of Test Sample for Model V Using (nftool and Levenberg Algorithm)

Table 9-9 Test Sample and Predicted Results for Model V-37 (nftool)

Case No.	Target (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83	83.387	0.028	0.150	3.33E-04
2	70	70.005	0.000	0.000	4.68E-06
3	30	29.306	0.050	0.482	1.65E-03
4	25	24.501	0.036	0.249	1.43E-03
5	21	21.010	0.001	0.000	3.42E-05
6	32	32.016	0.001	0.000	3.64E-05
7	142	141.970	0.002	0.001	1.52E-05
8	63	63.029	0.002	0.001	3.27E-05
9	83	83.015	0.001	0.000	1.26E-05
10	36	35.997	0.000	0.000	5.47E-06
11	83	83.644	0.046	0.415	5.54E-04
12	68	67.800	0.014	0.040	2.10E-04
13	69	69.022	0.002	0.000	2.28E-05
14	19	19.008	0.001	0.000	3.12E-05
Performance			MAE	RMSE	MAPE (%)
			0.183	0.309	0.437

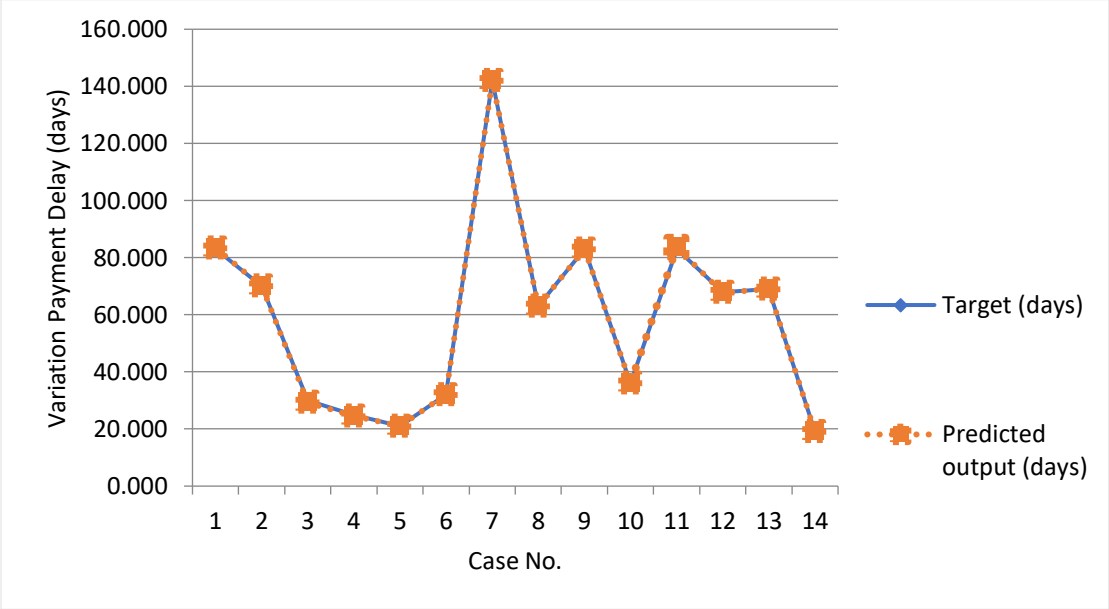


Figure 9-12 Test Sample and Predicted Results for Model V-37 (nftool)

9.3.2 Model V performance using Bayesian Regulation

The best ANN observed using Bayesian regulation algorithm is Model V-60 with 80 neurons in the hidden layer as per Table (9-10) and Figure (9-13). Model V-60 has a minimum value for RMSE of 0.066, MAE of 0.018 and MAPE of 0.058. The test sample is shown in Table (9-11) along with the estimated output by the selected network Model V-60 and its estimated performance (MAE, RMSE, MAPE). Figure (9-14) shows the targeted variation payment delay (days) and estimated variation payment delay (days) of the selected model. It is noticed that there is a perfect matching between the two curves reflecting a very promising high performance for the network. The calculation details for the predicted output for the thirteen models' trials are shown in Appendix 12.

Table 9-10 Performance of Test Sample for Model V Using (nftool and Bayesian Regulation)

Model No.	No. of Input Neurons	No. of Output Neurons	No. of Hidden layers	No. of hidden Neurons	Bayesian regulation		
					RMSE	MAE	MAPE
V-50	10	1	1	1	1.275	1.170	2.797
V-51	10	1	1	5	0.296	0.243	0.569
V-52	10	1	1	10	0.933	0.369	0.349
V-53	10	1	1	15	1.197	0.379	0.565
V-54	10	1	1	20	0.157	0.135	0.302
V-55	10	1	1	30	0.200	0.054	0.214
V-56	10	1	1	40	0.194	0.052	0.063
V-57	10	1	1	50	0.503	0.188	0.630
V-58	10	1	1	60	6.165	2.655	9.211
V-59	10	1	1	70	5.239	2.428	6.652
V-60	10	1	1	80	**0.066**	**0.018**	**0.058**
V-61	10	1	1	90	0.715	0.191	0.273
V-62	10	1	1	100	0.343	0.092	0.145

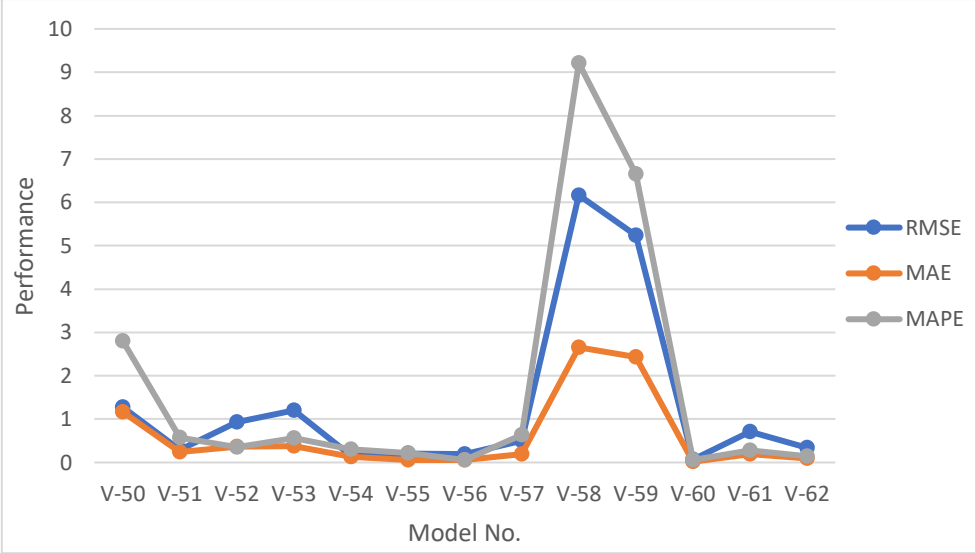


Figure 9-13 Performance of Test Sample for Model V Using (nntool and Bayesian Regulation)

Table 9-11 Test Sample and Predicted Results for Model V-60 (nftool)

Case No.	Target (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83	83	7E-11	6E-07	7.184E-09
2	70	70	8E-11	6E-07	9.203E-09
3	30	30	0.0601	0.0175	0.0005837
4	25	25	3E-11	4E-07	1.662E-08
5	21	21	2E-12	1E-07	5.168E-09
6	32	32	1E-11	3E-07	8.503E-09
7	142	142	9E-12	2E-07	1.486E-09
8	63	63	2E-11	3E-07	4.977E-09
9	83	83	1E-11	3E-07	3.128E-09
10	36	36	2E-11	3E-07	9.412E-09
11	83	83	2E-12	1E-07	1.253E-09
12	68	68	2E-12	1E-07	1.646E-09
13	69	69	3E-12	1E-07	1.667E-09
14	19	19	4E-12	1E-07	7.806E-09
Performance			RMSE	MAE	MAPE (%)
			0.066	0.018	0.058

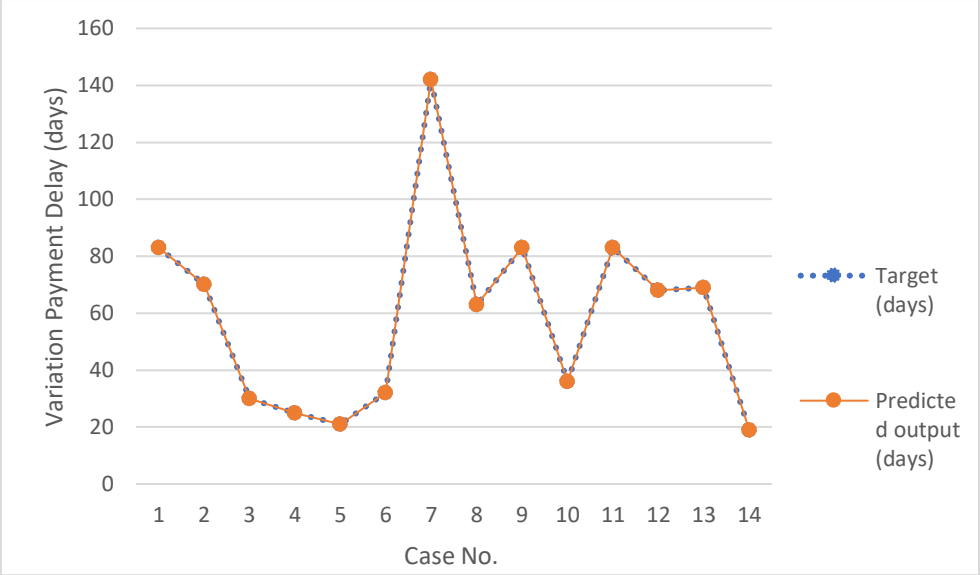


Figure 9-14 Test Sample and Predicted Results for Model V-60 (nftool)

9.3.3 Model V performance using Scaled Gradient

The best ANN observed using Scaled Conjugate Gradient is Model V-63 with 1 neuron in the hidden layer as per Table (9-12) and Figure (9-15). Model V-63 has a minimum value for RMSE of 1.120, MAE of 0.778 and MAPE of 2.163%. The test sample is shown in Table (9-13) along with the estimated output by the selected network Model V-63 and its estimated performance (MAE, RMSE, MAPE). Figure (9-16) shows the targeted variation payment delay (days) and estimated variation payment delay (days) of the selected model. It is noticed that there is a good matching between the two curves which may reflect promising results. The calculation details for the predicted output for the thirteen models' trials are shown in Appendix 12.

Table 9-12 Performance of Test Sample for Model V Using (nftool and Scaled Conjugate Gradient)

Model No.	No. of Input Neurons	No. of Output Neurons	No. of Hidden layers	No. of hidden Neurons	Scaled Conjugate Gradient		
					RMSE	MAE	MAPE (%)
V-63	10	1	1	1	**1.120**	**0.778**	**2.163**
V-64	10	1	1	5	6.969	4.009	7.576
V-65	10	1	1	10	9.560	7.170	15.301
V-66	10	1	1	15	3.181	2.350	5.662
V-67	10	1	1	20	7.181	4.650	14.313
V-68	10	1	1	30	9.070	5.503	15.933
V-69	10	1	1	40	10.871	3.810	11.111
V-70	10	1	1	50	10.586	7.373	18.734
V-71	10	1	1	60	10.072	6.615	12.038
V-72	10	1	1	70	22.796	15.174	46.103
V-73	10	1	1	80	17.031	8.889	33.226
V-74	10	1	1	90	13.971	9.735	24.308
V-75	10	1	1	100	3.197	2.321	4.746

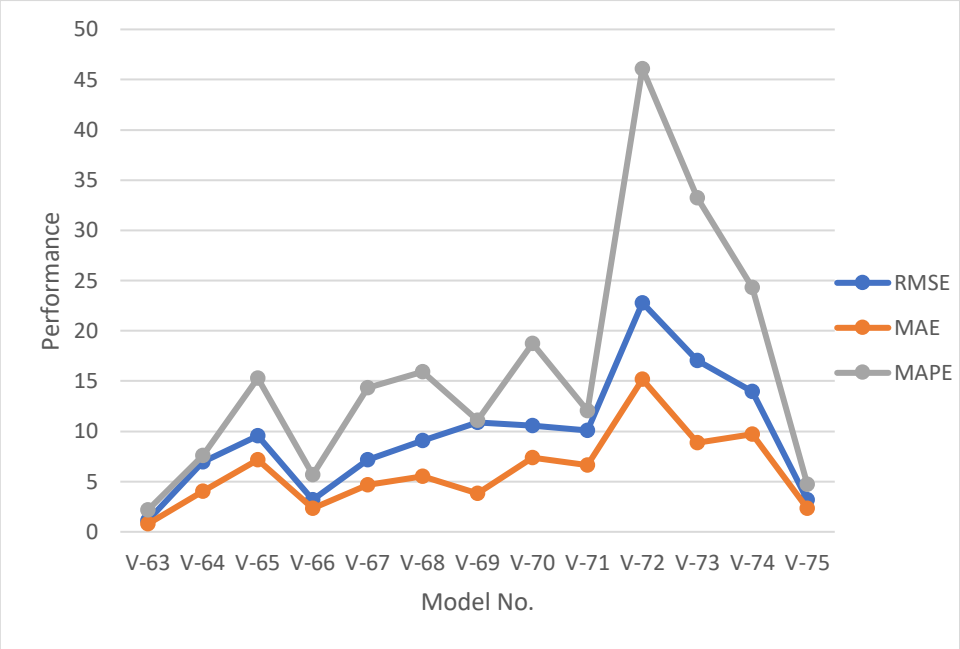


Figure 9-15 Performance of Test Sample for Model V Using (nftool and Scaled Conjugate Gradient)

Table 9-13 Test Sample and Predicted Results for Model V-63 (nftool)

Case No.	Target (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83.000	82.280	0.051	0.519	6.20E-04
2	70.000	69.517	0.035	0.233	4.93E-04
3	30.000	30.972	0.069	0.945	2.31E-03
4	25.000	26.667	0.119	2.780	4.76E-03
5	21.000	23.215	0.158	4.908	7.54E-03
6	32.000	32.206	0.015	0.043	4.60E-04
7	142.000	144.715	0.194	7.371	1.37E-03
8	63.000	62.864	0.010	0.019	1.54E-04
9	83.000	83.149	0.011	0.022	1.29E-04
10	36.000	36.487	0.035	0.237	9.66E-04
11	83.000	82.877	0.009	0.015	1.06E-04
12	68.000	68.201	0.014	0.040	2.11E-04
13	69.000	69.206	0.015	0.042	2.13E-04
14	19.000	19.611	0.044	0.373	2.30E-03
Performance			MAE	RMSE	MAPE (%)
			0.778	1.120	2.163

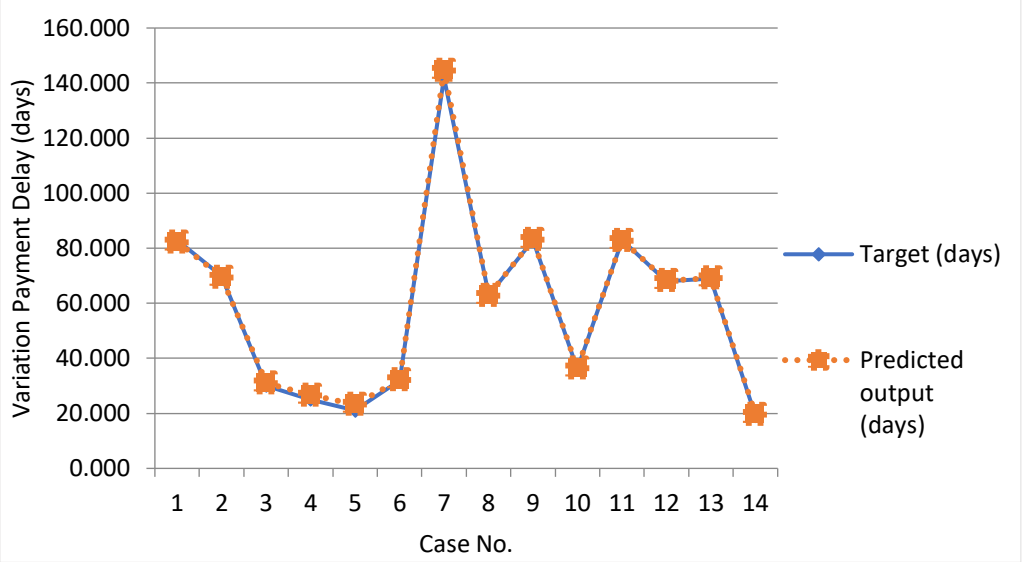


Figure 9-16 Test Sample and Predicted Results for Model V-63 (nftool)

9.3.4 Comparison of MATLAB nftool results

By comparing the computed results for each of the selected models using MATLAB (nftool), Model V-60 structure with 80 neurons in the hidden layer, based on Bayesian Regulation algorithm and tan-sigmoid function has been chosen as it has the lowest error values for variation payment prediction with RMSE of 0.066, MAE of 0.018 and MAPE value of 0.058% as shown in Table (9-14) and Figure (9-17). The ANN structure of the model chosen is shown in Figure (9-18). The best performance for the training sample of this model is at 378 epochs with MSE of 1.287×10^{-11} as shown in Figure (9-19), and R value of 1 which is reflecting a perfect of results and very high predictive power of the network as shown in Figure (9-20) and Appendix 11. The validation sample performance is not available because the MATLAB Programme sets the validation parameter for Bayesian Regulation as zero.

TABLE 9-14 Selected Models for Model V Using MATLAB (nftool)

Model No	RMSE	MAE	MAPE (%)	Training Algorithm
Model V-37	0.309	0.183	0.437	Levenberg
Model V-60	0.018	0.066	0.058	Bayesian
Model V-63	0.778	1.120	2.163	Scaled

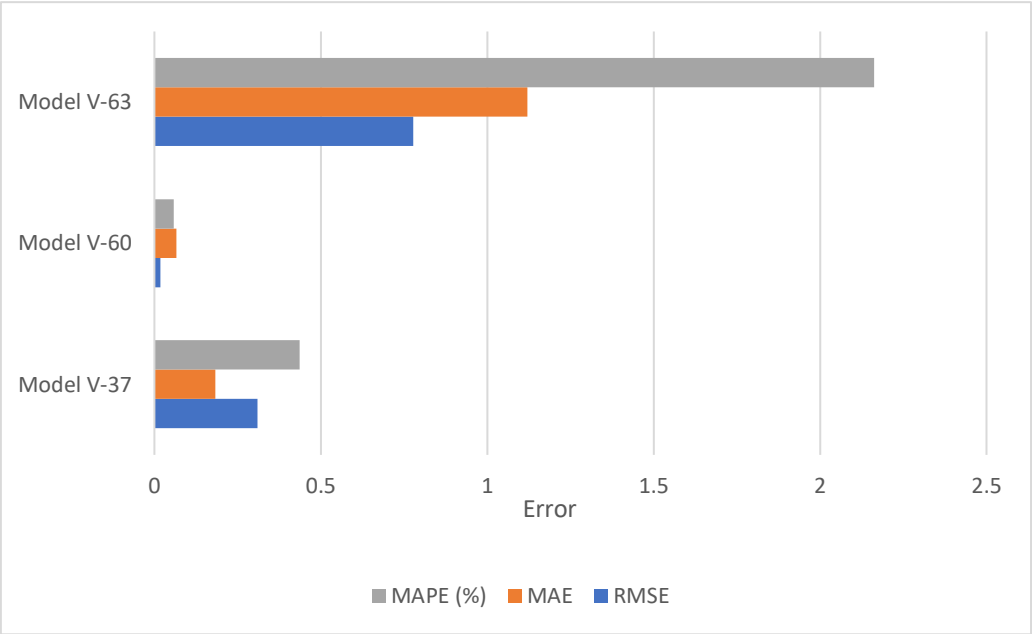


Figure 9-17 Selected Models for Model V from MATLAB nftool

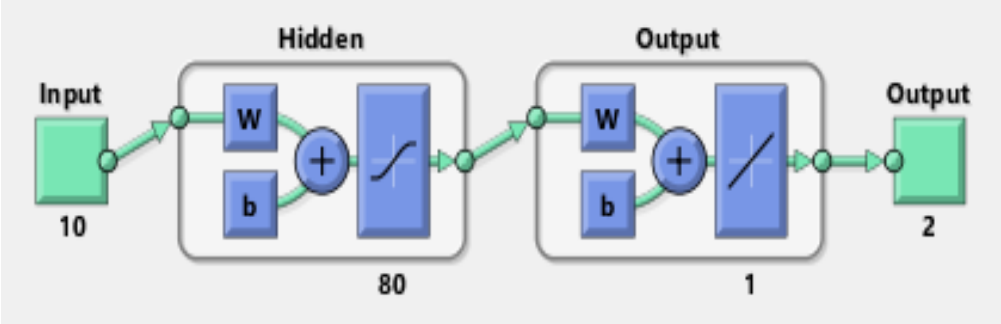


Figure 9-18 ANN Diagram for Model V-60

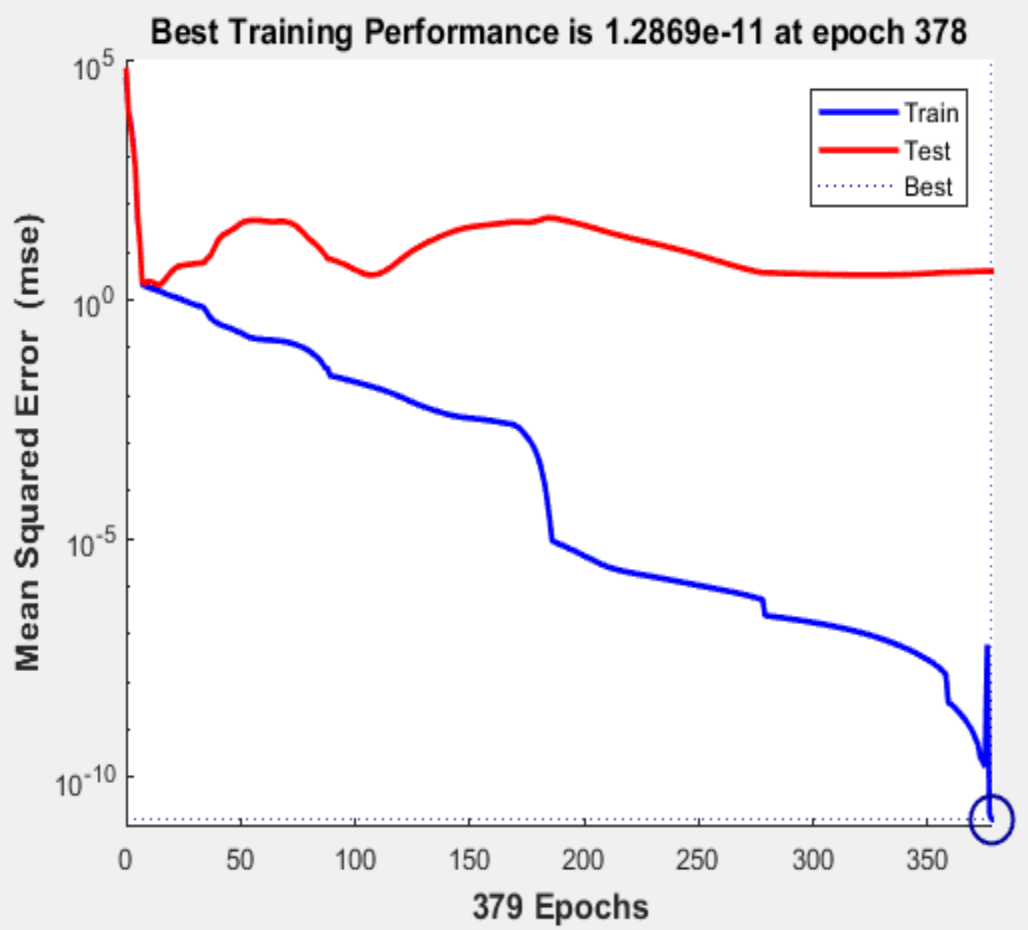


Figure 9-19 Training Performance For Model V-60

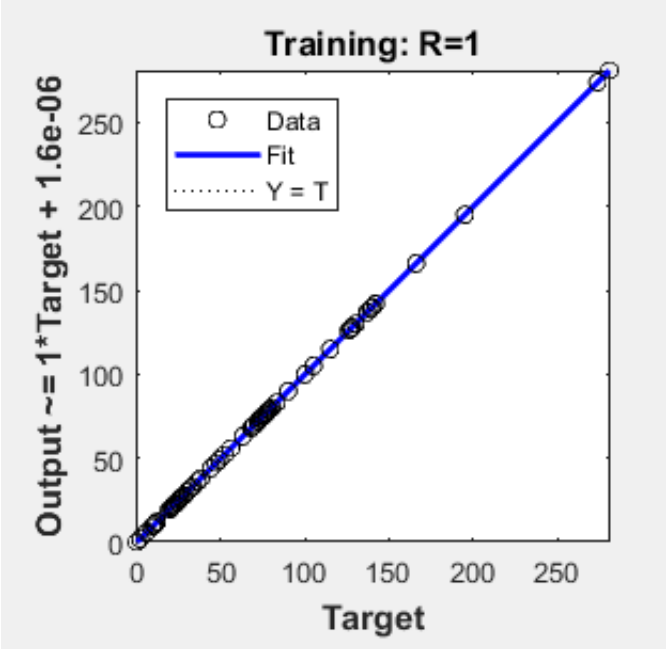


Figure 9-20 Regression Results for Model V-60

9.4 Developing of Model V Using Regression Excel Tool

Linear regression analysis is used to predict the output of dependent variable (variation payment delay) on the basis of the independent variables, which are: Claim review (X1), Payment processed by employer (X2), Variations orders evaluation and approval (X3), Payment amount (X4), Balance of contingency in the contract (X5), Available contingency in the contract (X6), Extension of time occurrence (X7), Contractor experience (X8), Consultant experience (X9), and Work progress (X10). All the independent variables are known from historical data as explained previously in Section (6.3). Linear regression analysis is used to predict the output of dependent variable (Variation payments) on the basis of the independent variables mentioned above. The linear regression equation output is as presented in Equation (9-1):

$$Y = -68.825 + 0.92*X1 + 0.952*X2 + 0.984*X3 + 0*X4 + 0*X5 + 0*X6 - 1.193*X7 + 0.137*X8 + 0.095*X9 - 0.02*X10 \quad \textbf{(9-1)}$$

The goodness of fit for the Regression Model is shown in Table (9-15) based on 95% confidence interval. The Multiple R value represents the correlation coefficient of determination with a value of 0.999 showing a strong linear relationship between the predicted output and targets. The calculated R-squared value of 99.8% is representing the goodness of fit for the above equation. This means that 99.8% of the variance in the dependent variable (variation payment delay) is explained by the model indicating a high predictive power for the model. The adjusted R square is equal to 99.7% and it represents R square value in term of the number of variables in the model. As shown both values are very close to each other. The computed standard error is equal to 2.963%, this tells that the average

distance for the predicted points falls about ±2*2.963 from the regression line on the basis of 95% confidence, this result shows very good prediction power of the model. The obtained P-value of 1.656×10^{-101} (considered extremely significant) and reflecting the probability for obtaining an R squared value of 99.8%.

Table 9-15 Goodness of Fit for Model V-76

Goodness of Fit >= 0.80	
Regression Statistics	
Multiple R	0.999
R Square	0.998
Adjusted R Square	0.997
Standard Error	2.963
P-value	1.656E-101
Observations	91

Table (9-16) shows the variables codes, coefficients, the standard error along with the lower and upper bounds of the confidence interval of each variable. The table shows that five out of eleven variables (54.5%) have positive biased coefficients, three out of eleven (27%) have negative biased coefficients, and three have zero values. As shown in the table for a 95% confidence prediction interval, about 95% of the observations should fall within coefficient ± 2*standard error from the regression line, these ranges of confidence intervals are expected to comprise the right value of the coefficient for each variable of the regression model.

Table 9-16 Regression Coefficients for Model V-76

Code	Variables	Coefficient	Standard Error	Lower 95%	Upper 95%
C	Constant	-68.825	7.249	-83.250	-54.400
X1	Claim review(days)	0.920	0.044	0.833	1.007
X2	Payment process by owner (days)	0.952	0.021	0.909	0.994
X3	Variation orders evaluation and approval (days)	0.984	0.006	0.972	0.996
X4	Payment amount (BD)	0.000	0.000	0.000	0.000
X5	Balance of contingency in the contract (BD)	0.000	0.000	0.000	0.000
X6	Allocated contingency in the contract (BD)	0.000	0.000	0.000	0.000
X7	Extension of time (binary)	-1.193	1.610	-4.397	2.011
X8	Contractor experience (years)	0.137	0.205	-0.271	0.544
X9	Consultant experience (years)	0.095	0.377	-0.655	0.845
X10	Work Progress (delay in days)	-0.020	0.017	-0.055	0.014

Table 9-17 Significant and Non-Significant Variables Model V-76

Code	Variables	t Stat	P-value	Significance
C	Constant	-9.495	9.378E-15	Significant
X1	Claim review(days)	21.073	2.147E-34	Significant
X2	Payment process by owner (days)	44.931	1.593E-58	Significant
X3	Variation orders evaluation and approval (days)	164.84	4.527E-103	Significant
X4	Payment amount	-0.241	0.810	Not Significant
X5	Balance of contingency in the contract	0.823	0.413	Not Significant
X6	Allocated contingency in the contract	0.481	0.632	Not Significant
X7	Extension of time	-0.741	0.461	Not Significant
X8	Contractor experience (years)	0.669	0.506	Not Significant
X9	Consultant experience (years)	0.252	0.802	Not Significant
X10	Work progress (delay in days)	-1.177	0.243	Not Significant

Table (9-17) shows the P-values of the regression model which examine the effect of each independent variable on the dependent variable and its significance to the model. The results show that four variables are considered significant including the constant which are: Claim review, Payment by owner, and Variations orders evaluation and approval. These variables show very low p-values (less than 0.05) indicating a high significance. On the other hand, seven variables are considered as not significant showing high p-values (more than 0.05), one of these seven is

extension of time, and it was input as binary (0,1) variable and it is included in the regression equation with low coefficient amount. The most three non-significant variable are real variables entered in the model as payment amounts in Bahraini dinar which are: Payment amount, Balance of contingency in the contract, and Allocated contingency in the contract, these factors will not be included in the model because their coefficients are equal to zero. The other three non-significant factors are Work progress, Contractor experience, and Consultant experience; these factors are included in the model with very low values of their coefficients. This may be due to their indirect relationship to payment delay.

Accordingly, the model is modified by eliminating the non-significant factors and including only the significant independent factors as per the model result which are: Claim review (days), Payment process by owner (days) and Variation orders evaluation and approval (days), as presented in Equation (9-2).

$$Y = -63.647 + 0.924*X1 + 0.940*X2 + 0.982*X3 \quad (9\text{-}2)$$

The goodness of fit for the Regression Model is shown in Table (9-18) based on 95% confidence intervals. The Multiple R value is equal to 0.999 showing a very good linear relationship between the predicted output and targets. The calculated R-squared value is equal to 99.8% which is indicating a great predictive power of the model. The computed standard error is equal to 2.923, this result asses a very good precision of the prediction by the model. The obtained P-value of 5.9×10^{-114}(considered extremely significant) and reflecting the probability for obtaining an R squared value of 99.8%.

Table 9-18 Goodness of Fit for Model V-76 Using Equation (9-2)

Regression Statistics	
Multiple R	0.999
R Square	0.998
Adjusted R Square	0.998
Standard Error	2.923
P-value	5.9E-114
Observations	91

Table 9-19 Regression Coefficients for Model V-76 Using Equation (9-2)

Code	Variables	Coefficient	Standard Error	Lower 95%	Upper 95%
C	Constant	-63.647	1.276	-66.182	-61.111
X1	Claim review(days)	0.924	0.033	0.858	0.989
X2	Payment process by owner (days)	0.940	0.018	0.904	0.977
X3	Variation orders evaluation and approval (days)	0.982	0.005	0.972	0.993

Table (9-19) shows the variables codes, coefficients, the standard error along with the lower and upper bounds of the confidence interval of each variable. The table shows that three out of four variables (75%) have a positive biased coefficient, and one out of four (25%) have negative biased coefficients. As shown in the table for a 95% confidence prediction interval, about 95% of the observations should fall within coefficient value ± 2*Standard error from the regression line, these ranges of confidence intervals are expected to comprise the right value of the coefficient for each variable of the regression model.

9.4.1 Test sample of the regression model

The test sample cases (14 cases) are used to validate the regression models of Equation (9-1) and Equation (9-2). The test sample along with the estimated output and the performance errors are shown in Table (9-20) and (9-21) for Equation (9-1) and (9-2), respectively. As shown in Table (9-20) and Figure (9-18), the performance error values for Equation (9-1) are for RMSE of 0.918, MAE of 0.842, and MAPE of 1.943. While Table (9-21) and Figure (9-19) show the performance error values for Equation (9-2) as follows: RMSE of 1.110, MAE of 0.958 and MAPE of 2.806%. Figure (9-21) and Figure (9-22) show the targeted variation payment delay (days) and estimated variation payment delay (days) of the regression model for Equation (9-1) and Equation (9-2), respectively. It is noticed that there is a remarkable matching between the two curves for Equation (9-1) results, which is reflecting very good performance for the regression equation. On the other hand, Equation (9-2) results are showing relatively less matching between the curves compared with that of Equation (9-1). Therefore, it is recommended to choose Equation (9-1) for the regression model (Model V-76). Thus, modify Equation (9-1) by excluding the variables with zero coefficient, it becomes:

$$Y = -68.825 + 0.92*X1 + 0.952*X2 + 0.984* X3 - 1.193*X7 + 0.137*X8 + 0.095*X9 - 0.02*X10 \quad \textbf{(9-3)}$$

Table 9-20 Test Sample of The Regression Model (Model V-76) Using Equation (9-1)

Case No.	Target output (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83	81.447	2.412	1.553	0.019
2	70	68.660	1.796	1.340	0.019
3	30	31.002	1.004	1.002	0.033
4	25	26.088	1.184	1.088	0.044
5	21	21.937	0.878	0.937	0.045
6	32	32.878	0.771	0.878	0.027
7	142	141.167	0.694	0.833	0.006
8	63	63.755	0.570	0.755	0.012
9	83	83.331	0.110	0.331	0.004
10	36	37.099	1.207	1.099	0.031
11	83	82.255	0.555	0.745	0.009
12	68	67.465	0.286	0.535	0.008
13	69	68.453	0.299	0.547	0.008
14	19	19.152	0.023	0.152	0.008
Performance			RMSE	MAE	MAPE (%)
			0.918	0.842	1.943

Table 9-21 Test Sample of the Regression Model (Model V-76) Using Equation (9-2)

Case No.	Target output (days)	Predicted output (days)	Squared error	Absolute error	Percentage error (%)
1	83	82.007	0.986	0.993	1.196
2	70	69.241	0.576	0.759	1.084
3	30	31.327	1.761	1.327	4.423
4	25	26.417	2.008	1.417	5.668
5	21	23.081	4.331	2.081	9.910
6	32	33.697	2.880	1.697	5.303
7	142	141.605	0.156	0.395	0.278
8	63	64.027	1.055	1.027	1.630
9	83	83.667	0.445	0.667	0.804
10	36	37.513	2.289	1.513	4.203
11	83	82.547	0.205	0.453	0.546
12	68	67.817	0.033	0.183	0.269
13	69	68.799	0.040	0.201	0.291
14	19	19.699	0.489	0.699	3.679
Performance			RMSE	MAE	MAPE (%)
			1.110	0.958	2.806

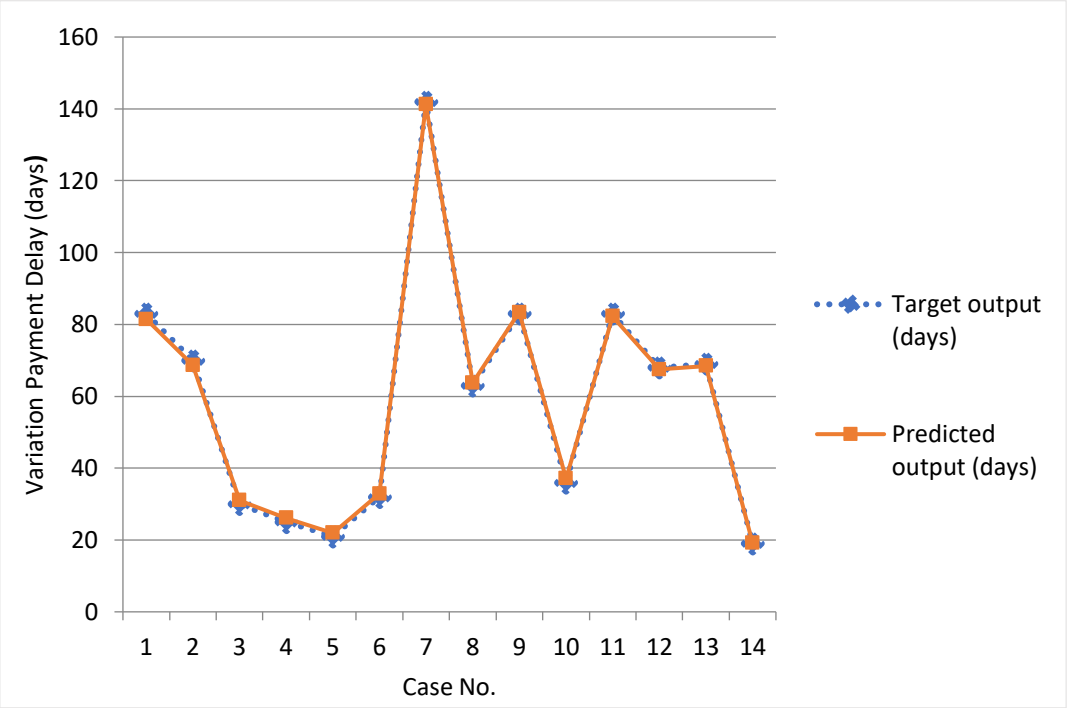


Figure 9-21 Performance of Test Sample of The Regression Model (Model V-76) Using Equation (9-1)

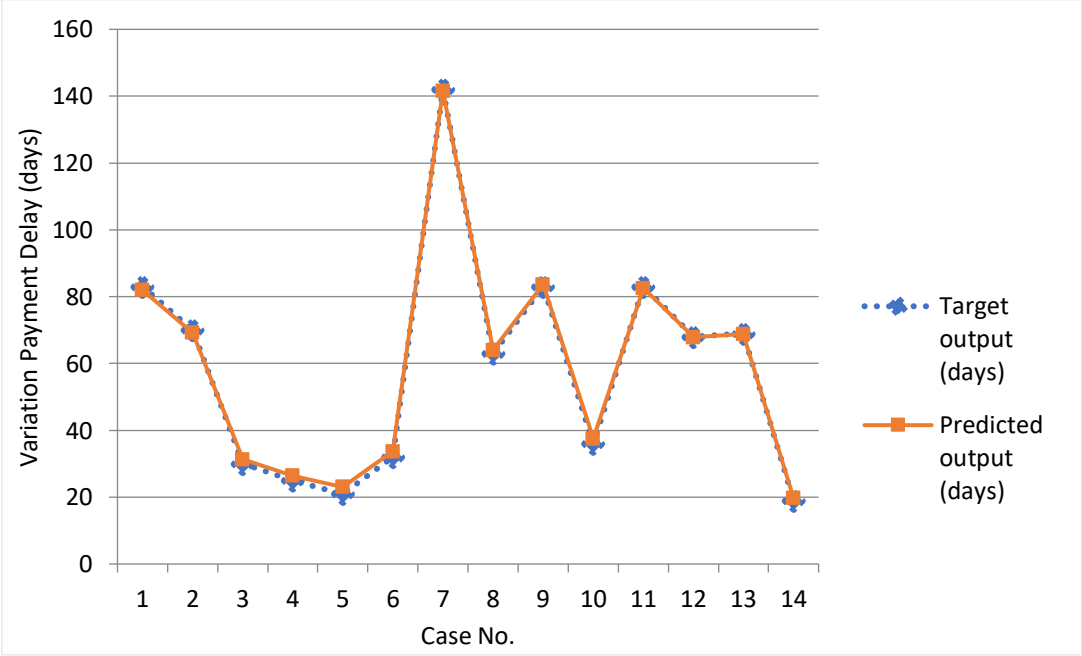


Figure 9-22 Performance of Test Sample for (Model 7-6) Using Equation (9-2)

9.5 Comparison and Discussion of Model V Results

Table (9-22) and Figure (9-23) show the comparison between the selected models developed for variation payment delay using MATLAB (nntool), MATLAB (nftool) and Excel Regression analysis tool. As per the computed results the best performance model is the neural network Model V-60 using MATLAB nftool with 80 neurons in hidden layer as shown in Figure (9-18) based on Bayesian Regulation algorithm and tan-sigmoid function. Model V-60 is having an error values for RMSE of 0.066, MAE of 0.018 and MAPE of 0.058%. In the second place comes the neural network Model V-14 with 5 neurons in hidden layer as shown in Figure (9-8) based on Bayesian Regulation algorithm and tan-sigmoid function. Model V-14 has a minimum value for RMSE of 0.304, MAE of 0.248 and MAPE of 0.586%. Finally, in the third place the regression model (Model V-76) with RMSE value of 0.918, MAE value of 0.842 and MAPE value of 1.943%. The ANN using MATLAB nftool shows relatively better results than Matlab nntool and regression model. Although, as discussed previously in Chapter 8, Section (8.5), on the basis of simplicity and ease of implementation of regression models, it will still give fairly good results for predicting of variation payment delay as well. The most significant factors for regression analysis model are: Variation orders evaluation and approval (days), Claim review (days) and Payment process by owner (days). All of these significant factors represent the main steps in MoW variation payment process explained previously in Chapter 3, Section (3.4), starting with submittion of the variation oerders evaluation and approval by consultant, then claim review and approval by the issuance of payment certificate, and finally the payment process by owner. On the other hand, the most significant factors for neural network model are not defined by MATLAB program as mentioned in Section (8.5).

The results of this chapter show that Bayesian Regulation algorithm always produces better results than Levenberge algorithm and Scaled Conjugate algorithm; this can be justified as discussed previously in Chapter 8, Section 8.5. This chapter also shows that MATLAB (nftool) always gives better results than MATLAB (nntool), the justification of this may be because MATLAB (nfool) generates all the weights, data normalizations and dividing of data set automatically. This requires less human interference which means less human errors in contrast of MATLAB (nntool) as shown in the process of each tool previously in Chapter 7, Subsections 7.5.1 and 7.5.2. MATLAB nftool can automatically adjust the dataset to properly fit the complication of the problem.

Table 9-22 Comparison Of the Selected Models for (Model V)

Model No	RMSE	MAE	MAPE%	R-square	Type	Tool
Model V-14	0.304	0.248	0.586	0.999	Neural Network	MATLAB nntool
Model V-60	0.066	0.018	0.058	1	Neural Network	MATLAB nftool
Model V-76	0.918	0.842	1.943	0.998	Regression Model	Excel ATP

9.6 Chapter Summary

The Variation payment delay model (model V) development passed through several steps started by choosing the type of model, dividing the data set, choosing the software used to build the model, entering the dependent and independent variables, choosing the different parameters for each type of model, and finally training and testing the models to choose the best model for variation payment delay prediction. A total of seventy-six (76) models were trained, validated and tested for Model V. The best

performance model proved to be neural network Model V-60 developed using MATLAB nfool. This model has 80 neurons in the hidden layer, and it is based on Bayesian Regulation algorithm and tan-sigmoid function. It has shown the minimum error results with RMSE value of 0.066, MAE value of 0.018 and MAPE value of 0.058%.

CHAPTER 10
Conclusions and Recommendations

10.1 Introduction
10.2 Conclusions
10.3 Recommendations
10.4 Limitation of the Study
10.5 Further Recommended Studies

Chapter 10
Conclusions and Recommendations

10.1 Introduction

Payment has been described as a very important element in the construction industry which can be hugely affected by delay risk. Payment delay results in accumulated problems through the construction pyramid starting from the owner and all the way to contractors and sub-contractors. This chapter summarizes the outcomes from the earlier chapters and reflects the juice of the work done. Moreover, it shows that the objectives and aims of the study have been achieved. The first objective of this study was to identify factors and consequences of payment delay. The second objective was to create a prediction model that establishes the delay (days) of two types of payments, namely, Interim payment and Variation payment for the contractors working for MoW.

10.2 Conclusions

The key findings and results of the study are as follow: -

The factors that contribute to payment delay in construction projects are ranked as per the values of their RII. These factors are divided to three groups, group (1): owner related factors consisting of five factors, group (2): consultant's related factors consisting of twelve factors, group (3): contractors related factors consisting of fifteen factors; and group (4): other related payment delay factors consisting of three factors. The outcome of the RII analysis has revealed that "contractor related factors" group is the most significant group as per consultant perspective, while "owner related factors" group is the most significant as per contractor’s perspective. This is expected because every part is blaming the other and accusing him as the cause of payment delay. These results reflect the important role each of the

owner and the contractor plays in the occurrence of payment delay. Moreover, the higher RIIs of "contractor related factors" group as per consultant's perspective and the higher number of factors related to this group indicate the major role of contractors in the occurrence of payment delay, and reveal that by addressing these factors the delay can be decreased effectively. The ranking of the individual factors of payment delay reference to their RII show that three out of the top ten ranked factors as per the perspectives of consultant and contractors are common, these are: Changes in scope; Long and bureaucratic process in governmental departments; and Delay in extension of time approval.

Similarly, the consequences of payment delay on construction projects are ranked as per the values of their RIIs. The effect and consequences of payment are divided into two groups; group (1) Consultants and project characteristics group consisting of twelve consequences, and group (2) is Contractors consequences group consisting of twelve consequences**.** The results show that consequences related to Consultant and project characteristics has the highest RIIs as per consultant perspective, while Contractors consequences has the highest RII as per contractor's perspective. Also, the results show that nine consequences as per consultant's and contractor's perspective are common. These eight consequences are: Contractor slow down progress until receiving his payment, Inability of contractor to procure material, equipment and services, Accumulation of uncompleted projects due to payment delay, Inability to control project and deliver it on time, Cash flow problems, Inability of contractor to pay his staff salaries, Dispute between contract parties, Consultant spend longer time than planned, and Extension of project time. These consequences are very common in construction projects suffering from payment delay issues. Specially for small contractors with modest capital.

Thirteen solutions to overcome payment delay issue in Kingdom of Bahrain are suggested by the field experts in this study. The top six effective solutions that are assessed as high by both consultant's and contractor's perspectives are: Improve and ease the process of payments valuation and certification; Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time; Proper planning and budgeting of all governmental projects; Proper management of cash flow as per approved scope of work and schedule program; Manage to anticipate any risk that may delay the project due to payment issues; and Briefings and meetings prior start of works.

Two models are developed in this study for the prediction of interim payment delay (Model I) and prediction of variation payment delay (Model V). Models development is achieved through several steps starting by choosing the type of model, dividing the data set, choosing the software used to build the model, entering the dependent and independent variables, choosing the different parameters for each type of model and finally training and testing the models to choose the best model. Model I and Model V are developed using eleven and ten independent variables, for seventy and seventy-six trial models, respectively, using different parameters, programs and Modeling techniques including artificial neural models and regression models.

For Model I for interim payment delay (days), the best performance model is a neural network Model I-48 developed using MATLAB nftool. This model is having 10 neurons in the hidden layer, and it is based on Bayesian Regulation algorithm, and tan-sigmoid function. It has the minimum error results of RMSE of 1.520, MAE of 0.969 and MAPE of 3.767%. In the second place the regression model Model I-70 with RMSE of 3.928, MAE

of 3.655 and MAPE of 11.944%. For Model V for variation payment delay, the best performance model is neural network Model V-60 developed using MATLAB nfool. This model is having 80 neurons in the hidden layer and it is based on Bayesian Regulation algorithm, and tan-sigmoid function. It has performance result of RMSE value of 0.066, MAE value of 0.018 and MAPE value of 0.058%. In the second place comes the neural network Model V-14 developed using MATLAB nntool. This model is having 5 neurons in hidden layer based on Bayesian Regulation algorithm, and tan-sigmoid function. It has performance result of RMSE of 0.304, MAE of 0.248 and MAPE of 0.586%. Finally, in the third place the regression model (Model V-76) with RMSE value of 0.918, MAE value of 0.842 and MAPE value of 1.943%.

Finally, as the results show by comparing the Neural Networks and linear regression approach, it is shown that the estimation accuracy of Neural Networks approach gives relatively better results than linear regression analysis for payment delay (days) for governmental building construction projects.

10.3 Recommendations

This study has shown the important role each of the contract parties has on the occurrence of payment delay, some practices can increase the risk of payment delay while others can help in eliminating the risk, in this section some recommendations are presented to help contract parties in overcoming this issue: -

1- The owner of the project is recommended to define accurate requirements for scope of work in order to avoid any additional requests during construction stage which may affect the payment process. This can be done by proper documentation of lessons learned

of previous projects and using it as reference to avoid the repetition of same slip-ups.

2- Projects with external funding must have a separate payment process in order to speed up the approvals required from different parties. A representative that has the power for decision making must be available during the construction stage to approve and prompt the payments.
3- MoW projects need contractors with high quality work and highly qualified employees to avoid factors of payment delay. Therefore, during the tendering stage contract must be awarded to competent contractor who can comply with MoW requirements and not only to the lowest bidder.
4- MoW pre-qualification process of contractors must include additional requirements from contractors, who desire to handle MoW projects by attending specific workshops to learn the process of the ministry and all the documents, work procedures and required specifications. Such workshops enhance the communication, decrease the duplication of work, decrease disputes, and enable contractors to understand the payment risk that might occur in order to take proper precautions to avoid any payment risk during construction such as payment delay.
5- MoF process needs to be studied in more details in order to know the reasons of delay and find solution for it.
6- MoW is recommended to use the models developed in this study to enhance the current payment process by predicting the payment delay risk in days and trying to avoid it by taking proper measures during the planning stage of projects.
7- It is recommended for MoW to use an electronic approval system to speed up the approval process and enhance communication. This can be implemented using an electronic signature to avoid the normal and slow cycle of hard documents approval.

8- The consultant is recommended to revise carefully the drawings and the bill of quantity in order to avoid any unnecessary variations or disputes in future that may affect payments.

9- Consultant is recommended to monitor the payments of the main contractor to the subcontractors and suppliers to avoid any payment delay to these parties in the project.

10- Contractor is recommended to use the models presented in this study in order to predict the delay in payment and to know when to make early claim of payments along with full required documents to avoid delay. Moreover, knowing the amount of delay risk for the contractor can help him to arrange the cash needed prior beginning of the project to avoid financial problems.

11- Contractor is recommended to use the model to have a good view about the expected payment delays in project, and to plan a cash flow programme that is applicable during construction stage.

10.4 Limitation of the study:

The major limitation of this study is lack of data which is manifested in inadequate cases in payment delay. The study is also limited to one directorate of MoW, which is concerned with the building construction section; other directorates concerned with road and sanitary section are not covered. Another limitation is the scope of contractors being covered by the questionnaire by including only contractors of class A and B, and excluding other classes.

10.5 Future recommended studies

1- To Study the payment delay disputes of construction projects in Bahrain courts, and the remedial actions (verdicts) taken for those whose payments were delayed in each law case. A Model can be

created thereafter to predict the remedies by ranking the factors taken from all these cases to create a clear picture for the payment delay compensation, and the most type of payment that is facing delay or non-payment.

2- To conduct a comparative study between the payment delay in governmental and private projects in Bahrain, and to determine the sector that is more sensitive to payment delay.
3- To study the payment delay for other departments in MoW such as road and sanitary.
4- To develop payment delay models for governmental construction projects with more data and by including other types of payments such as advanced and final payment.

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Appendices

Appendix 1: Questionnaire Format
Appendix 2: Questionnaire Results and Calculations
Appendix 3: Historical Cases for Governmental Buildings Projects for Models Design
Appendix 4: nntool Code for Data Entry and Normalization
Appendix 5: Model I nntool Performance for the Training and Validation Samples
Appendix 6: Performance of Test Sample for Model I Using nntool
Appendix 7: Model I nftool Performance for the Training and Validation Samples
Appendix 8: Performance of Test Sample for Model I Using nftool
Appendix 9: Model V nntool Performance for the Training and Validation Samples
Appendix 10: Performance of Test Sample for Model V Using nntool
Appendix 11: Model V nftool Performance for the Training and Validation Samples
Appendix 12: Performance of Test Sample for Model V Using nftool
Appendix 13: Simulation Function for Model I-48
Appendix 14: Simulation Function for Model V-60

Appendix 1
Questionnaire Format

University of Bahrain

College of Engineering

Department of Mechanical Engineering



2 Questionnaire

SECTION (A): General Information.

1. **Place of work**

☐ MoW ☐ Contracting Company

Optional: name of Company_____

2. **Age**

☐ 25-30 ☐ 36-40 ☐ 46 and above

☐ 31-35 ☐ 41-45

2. **Educational background**

☐ Architect ☐ Electrical Engineer ☐ Quantity Survey Engineer

☐ Civil Engineer ☐ Mechanical Engineer ☐ Other_____

3. **Total Work Experience**

☐ 3-7 ☐ 12-15 ☐ 20-23 ○ 28-31

☐ 8-11 ☐ 16-19 ☐ 24-27 ○ 32 and above

4. **How many projects have you participated in**

☐ 5-10 ☐ 20-30 ☐ 40-50

☐ 10-20 ☐ 30-40 ☐ 50 and more

5. **Payment is an issue in Kingdom of Bahrain public building construction projects**

☐ Strongly Agree ☐ Agree ☐ Strongly Disagree

☐ Disagree ☐ Unsure/Uncertain

SECTION (B): The questions of this section are intended to allocate the causes of payment delays.

- **Please indicate the factors that contribute to causes of payment delay.**

No	The Causes of payment delay	Always	Often	Sometimes	Rare	Never
	(1) Owner related factors (other Ministries)					
1	Changes in scope					
2	Long and Bureaucratic process in governmental departments					
3	Unavailability of funds					
4	Refusal to pay for materials stored on job site					
5	Refusal to pay interest on late payment					
	(2) Consultant related factors (MoW)					
1	Delay in claim review and evaluation process.					
2	Delay in issuance of payment certificate Process.					
3	Slow processing of variations orders.					
4	Excess work load on the consultant employees.					
5	Consultant's experience					
6	Delays of documentation required to fulfill payments (site instructions, control forms, material approval forms… etc)					
7	Bureaucracy or wrong channels of communication.					
8	Slow processing of final accounts					

9	Less periodical meetings to address work and payment problems					
10	Weakness in making decisions on issues arising in the course of construction					
11	Delay in Extension of time approval					
13	Inaccurate bill of quantities					
(3) Contractor related factors						
1	Submit claims with calculation mistakes.					
2	Delay in submitting the payment evaluation (Claim) by the contractor.					
3	Contractor's experience with governmental projects.					
4	Incomplete documents for variation claims.					
5	Delay in the progress of works and activities.					
6	Failure to understand the contract agreement					
7	Inability to follow certain procedures of MoW.					
8	Failure to do work based on bill of quantity					
9	Accuracy of payment scheduling program					
10	Un-appropriate implementation of projects program					
11	Duplication of work					
12	Inappropriate project team					
13	Inattention of risk					

14	Accuracy of estimation					
15	Inadequate Financial resource					
Others						
1	Ministry of Finance processes can delay the payment as from the day the certificate is issued until is it received by the contractor. (related to MoF Processes & regulations)					
2	Changes in rules and regulations					
3	Economic changes					

Section (C): The questions of this section are intended to allocate the consequences of payment delays.

- **Please indicate the factors that contribute to the consequences of payment delay.**

No	The consequences in construction projects	Always	Often	Sometimes	Rare	Never
(1) Consultant and project characteristic related Consequences						
1	Consultants spend longer time than planned					
2	Accumulation of uncompleted projects due to payment delay.					
3	Not being able to get start with new projects on the waiting list.					
4	Extension of project time					
5	Contractor could stop/abandon the works.					
6	Contractor slow down the progress until payment is received.					
7	Affects the ability to control the project and deliver it on time.					

8	Dispute between the parties in the contract					
9	Low quality works					
10	Poor site safety					
11	Termination of contract by owner or contractor					
12	Bad reputation of the consultant					
(2) Contractor related consequences						
1	Inability of the contractor to procure material, equipment's and services					
2	Inability of the contractor to pay his staff salaries					
3	Forcing the contractor to take loans with high interest rate to pay the due expenditures. (**borrow from financial organization**).					
4	Bankruptcy of contractors					
5	Cash flow problems					
6	Difficulty for tendering for new projects					
7	Contract termination					
8	Seek legal entity to resolve payment issues					
9	Sub-contractor refuse to continue works on the project					
10	Loose of good reputation.					
11	Loses of materials.					
12	Escape of labors and engineers.					

SECTION (D): The effectiveness of the suggested solution to the payment delay

Each Scale represents the following rating

Rate of scale points	**1**	**2**	**3**	**4**	**5**
Classification	Very low effectiveness	Low effectiveness	Moderate effectiveness	High effectiveness	Very high effectiveness

- **Please indicate the possible solutions to mitigate the payment delay problem in the government Building construction projects in Kingdom of Bahrain.**

No	**Suggested solution to the payment delay**	**1**	**2**	**3**	**4**	**5**
1	Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time. (by improving pre-award procedures such as tech evaluation and pre-qualification)					
2	Calculate the work load of each staff from both the consultant and contractor's side and distribute the works load evenly.					
3	To introduce a well-studied regulation that will grant an advanced payment for the contractor to allow ordering the required materials to expedite the works.					
4	Raise contractor's awareness of contracts and payment process in governmental projects.					
5	Improve and ease the process of payments valuation and certification (CED-FRD-MOF).					
6	Proper planning and budgeting of all government projects.					
7	Proper management of cash flow as per approved scope of work and schedule program.					
8	Manage to anticipate any risk that may delay the project due to payment issues.					

9	Briefings and meetings prior start of works					
10	Compensating for late payment					
11	Proper communication among contract parties (the client, consultants as well as the contractors to resolve issues).					
12	Contractors should submit timely accurate invoices with complete documents.					
13	Avoiding bureaucracy in governmental system.					

Appendix 2

Questionnaire Results and calculations

This section includes the questionnaire results and calculations as per the consultant's and contractor's perspective for the following sections: -

1- Section (A): General Information by Consultant's and Contractor's perspective.
2- Section (B): Factors Causing Payment Delay (Consultant's Perspective)
3- Section (B): Factors Causing Payment Delay (Contractor's Perspective)
4- Section (C): Consequences of Payment Delay (Consultant's Perspective)
5- Section (C): Consequences of Payment Delay (Contractor's Perspective)
6- Section (D): Effectiveness of Suggested Solutions to the Payment Delay (Contractor's Perspective)
7- Section (D): Effectiveness of Suggested Solutions to the Payment Delay (Contractor's Perspective)

Section(A) General Information

- **Consultants participant's Age:-**

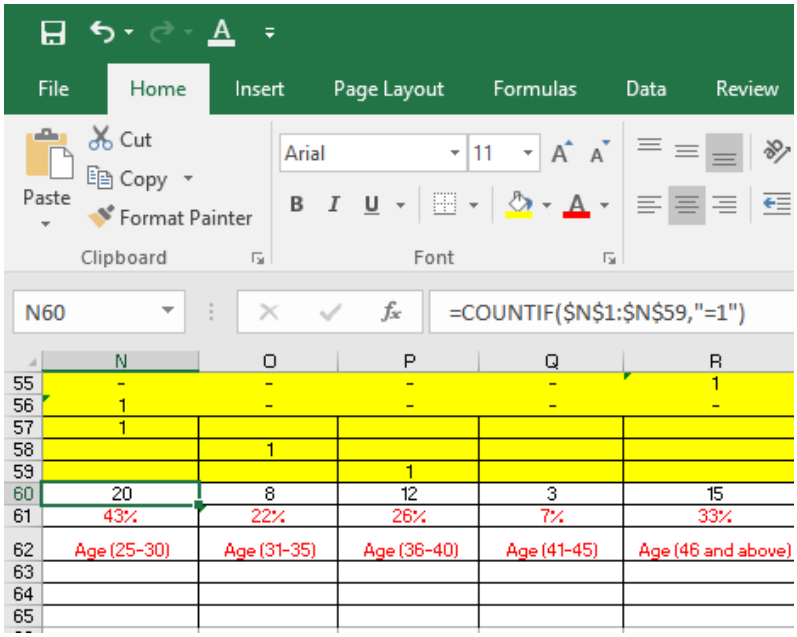
Participant NO	Q2 - Place of work: (Ministry of Works)	Q2 - Place of work: (Contracting Company)	Q3 - Name of Contracting Company (Optional):	Q4 - Age (25-30)	Q4 - Age (31-35)	Q4 - Age (36-40)	Q4 - Age (41-45)	Q4 - Age (46 and above)
1	true	-	-	1	-	-	-	-
2	true	-	-	1	-	-	-	-
3	true	-	-	-	-	1	-	-
4	true	-	-	1	-	-	-	-
5	true	-	-	1	-	-	-	-
6	true	-	-	1	-	-	-	-
7	true	-	-	1	-	-	-	-
8	true	-	-	-	-	-	-	1
9	true	-	-	-	-	1	-	-
10	true	-	-	-	-	-	-	1
11	true	-	-	-	-	-	1	-
12	true	-	-	-	1	-	-	-
13	true	-	-	1	-	-	-	-
14	true	-	-	-	-	1	-	-
15	true	-	-	1	-	-	-	-
16	true	-	-	-	1	-	-	-
17	true	-	-	1	-	-	-	-
18	true	-	-	-	1	-	-	-

19	true	-	-	-	-	-	-	1
20	true	-	-	1	-	-	-	-
21	true	-	-	-	-	-	-	1
22	true	-	-	-	-	-	-	1
23	true	-	-	-	-	1	-	-
24	true	-	-	-	-	-	-	1
25	true	-	-	-	-	1	-	-
26	true	-	-	-	-	-	-	1
27	true	-	-	-	-	-	-	1
28	true	-	-	1	-	-	-	-
29	true	-	-	-	-	1	-	-
30	true	-	-	-	-	-	-	1
31	true	-	-	-	-	-	-	1
32	true	-	-	-	-	1	-	-
33	true	-	-	-	1	-	-	-
34	true	-	-	-	-	-	-	1
35	true	-	-	-	-	1	-	-
36	true	-	-	1	-	-	-	-
37	true	-	-	1	-	-	-	-
38	true	-	-	-	-	-	-	1
39	true	-	-	-	-	-	-	1
40	true	-	-	-	1	-	-	-
41	true	-	-	1	-	-	-	-
42	true	-	-	1	-	-	-	-
43	true	-	-	-	-	-	1	-
44	true	-	-	-	-	-	1	-
45	true	-	-	-	1	-	-	-

46	true	-	-	-	-	1	-	-
47	true	-	-	1	-	-	-	-
48	true	-	-	-	-	1	-	-
49	true	-	-	-	1	-1	-	-
50	true	-	-	-	-	1	-	-
51	true	-	-	1	-	-	-	-
52	true	-	-	-	-	-	-	1
53	true	-	-	1	-	-	-	0
54	true	-	-	-	-	-	-	1
55	true	-	-	1	-	-	-	-
56	true	-	-	1				
57	true	-	-		1			
58	true	-	-			1		

Calculation: -

"COUNTIF" function was used in Excel to calculate the number of respondents in each category and it was used to count the answers of the questions for both Consultants and contractors participants.



- **Contractors participant's age: -**

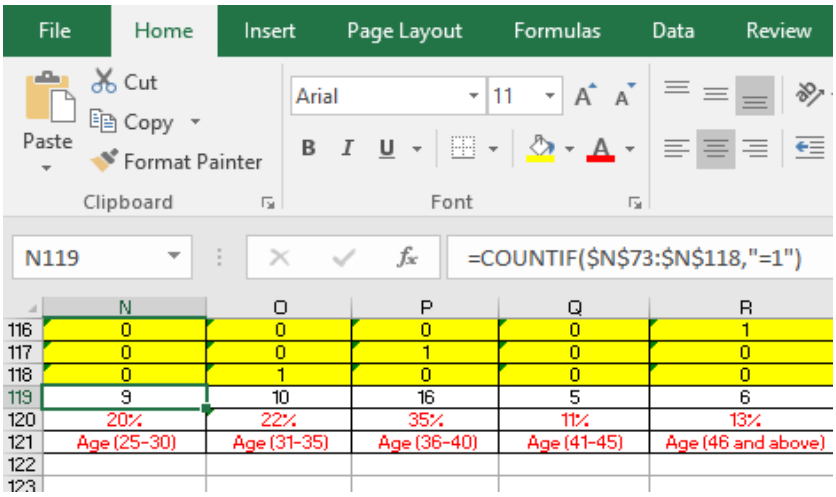
Participant NO	Q2 - Place of work: (Ministry of Works)	Q3 - Name of Contracting Company (Optional) :	Q2 - Place of work: (Contracting Company)	Q4 - Age (25-30)	Q4 - Age (31-35)	Q4 - Age (36-40)	Q4 - Age (41-45)	Age (46 and above)
1	-	-	true	1	-	-	-	-
2	-	-	true	-	-	-	-	1
3	-	Al Hedaya Contracting Co. WLL	true	-	-	-	-	1
4	-	First Kuwaiti Trading & Contracting	true	-	-	1	-	-
5	-	Abdullah Hassan Al darazi & Sons	true	-	-	1	-	-
6	-	First Kuwaiti Trading & contracting	true	1	-	-	-	-
7	-	-	true	-	-	-	1	-
8	-	Alhganah contractor	true	-	-	1	-	-
9	-	Terna Contracting W.L.L	true	-	1	-	-	-
10	-	Poullaides Construction Company W.L.L	true	-	-	1	-	-
11	-	-	true	-	-	1	-	-
12	-	-	true	-	-	1	-	-
13	-	Aldahrani	true	-	-	-	-	1

14	-	-	true	-	-	-	1	-
15	-	TAMCON CONTRACTING COMPANY	true	1	-	-	-	-
16	-	Dadabhai Construction	true	-	-	-	1	-
17	-	Tamcon Contracting Co. B.S.C.(C)	true	-	-	1	-	-
18	-	-	true	1	-	-	-	-
19	-	Dar Al Khaleej	true	-	-	1	-	-
20	-	Alghanah group	true	-	1	-	-	-
21	-	Alwardi Construction	true	-	1	-	-	-
22	-	Poullaides Construction Company W.L.L	true	-	-	1	-	-
23	-	Hafeera	true	-	-	1	-	-
24	-	-	true	-	-	-	-	1
25	-	Rp construction	true	-	1	-	-	-
26	-	-	true	1	0	0	0	0
27	-	-	true	0	1	0	0	0
28	-	-	true	-	0	1	0	0
29	-	-	true	-	0	0	1	0
30	-	-	true	-	0	0	0	1
31	-	-	true	1	0	0	0	0
32	-	-	true	0	1	0	0	0

33	-	-	true	0	0	1	0	0
34	-	-	true	1	0	0	0	0
35	-	-	true	1	0	0	0	0
36			true	1	0	0	0	0
37			true	0	1	0	0	0
38	-	-	true	0	0	1	0	0
39	-	-	true	0	1	0	0	0
40	-	-	true	0	0	1	0	0
41	-	-	true	0	0	1	0	0
42	-	-	true	0	1	0	0	0
43	-	-	true	0	0	0	1	0
44	-	-	true	0	0	0	0	1
45	-	-	true	0	0	1	0	0
46	-	-	true	0	1	0	0	0

Calculation: -

"COUNTIF" function was used in Excel to calculate the number of respondents in each category and it was used to count the answers of the questions for both Consultants and contractors participants.



Calculation of total participants:

Example:

Percentage of age (25-30) = 29/104*100= 27.88%

Range	No of responses	Percentage= No of responses/total respondents
Age (25-30)	29.00	27.88%
Age (31-35)	18	17.31%
Age (36-40)	28	25.96%
Age (41-45)	8	7.69%
Age (46 and above)	21	20.19%

The collected results by consultants and contractor's perspective for question 5 to question 8 is shown below: -

Consultant Perspective					Contractors Perspective				
Participant NO	Q5 - Educational background:	Q6 - Total Work Experience:	Q7 - How many projects have you participated in?	Q8 - (Payment is an issue in Kingdom of Bahrain public building construction projects).	Participant NO	Q5 - Educational background:	Q6 - Total Work Experience:	Q7 - How many projects have you participated in?	Q8 - (Payment is an issue in Kingdom of Bahrain public building construction projects).
1	1	1	2	2	1	6	2	1	1
2	1	1	2	2	2	1	5	5	2
3	1	3	2	2	3	1	6	4	1
4	1	1	1	2	4	1	2	1	3
5	1	1	1	2	5	1	4	3	2
6	1	1	1	1	6	1	1	1	2
7	1	1	1	1	7	2	5	2	2
8	1	6	5	2	8	3	2	5	2
9	1	3	3	2	9	1	1	2	1
10	1	5	3	2	10	1	3	1	2
11	1	6	3	2	11	3	8	6	3
12	4	3	2	1	12	1	4	6	2

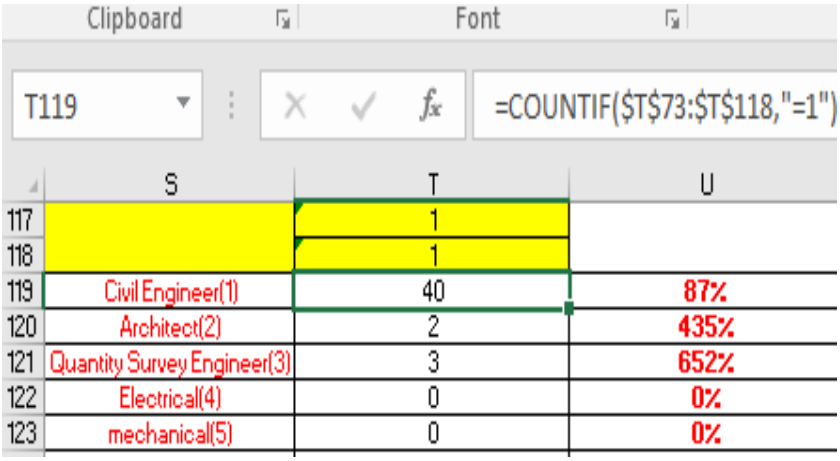
13	1	1	1	2	13	1	8	6	2
14	1	3	1	1	14	3	6	6	1
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16	1	2	1	4	16	1	3	2	2
17	1	1	1	2	17	1	4	2	1
18	3	2	6	3	18	1	1	1	1
19	1	7	6	4	19	1	3	1	2
20	1	1	4	2	20	2	2	1	2
21	2	8	6	1	21	1	3	3	1
22	1	6	3	2	22	1	3	1	2
23	1	3	1	2	23	1	5	6	2
24	2	8	6	1	24	1	7	5	1
25	1	4	6	1	25	1	2	1	2
26	2	7	6	1	26	1	1	1	2
27	1	6	5	2	27	1	1	2	2
28	2	1	2	5	28	1	1	2	2
29	3	2	6	1	29	1	1	1	2
30	1	5	2	3	30	1	1	1	2
31	1	6	4	2	31	1	1	1	2
32	3	3	5	2	32	1	3	3	2
33	3	2	6	2	33	1	3	1	2
34	1	8	6	4	34	1	5	1	2
35	3	8	6	4	35	1	3	5	1
36	3	1	6	2	36	1	3	4	1
37	3	2	6	2	37	1	5	1	2
38	3	6	6	4	38	1	3	1	1
39	3	5	6	2	39	1	3	1	1
40	4	3	6	1	40	1	5	1	2
41	1	1	6	1	41	1	3	3	1
42	4	1	1	3	42	1	3	1	1

43	5	4	6	2	43	1	3	1	3
44	4	5	4	2	44	1	2	5	4
45	1	2	3	2	45	1	2	4	2
46	5	2	6	1	46	1	2	1	2
47	1	1	5	2					
48	4	4	6	1					
49	1	2	1	1					
50	1	3	6	2					
51	1	2	6	2					
52	1	6	6	1					
53	2	1	1	3					
54	4	2	6	4					
55	5	1	1	3					
56	1	1	1	2					
57	1	1	1	2					
58	1	7							

Q5 - Educational background:

The used Function is COUNTIF for example if COUNTIF($T$73:$T$118,"=1") one participants is added to civil engineering major.

Example : Percentage of Civil engineering = 75/104*100= 72.12%



Code	Options	Consultant	Contractors	Total	Percentage%
1	Civil Engineer (1)	35	40	75	72.12%
2	Architect (2)	5	2	7	6.73%
3	Quantity Survey Engineer (3)	9	3	12	11.54%
4	Electrical (4)	6	0	6	5.77%
5	mechanical (5)	3	0	3	2.88%
6	other (6)	0	0	1	0.96%

Q6 - Total Work Experience:

Example: Percentage of (3-7 years of experience) = 29/104*100= 27.9%

Code	Options	Consultant	Contractors	Total	Percentage%
1	3-7 (1)	19	10	29	27.9
2	8-11 (2)	10	8	18	17.3
3	12-15 (3)	8	14	22	21.2
4	16-19(4)	3	3	6	5.8
5	20-23 (5)	4	6	10	9.6

6	24-27 (6)	7	10	9	8.7
7	28-31 (7)	3	8	4	3.8
8	32 and above (8)	4	14	6	5.8

Q7 - How many projects have you participated in?

Example: Percentage of (5-10 projects) = 40/104*100= 38.83%

Code	Options	Consultant	Contractors	Total	Percentage%
1	5-10 (1)	17	23	40	38.83%
2	10-20(2)	6	6	12	11.65%
3	20-30 (3)	5	4	9	8.74%
4	30-40 (4)	3	3	6	5.83%
5	40-50 (5)	4	5	9	8.74%
6	50 and more (6)	23	23	28	27.18%

Q8 - (Payment is an issue in Kingdom of Bahrain public building construction projects).

Example: Percentage of (strongly agree) = 29/104*100= 28.16%

Code	Options	Consultant	Contractors	Total	Percentage%
1	Strongly Agree(1)	15	14	29	28.16%
2	Agree(2)	30	27	57	55.34%
3	Unsure/Uncertain(3)	5	3	8	7.77%
4	Disagree(4)	6	2	8	7.77%
5	Strongly Disagree(5)	2	0	2	1.94%

Section (B): Factors Causing Payment Delay (Consultant Perspective)

Participants No	1- Changes in scope	2- Long and Bureaucratic process in governmental departments	3- Unavailability of funds	4- Refusal to pay for materials stored on job site	5- Refusal to pay interest on late payment	1-Delay in claim review and evaluation process	2-Delay in issuance of payment certificate Process	3-Slow processing of variations orders.	4-Excess work load on the consultant employees	5-Consultant's experience.	6-Delays of documentation required for payments	7-Bureaucracy or wrong channels of communication	8-Slow processing of final accounts.	9-Less periodical meetings to address work and payment problems.)	10-Weakness in making decisions on issues arising in the course of	11-Delay in Extension of time approval	12-Inaccurate bill of quantities	1-Submit claims with calculation mistakes	2-Delay in submitting the payment evaluation (Claim) by the	3-Contractor's experience with governmental projects	4-Incomplete documents for variation claims	5-Delay in the progress of works and activities	6-Failure to understand the contract agreement	7-Inability to follow certain procedures of MoW	8-Failure to do work based on bill of quantity	9-Accuracy of payment scheduling program	10-Un-appropriate implementation of projects program	11-Duplication of work	12-Inappropriate project team	13-Inattention of risk	14-Accuracy of estimation	15-Inadequate Financial resource	1-Ministry of Finance processes	2-Changes in rules and regulations	3-Economic changes
1	1	3	4	3	4	1	1	2	2	5	2	2	2	2	2	2	3	3	2	4	3	3	5	4	3	2	2	3	4	4	1	2	3	3	4
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Calculation (continue next page)

RII%	total	never (5)	rare (4)	sometimes (3)	often (2)	always (1)	Options
78.3	5	0	3	17	2	1	1- Changes in scope
75.17	5	0	5	18	2	1	2- Long and Bureaucratic process in governmental departments
62.07	5	2	1	17	1	5	3- Unavailability of funds
47.93	5	9	2	21	4	1	4- Refusal to pay for materials stored on job site
57.58	5	1	1	20	4	1	5- Refusal to pay interest on late payment
66.20	5	0	1	18	2	6	1-Delay in claim review and evaluation process
58.96	5	1	2	21	1	5	2-Delay in issuance of payment certificate Process
69.65	5	1	5	26	1	9	3-Slow processing of variations orders.
64.13	5	1	1	26	1	5	4-Excess work load on the consultant employees
62.75	5	3	1	24	1	7	5-Consultant’s experience.
72.1	5	0	4	24	2	9	6-Delays of documentation required for payments
62.4	5	3	1	26	1	4	7-Bureaucracy or wrong channels of communication
70	5	1	6	25	1	1	8-Slow processing of final accounts.
66.55	5	0	9	28	1	7	9-Less periodical meetings to address work and payment problems.)
68.96	5	1	9	20	1	9	10-Weakness in making decisions on issues arising in the course of
73.4	5	0	7	16	2	1	11-Delay in Extension of time approval
64.5	5	2	1	18	1	7	12-Inaccurate bill of quantities
72.4	5	1	3	23	2	1	1-Submit claims with calculation mistakes
73.79	5	0	5	18	2	1	2-Delay in submitting the payment evaluation (Claim) by the
72.41	5	0	8	17	2	1	3-Contractor’s experience with governmental projects
76.2	5	0	4	17	2	1	4-Incomplete documents for variation claims
75.2	5	1	3	17	2	1	5-Delay in the progress of works and activities
70.3	5	1	8	21	1	1	6-Failure to understand the contract agreement
71	5	1	9	19	1	1	7-Inability to follow certain procedures of MoW
65.5	5	1	1	17	2	4	8-Failure to do work based on bill of quantity
67.6	5	1	8	22	2	5	9-Accuracy of payment scheduling program
72.4	5	0	4	25	1	1	10-Un-appropriate implementation of projects program
57.6	5	5	1	21	1	3	11-Duplication of work
64.1	5	2	1	24	1	6	12-Inappropriate project team
62.4	5	3	9	27	1	3	13-Inattention of risk
70.3	5	0	7	23	1	9	14-Accuracy of estimation
66.89	5	2	9	20	2	6	15-Inadequate Financial resource
70.68	5	0	6	23	2	8	1-Ministry of Finance processes
57.24	5	1	1	33	9	0	2-Changes in rules and regulations
60.34	5	4	1	23	1	4	3-Economic changes

Section (B): Factors Causing Payment Delay (Contractors Perspective)

7	6	5	4	3	2	1	Participants No
1	2	3	2	3	2	1	1- Changes in scope
1	3	1	4	1	1	2	2- Long and Bureaucratic process in governmental departments
1	5	5	4	3	2	4	3- Unavailability of funds
1	3	5	5	3	1	3	4- Refusal to pay for materials stored on job site
1	3	5	4	5	1	4	5- Refusal to pay interest on late payment
3	3	3	3	1	2	3	1-Delay in claim review and evaluation process
3	3	2	5	1	2	3	2-Delay in issuance of payment certificate Process
1	2	5	2	1	2	2	3-Slow processing of variations orders.
3	5	3	3	4	3	4	4-Excess work load on the consultant employees
3	1	5	5	3	2	2	5-Consultant's experience.
1	3	5	3	4	3	2	6-Delays of documentation required for payments
3	5	5	4	4	2	1	7-Bureaucracy or wrong channels of communication
3	3	5	3	1	2	3	8-Slow processing of final accounts.
3	2	3	4	1	4	2	9-Less periodical meetings to address work and payment problems.)
1	5	5	4	1	2	2	10-Weakness in making decisions on issues arising in the course of
1	3	3	3	1	1	3	11-Delay in Extension of time approval
1	5	3	2	4	1	2	12-Inaccurate bill of quantities
4	3	3	2	3	2	2	1-Submit claims with calculation mistakes
2	3	1	2	5	4	1	2-Delay in submitting the payment evaluation (Claim) by the
3	3	3	3	3	4	2	3-Contractor's experience with governmental projects
3	3	3	3	3	4	3	4-Incomplete documents for variation claims
3	3	1	3	4	3	1	5-Delay in the progress of works and activities
3	3	5	2	2	4	3	6-Failure to understand the contract agreement
3	3	5	3	2	4	4	7-Inability to follow certain procedures of MoW
3	3	5	3	4	4	2	8-Failure to do work based on bill of quantity
3	3	3	3	4	3	3	9-Accuracy of payment scheduling program
3	3	3	4	3	4	2	10-Un-appropriate implementation of projects program
3	3	3	4	5	4	3	11-Duplication of work
3	3	5	4	3	4	4	12-Inappropriate project team
3	3	5	4	4	3	4	13-Inattention of risk
3	3	5	4	3	3	2	14-Accuracy of estimation
3	3	5	3	3	4	1	15-Inadequate Financial resource
1	3	5	3	3	2	2	1-Ministry of Finance processes
1	3	5	3	3	4	2	2-Changes in rules and regulations
1	5	5	3	3	4	3	3-Economic changes

8	1	3	2	4	4	2	2	3	3	5	3	4	2	2	3	4	4	5	4	5	4	4	5	5	5	4	5	5	5	5	5	5	3	3	3
9	3	3	4	3	5	4	3	4	2	3	5	4	5	2	4	5	4	2	1	2	2	4	2	3	5	3	3	4	4	3	4	4	4	3	4
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16	3	2	2	3	2	3	2	2	2	3	2	3	2	1	2	2	2	3	3	3	3	3	3	3	3	3	3	3	3	3	3	3	2	3	2
17	2	2	3	3	5	2	2	1	3	3	3	3	1	2	2	2	3	4	3	4	3	4	5	4	4	4	3	4	4	4	4	3	1	2	3
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22	1	3	1	4	5	3	3	1	4	4	3	4	2	3	2	3	1	4	5	5	3	2	3	4	3	1	1	4	4	4	1	4	5	5	4
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46	3	1	4	3	3	2	2	2	4	1	4	4	5	4	2	3	1	3	3	3	4	3	4	3	3	3	1	2	1	4	2	4	3	3	3

Calculation (continue next page)

RII%	total	never (5)	rare (4)	sometimes (3)	often (2)	always (1)	Options
74.3478	4	3	2	15	1	15	1- Changes in scope
72.6087	4	2	4	15	1	12	2- Long and Bureaucratic process in governmental departments
58.2608	4	6	1	13	1	5	3- Unavailability of funds
45.6521	4	1	1	18	0	3	4- Refusal to pay for materials stored on job site
65.2173	4	1	5	7	7	16	5- Refusal to pay interest on late payment
71.3043	4	3	4	15	1	12	1-Delay in claim review and evaluation process
65.2173	4	5	3	16	1	3	2-Delay in issuance of payment certificate Process
70.4347	4	4	4	11	1	9	3-Slow processing of variations orders.
48.6956	4	1	1	17	5	1	4-Excess work load on the consultant employees
56.0869	4	1	7	16	8	5	5-Consultant's experience.
56.5217	4	6	1	19	8	3	6-Delays of documentation required for payments
47.8260	4	1	1	14	3	3	7-Bureaucracy or wrong channels of communication
70	4	3	2	17	1	7	8-Slow processing of final accounts.
56.5217	4	8	1	13	1	3	9-Less periodical meetings to address work and payment
63.0434	4	5	1	10	1	6	10-Weakness in making decisions on issues arising in the course
72.6087	4	3	3	16	1	14	11-Delay in Extension of time approval
60.8695	4	6	1	13	7	9	12-Inaccurate bill of quantities
54.7826	4	5	1	18	9	1	1-Submit claims with calculation mistakes
51.7391	4	8	1	15	4	4	2-Delay in submitting the payment evaluation (Claim) by the
54.7826	4	1	4	22	8	2	3-Contractor's experience with governmental projects
56.9565	4	3	1	19	7	3	4-Incomplete documents for variation claims
54.7826	4	5	1	23	5	2	5-Delay in the progress of works and activities
48.2608	4	1	1	18	6	0	6-Failure to understand the contract agreement
50.8695	4	7	1	16	5	2	7-Inability to follow certain procedures of MoW
48.2608	4	9	1	20	4	0	8-Failure to do work based on bill of quantity
52.6087	4	5	1	24	2	2	9-Accuracy of payment scheduling program
60.8695	4	5	9	17	9	6	10-Un-appropriate implementation of projects program
55.2173	4	8	1	14	7	5	11-Duplication of work
51.7391	4	9	1	15	3	5	12-Inappropriate project team
46.9565	4	9	1	16	3	1	13-Inattention of risk
53.9130	4	7	1	16	7	3	14-Accuracy of estimation
50	4	1	9	22	4	1	15-Inadequate Financial resource
54.3478	4	1	8	17	7	4	1-Ministry of Finance processes
60.4347	4	4	9	18	1	3	2-Changes in rules and regulations
60	4	4	9	21	7	5	3-Economic changes

Section (C): Consequences of Payment Delay (Consultant Perspective)

Participants No	1-Consultants spend longer time than planned.	2-Accumulation of uncompleted projects due to payment delay.	3-Not being able to get start with new projects on the waiting	4-Extension of project time.	5-Contractor could stop/abandon the works.	6-Contractor slow down the progress until payment is received.	7-Affects the ability to control the project and deliver it on	8-Dispute between the parties in the contract.	9-Low quality works.)	10-Poor site safety.)	11-Termination of contract by owner or contractor.)	12-Bad reputation of the consultant.	1-Inability of the contractor to procure material, equipment's	2-Inability of the contractor to pay his staff salaries.)	3-Forcing the contractor to take loans with high interest rate to	4-Bankruptcy of contractors.	5-Cash flow problems.	6-Difficulty for tendering for new projects.	7-Contract termination.	8-Seek legal entity to resolve payment issues.	9-Sub-contractor refuse to continue works on the project.	10-Loose of good reputation.	11-Loses of materials.	12-Escape of labors and engineers.
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57	4	4	3	2	4	4	1	4	4	3	2	3	2	2	3	2	2	4	3	3	3	4	4	3
58	3	3	4	3	3	5	2	1	3	4	3	4	3	3	4	3	3	3	2	2	4	5	3	4

Calculation (continue next page)

RII%	total	never (5)	rare (4)	sometimes (3)	often (2)	always (1)	Options
70.345	58	0	6	2	2	6	1-Consultants spend longer time than planned.
65.862	58	0	9	2	1	5	2-Accumulation of uncompleted projects due to payment delay.
61.724	58	3	1	2	1	6	3-Not being able to get start with new projects on the waiting list.
75.862	58	0	5	1	2	1	4-Extension of project time.
55.862	58	1	2	1	8	4	5-Contractor could stop/abandon the works.
70.000	58	1	7	2	2	9	6-Contractor slow down the progress until payment is received.
74.483	58	0	5	1	2	1	7-Affects the ability to control the project and deliver it on time.
68.276	58	1	9	2	1	1	8-Dispute between the parties in the contract.
62.069	58	4	1	2	1	4	9-Low quality works.)
58.966	57	5	1	2	1	4	10-Poor site safety.)
51.379	58	5	2	1	8	1	11-Termination of contract by owner or contractor.)
55.172	58	6	1	2	1	0	12-Bad reputation of the consultant.
73.793	58	0	7	1	1	1	1-Inability of the contractor to procure material, equipment’s and
71.034	58	0	9	1	2	7	2-Inability of the contractor to pay his staff salaries.)
60.000	58	5	1	1	1	5	3-Forcing the contractor to take loans with high interest rate to pay
55.862	58	3	2	1	1	1	4-Bankruptcy of contractors.
70.690	58	0	5	2	2	7	5-Cash flow problems.
65.862	58	0	1	2	2	3	6-Difficulty for tendering for new projects.
51.034	58	3	2	2	5	0	7-Contract termination.
55.517	58	2	2	2	1	1	8-Seek legal entity to resolve payment issues.
64.828	58	1	1	2	1	6	9-Sub-contractor refuse to continue works on the project.
65.517	58	2	7	2	1	6	10-Loose of good reputation.
61.379	58	2	1	3	1	4	11-Loses of materials.
61.379	58	1	1	3	9	5	12-Escape of labors and engineers.

Section (C): Consequences of Payment Delay (Contractors Perspective)

Participants No	1-Consultants spend longer time than planned.	2-Accumulation of uncompleted projects due to payment delay.	3-Not being able to get start with new projects on the waiting list.	4-Extension of project time.	5-Contractor could stop/abandon the works.	6-Contractor slow down the progress until payment is received.	7-Affects the ability to control the project and deliver it on time.	8-Dispute between the parties in the contract.	9-Low quality works.)	10-Poor site safety.)	11-Termination of contract by owner or contractor.)	12-Bad reputation of the consultant.	1-Inability of the contractor to procure material, equipment's and	2-Inability of the contractor to pay his staff salaries.)	3-Forcing the contractor to take loans with high interest rate to pay	4-Bankruptcy of contractors.	5-Cash flow problems.	6-Difficulty for tendering for new projects.	7-Contract termination.	8-Seek legal entity to resolve payment issues.	9-Sub-contractor refuse to continue works on the project.	10-Loose of good reputation.	11-Loses of materials.	12-Escape of labors and engineers.
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42	5	1	2	1	3	2	2	5	2	2	5	5	5	1	2	5	3	2	5	3	5	5	2	3
43	4	1	3	4	5	4	3	4	3	5	2	3	4	4	4	4	4	3	2	4	4	2	3	4
44	3	2	4	3	4	3	4	3	4	3	3	4	3	3	5	3	2	4	4	2	3	4	4	2
45	2	3	5	2	2	5	5	2	5	4	4	2	2	2	3	2	5	5	3	5	2	3	5	5
46	3	1	4	3	3	2	2	2	4	4	4	4	3	4	2	3	1	3	3	3	4	3	4	3
Calculation (continue next page)																								

RII%	total	never (5)	rare (4)	sometimes (3)	often (2)	always (1)	Options
65.65	46	4	6	17	1	8	1-Consultants spend longer time than planned.
68.26	46	1	8	16	1	8	2-Accumulation of uncompleted projects due to payment
53.91	46	6	1	17	6	3	3-Not being able to get start with new projects on the
63.04	46	4	9	16	1	7	4-Extension of project time.
65.22	46	3	8	16	1	7	5-Contractor could stop/abandon the works.
69.57	46	3	5	14	1	9	6-Contractor slow down the progress until payment is
66.96	46	3	5	17	1	6	7-Affects the ability to control the project and deliver it on
65.65	46	4	7	12	1	5	8-Dispute between the parties in the contract.
47.39	46	9	1	13	5	1	9-Low quality works.)
47.39	46	9	1	13	5	1	10-Poor site safety.)
47.39	46	9	1	13	5	1	11-Termination of contract by owner or contractor.)
50.00	46	7	1	16	4	2	12-Bad reputation of the consultant.
69.57	46	4	3	16	1	1	1-Inability of the contractor to procure material,
66.96	46	3	9	13	1	1	2-Inability of the contractor to pay his staff salaries.)
60.00	46	7	9	11	1	4	3-Forcing the contractor to take loans with high interest rate
64.78	46	5	9	12	1	1	4-Bankruptcy of contractors.
66.96	46	5	6	13	1	1	5-Cash flow problems.
60.43	46	5	9	17	1	5	6-Difficulty for tendering for new projects.
51.30	46	6	1	17	6	1	7-Contract termination.
51.74	46	8	1	18	7	1	8-Seek legal entity to resolve payment issues.
60.87	46	4	1	11	7	9	9-Sub-contractor refuse to continue works on the project.
57.83	46	8	1	13	6	8	10-Loose of good reputation.
59.13	46	6	1	13	8	7	11-Loses of materials.
59.57	46	5	1	13	1	5	12-Escape of labors and engineers.

Section (D): Effectiveness of Suggested Solutions to the Payment Delay (Consultant Perspective)

Participants No	1-Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time. (by improving pre-award procedures such as tech evaluation and pre-qualification))	2-Calculate the work load of each staff from both the consultant and contractor's side and distribute the works load evenly.	3-To introduce a well-studied regulation that will grant an advanced payment for the contractor to allow ordering the required materials to expedite the works.	4-Raise contractor's awareness of contracts and payment process in governmental projects.	5-Improve and ease the process of payments valuation and certification.	6-Proper planning and budgeting of all government projects.	7-Proper management of cash flow as per approved scope of work and schedule program.	8-Manage to anticipate any risk that may delay the project due to payment issues.	9-Briefings and meetings prior start of works.	10-Compensating for late payment.	11-Proper communication among contract parties (the client, consultants as well as the contractors to resolve	12-Contractors should submit timely accurate invoices with complete documents.	13-Avoiding bureaucracy in governmental system.
1	1	3	4	4	4	4	1	2	1	5	5	3	1
2	3	4	2	3	4	3	3	3	4	3	3	3	3
3	4	5	4	4	5	5	4	4	4	5	5	4	4
4	5	4	5	4	4	5	5	5	5	5	5	4	5
5	3	2	5	2	5	3	2	3	1	4	4	3	3
6	3	5	2	5	3	3	3	2	5	3	2	3	3
7	4	4	5	4	4	4	4	5	3	4	5	5	4

8	3	2	2	2	3	2	2	1	3	3	1	3	3
9	4	5	4	4	5	5	4	5	3	5	4	4	4
10	3	5	5	4	5	5	5	5	5	5	5	4	3
11	2	2	2	3	3	3	2	1	2	1	2	2	2
12	3	4	3	5	5	4	4	4	3	5	3	3	3
13	3	2	4	4	2	3	4	2	4	2	2	3	3
14	5	4	5	5	5	5	4	5	5	5	5	5	5
15	2	2	2	1	1	2	2	3	2	1	2	1	2
16	1	1	1	2	1	1	1	1	2	2	1	1	1
17	2	2	1	1	2	3	2	1	2	1	1	3	2
18	2	2	1	1	2	1	1	2	3	2	2	1	2
19	3	3	3	3	4	4	4	5	4	5	4	2	3
20	4	4	4	4	4	4	4	5	4	5	5	4	4
21	3	3	4	3	4	4	3	4	3	3	3	3	3
22	1	2	5	4	5	5	5	3	1	4	5	3	1
23	3	3	3	4	5	5	5	3	1	3	4	2	3
24	5	5	5	5	5	5	5	5	4	5	4	4	5
25	4	5	5	5	5	5	5	5	3	5	5	5	4
26	5	5	5	5	5	5	5	5	5	5	5	5	5
27	3	3	3	4	4	4	4	3	3	4	4	4	3

28	3	5	3	4	4	4	4	3	4	4	4	3	3
29	5	5	5	5	5	5	5	4	4	5	5	5	5
30	4	3	5	4	5	5	5	5	5	5	5	5	4
31	4	1	3	4	5	5	4	3	4	4	5	5	4
32	3	4	4	3	5	5	3	3	5	5	5	4	3
33	4	4	4	5	5	4	5	4	4	5	4	4	4
34	5	1	4	5	5	4	5	5	1	4	5	5	5
35	3	4	4	4	4	4	4	5	2	3	4	5	3
36	3	1	5	5	5	5	5	5	3	5	5	2	3
37	4	2	5	4	4	4	5	5	3	1	2	2	4
38	2	4	4	4	4	4	3	2	2	5	5	3	2
39	3	3	4	5	4	4	3	4	2	3	5	4	3
40	3	5	5	3	2	2	4	3	2	2	4	4	3
41	4	4	3	4	4	4	3	5	5	5	4	4	4
42	3	4	4	4	4	4	4	4	3	4	4	4	3
43	4	4	4	4	4	4	4	4	4	4	4	5	4
44	5	3	5	5	5	5	4	5	4	4	5	3	5
45	5	4	4	4	4	5	5	4	4	4	4	5	5
46	4	2	3	3	4	3	4	4	4	4	4	3	4
47	3	3	4	2	2	3	3	3	3	3	3	3	3

48	3	5	4	5	5	5	5	4	5	5	5	4	3
49	3	2	5	5	5	5	5	4	5	4	4	3	3
50	5	5	5	5	5	4	5	3	3	4	4	5	5
51	1	2	4	5	4	3	4	3	3	4	5	5	1
52	1	4	5	3	5	5	5	5	3	5	5	5	1
53	2	3	3	2	3	4	3	3	3	2	4	2	2
54	5	4	4	3	5	4	5	4	4	3	3	3	5
55	4	5	2	3	3	3	4	2	3	4	5	3	4
56	5	4	5	3	3	5	5	3	3	5	5	3	5
57	4	5	4	4	5	4	3	4	5	4	4	5	4
58	3	3	3	5	4	3	4	5	4	3	3	4	3

Calculation (continue next page)

Mean	RII%	total	never (5)	rare (4)	sometimes (3)	often (2)	always (1)	Options
4.138	82.76	58	31	12	10	2	3	1-Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time. (by improving pre-award procedures such as tech evaluation and pre-qualification))
3.345	66.90	58	11	14	22	6	5	2-Calculate the work load of each staff from both the consultant and contractor's side and distribute the works load evenly.
3.431	68.62	58	14	17	11	12	4	3-To introduce a well-studied regulation that will grant an advanced payment for the contractor to allow ordering the required materials to expedite the works.
3.793	75.86	58	19	20	10	6	3	4-Raise contractor's awareness of contracts and payment process in governmental projects.
3.776	75.52	58	17	22	11	5	3	5-Improve and ease the process of payments valuation and certification.
4.448	88.97	58	25	20	6	5	2	6-Proper planning and budgeting of all government projects.
3.966	79.31	58	21	21	11	3	2	7-Proper management of cash flow as per approved scope of work and schedule program.
3.845	76.90	58	20	20	10	5	3	8-Manage to anticipate any risk that may delay the project due to payment issues.
3.655	73.10	58	19	14	15	6	4	9-Briefings and meetings prior start of works.
3.345	66.90	58	11	16	18	8	5	10-Compensating for late payment.
3.828	76.55	58	22	17	10	5	4	11-Proper communication among contract parties (the client, consultants as well as the contractors to resolve
3.948	78.97	58	24	19	6	6	3	12-Contractors should submit timely accurate invoices with complete documents.
3.569	71.38	58	15	15	19	6	3	13-Avoiding bureaucracy in governmental system.

Section (D): Effectiveness of Suggested Solutions to the Payment Delay (Contractors Perspective)

Participants No	1-Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time. (by improving pre-award procedures such as tech evaluation and pre-qualification))	2-Calculate the work load of each staff from both the consultant and contractor's side and distribute the works load evenly.	3-To introduce a well-studied regulation that will grant an advanced payment for the contractor to allow ordering the required materials to expedite the works.	4-Raise contractor's awareness of contracts and payment process in governmental projects.	5-Improve and ease the process of payments valuation and certification.	6-Proper planning and budgeting of all government projects.	7-Proper management of cash flow as per approved scope of work and schedule program.	8-Manage to anticipate any risk that may delay the project due to payment issues.	9-Briefings and meetings prior start of works.	10-Compensating for late payment.	11-Proper communication among contract parties (the client, consultants as well as the contractors to resolve	12-Contractors should submit timely accurate invoices with complete documents.	13-Avoiding bureaucracy in governmental system.
1	2	3	2	2	4	1	2	2	3	2	2	4	2
2	5	5	5	5	5	5	5	5	5	5	5	4	5
3	2	3	1	1	1	1	1	2	2	1	1	1	2
4	3	4	4	3	3	3	3	3	3	3	3	3	3
5	2	4	5	5	5	5	5	4	4	5	5	5	4
6	2	3	3	3	3	3	3	3	2	3	3	2	2
7	5	5	5	5	5	5	5	5	5	5	5	5	5

8	5	4	4	4	5	5	5	4	4	3	4	5	5
9	4	4	4	5	5	5	4	5	5	4	4	4	3
10	5	4	4	3	5	5	5	4	5	2	5	5	5
11	4	2	3	3	4	3	3	4	3	4	4	4	3
12	3	3	4	3	3	4	4	3	4	2	3	4	1
13	5	4	5	5	5	5	5	4	3	5	5	5	5
14	3	2	1	3	1	1	1	2	2	1	1	1	3
15	5	4	5	4	5	4	5	4	4	4	4	5	5
16	4	4	4	5	4	4	5	4	4	5	5	5	5
17	5	4	5	5	5	5	5	5	4	5	5	5	5
18	5	3	5	5	5	5	5	5	5	5	5	5	5
19	4	3	4	3	5	5	4	3	3	4	3	3	3
20	4	4	5	2	4	4	4	5	2	5	4	3	3
21	4	5	3	5	5	4	3	4	3	3	3	4	4
22	4	4	3	4	4	4	5	1	3	4	4	4	1
23	2	2	4	2	4	2	3	4	4	4	5	5	5
24	5	3	5	2	2	4	4	5	2	4	1	3	4
25	3	4	5	4	4	5	4	5	4	2	3	4	4
26	4	4	3	3	4	4	4	3	4	2	3	2	2
27	3	3	2	2	4	5	5	5	4	2	3	2	2

28	2	2	1	1	3	3	3	3	5	1	3	1	1
29	4	3	3	3	2	2	4	2	3	3	2	3	3
30	4	4	4	2	3	3	5	4	4	4	2	4	4
31	3	3	5	3	5	4	3	5	3	2	1	2	2
32	5	3	3	2	3	5	3	5	5	3	3	3	3
33	3	4	1	1	5	3	4	4	3	2	4	2	2
34	3	3	2	3	4	4	4	4	2	3	2	3	3
35	4	2	3	4	4	5	2	5	4	4	3	4	4
36	3	4	2	5	5	3	3	4	5	3	2	3	3
37	2	4	1	3	3	4	2	3	5	2	3	2	2
38	3	3	2	1	2	5	1	2	4	3	4	3	3
39	4	5	4	2	1	3	2	5	4	3	3	3	3
40	3	3	3	3	1	3	4	3	5	2	2	2	2
41	3	3	2	1	2	4	3	2	4	2	3	2	2
42	5	5	5	2	3	5	2	2	3	5	3	2	5
43	4	2	4	3	4	4	3	3	4	4	4	3	4
44	3	4	3	4	2	3	4	4	2	3	2	4	3
45	2	3	2	5	5	2	5	5	5	2	5	5	2
46	3	3	1	2	1	4	2	4	3	3	3	3	3

Mean	RII%	total	never (5)	rare (4)	sometimes (3)	often (2)	always (1)	Options
3.59	71.74	46	11	13	14	8	0	1-Awarding the contract to competent contractors who have enough staff and experience to provide proper submittals in proper time. (by improving pre-award procedures such as tech evaluation and pre-qualification))
3.48	69.57	46	5	18	17	6	0	2-Calculate the work load of each staff from both the consultant and contractor's side and distribute the works load evenly.
3.35	66.96	46	12	11	10	7	6	3-To introduce a well-studied regulation that will grant an advanced payment for the contractor to allow ordering the required materials to expedite the works.
3.17	63.48	46	11	6	14	10	5	4-Raise contractor's awareness of contracts and payment process in governmental projects.
3.63	72.61	46	16	12	8	5	5	5-Improve and ease the process of payments valuation and certification.
3.80	76.09	46	16	14	10	3	3	6-Proper planning and budgeting of all government projects.
3.61	72.17	46	14	12	11	6	3	7-Proper management of cash flow as per approved scope of work and schedule program.
3.74	74.78	46	14	15	9	7	1	8-Manage to anticipate any risk that may delay the project due to payment issues.
3.67	73.48	46	11	16	12	7	0	9-Briefings and meetings prior start of works.
3.22	64.35	46	9	10	12	12	3	10-Compensating for late payment.
3.30	66.09	46	10	9	16	7	4	11-Proper communication among contract parties (the client, consultants as well as the contractors to resolve issues
3.39	67.83	46	11	11	12	9	3	12-Contractors should submit timely accurate invoices with complete documents
3.26	65.22	46	11	7	14	11	3	13-Avoiding bureaucracy in governmental system.

Apprndix3

Historical Cases for Governmental Buildings Projects for Models Design

This section includes the Historical Cases used for the development of Model I and Model V, These cases are 114 interim payment cases and 91 variation payment cases for the Model I and Model V, respectively.

Historical cases for Model I	** Confidential information

Case NO	Delay in submitting valuation or Claim by the contractor(days)	Claim review(days)	Payment process by employer (days)	Variations	Extension of time	Contractor Experience (years)	Consultant Experience (years)	GCC Funded	Local Funded	Work Progress (Delay in days)	Payment Amount (BD)	Payment delay (days) ref to MOW clueses
1	3	3	80	0	0	4	5	1	0	0	**	41
2	9	5	49	0	0	4	5	1	0	0	**	16
3	4	7	63	1	0	4	5	1	0	0	**	25
4	12	9	89	0	0	4	5	1	0	140	**	59
5	18	11	102	1	0	4	5	1	0	140	**	78
6	15	15	56	1	0	4	5	1	0	140	**	44
7	8	7	21	1	0	4	5	1	0	70	**	0
8	5	7	63	0	0	4	5	1	0	84	**	26
9	4	6	34	1	0	4	5	1	0	84	**	0
10	29	1	40	0	0	4	5	1	0	84	**	27
11	12	10	75	0	0	4	5	1	0	86.1	**	45
12	2	6	50	1	0	4	5	1	0	143.5	**	10
13	24	2	48	1	1	4	5	1	0	140	**	30
14	4	6	62	0	0	4	5	1	0	0	**	24
15	9	5	41	0	0	4	5	1	0	0	**	8
16	7	5	69	1	0	4	5	1	0	90	**	34
17	12	12	78	0	1	4	5	1	0	90	**	48
18	8	7	56	0	0	4	5	1	0	90	**	22

19	39	23	56	0	0	4	5	1	0	90	**	76
20	48	2	36	1	0	4	5	1	0	90	**	42
21	58	2	41	0	0	4	5	1	0	90	**	57
22	0	19	148	0	0	10	8	0	1	19	**	125
23	0	20	48	0	0	10	8	0	1	0	**	26
24	4	20	26	0	0	10	8	0	1	2.67	**	8
25	3	18	28	0	0	10	8	0	1	0	**	7
26	2	22	21	0	0	10	8	0	1	0	**	3
27	5	23	21	0	0	10	8	0	1	16.02	**	7
28	0	31	29	0	0	10	8	0	1	64.08	**	18
29	0	30	62	0	0	10	8	0	1	53.4	**	50
30	1	37	56	0	0	10	8	0	1	42.72	**	52
31	1	21	38	1	0	10	8	0	1	37.38	**	18
32	0	15	48	1	0	10	8	0	1	42.72	**	21
33	0	18	42	1	1	10	8	0	1	5.34	**	18
34	0	14	45	1	0	10	8	0	1	0	**	17
35	0	18	42	1	0	10	8	0	1	0	**	18
36	0	74	14	1	0	10	8	0	1	3.204	**	46
37	0	151	43	0	0	10	8	0	1	2.67	**	152
38	0	246	37	0	0	10	8	0	1	2.67	**	241
39	0	10	134	0	0	8	5	1	0	0	**	92
40	0	18	87	0	0	8	5	1	0	0	**	63
41	3	9	63	0	0	8	5	1	0	0	**	24
42	8	21	90	0	0	8	5	1	0	0	**	77
43	30	3	90	0	0	8	5	1	0	0	**	78
44	6	6	89	0	0	8	5	1	0	0	**	53
45	21	8	64	0	0	8	5	1	0	0	**	43
46	7	5	49	0	0	8	5	1	0	0	**	14
47	9	8	60	0	0	8	5	1	0	0	**	27
48	9	9	92	0	0	8	5	1	0	0	**	59

49	13	5	43	0	0	8	5	1	0	112	**	14
50	18	11	69	0	0	8	5	1	0	130	**	45
51	11	7	49	0	0	8	5	1	0	130	**	18
52	13	5	43	0	0	8	5	1	0	130	**	14
53	18	4	43	0	0	8	5	1	0	130	**	19
54	13	9	51	0	0	8	5	1	0	130	**	22
55	19	5	42	0	0	8	5	1	0	56	**	19
56	18	4	62	1	0	8	5	1	0	56	**	38
57	0	43	67	1	0	8	5	1	0	91	**	68
58	0	94	59	1	1	8	5	1	0	0	**	111
59	0	16	119	0	0	3	7	1	0	56	**	93
60	11	7	86	0	0	3	7	1	0	77	**	55
61	3	70	1	0	0	3	7	1	0	84	**	32
62	0	21	50	0	0	3	7	1	0	84	**	29
63	8	3	29	0	0	3	7	1	0	84	**	0
64	11	20	37	1	0	3	7	1	0	84	**	26
65	0	2	111	1	0	3	7	1	0	84	**	69
66	6	32	45	0	0	3	7	1	0	84	**	41
67	2	2	59	1	0	3	7	1	0	84	**	19
68	5	2	71	1	0	3	7	1	0	84	**	34
69	0	3	45	1	0	3	7	1	0	84	**	3
70	0	14	59	0	0	3	7	1	0	84	**	31
71	0	14	60	0	0	3	7	1	0	84	**	32
72	0	23	147	0	0	3	7	1	0	84	**	128
73	6	4	53	1	0	3	7	1	0	84	**	17
74	0	18	48	0	0	3	7	1	0	84	**	24
75	0	9	34	0	0	3	7	1	0	84	**	0
76	0	13	36	0	1	3	7	1	0	84	**	0
77	0	18	64	1	1	3	7	1	0	0	**	40
78	0	25	127	1	1	3	7	1	0	0	**	110

79	0	4	71	1	1	3	7	1	0	0	**	29
80	0	11	63	0	1	3	7	1	0	0	**	21
81	8	9	85	0	0	10	7	1	0	0	**	51
82	3	3	54	0	0	10	7	1	0	42	**	15
83	5	2	106	1	0	10	7	1	0	42	**	69
84	0	2	52	0	0	10	7	1	0	42	**	10
85	2	0	39	0	0	10	7	1	0	42	**	0
86	4	5	36	0	0	10	7	1	0	42	**	0
87	0	1	75	1	0	10	7	1	0	42	**	33
88	0	2	42	0	0	10	7	1	0	42	**	0
89	0	1	66	0	0	10	7	1	0	56	**	24
90	0	5	38	1	0	10	7	1	0	63	**	0
91	0	13	42	0	0	4	4	1	0	175	**	0
92	0	12	29	0	1	4	4	1	0	154	**	0
93	0	8	42	0	0	4	4	1	0	182	**	0
94	5	4	44	0	0	10	7	1	0	42	**	7
95	5	7	54	1	0	10	7	1	0	42	**	17
96	0	24	30	1	0	10	7	1	0	42	**	12
97	1	22	43	1	0	10	7	1	0	77	**	24
98	0	43	63	0	0	4	4	1	0	35	**	64
99	3	26	128	0	0	4	4	1	0	175	**	115
100	8	4	60	1	0	10	7	1	0	77	**	26
101	10	4	41	1	0	10	7	1	0	77	**	9
102	0	14	90	1	0	4	4	1	0	196	**	62
103	2	10	63	0	0	4	4	1	0	196	**	23
104	15	15	42	0	0	4	4	1	0	196	**	30
105	0	3	63	0	0	4	4	1	0	196	**	21
106	0	71	38	1	1	4	4	1	0	196	**	67

107	4	15	42	0	1	4	4	1	0	140	**	19
108	9	14	79	0	0	4	4	1	0	140	**	60
109	5	10	56	1	0	4	4	1	0	140	**	19
110	25	48	59	0	0	10	7	1	0	77	**	90
111	0	9	69	0	1	4	4	1	0	182	**	27
112	0	38	44	1	0	4	4	1	0	182	**	40
113	25	2	42	0	1	4	4	1	0	35	**	25
114	10	15	47	0	1	4	4	1	0	49	**	30

Historical cases for Model V						** Confidential information					
Case NO	**Claim review(days)**	**Payment by employer(days)**	VO evaluation & Approval (days)	Amount	Balance of contingincy	Available contingency in the contract	**Extension of time**	**Contractor Experience (years)**	**Cunsultant Experience (years)**	**Work Progress (Delay in days)**	VO approval with payment process
1	20	37	113	**	**	**	0	3	7	84	100
2	20	37	60	**	**	**	0	3	7	84	47
3	20	37	48	**	**	**	0	3	7	84	35
4	20	37	40	**	**	**	0	3	7	84	27
5	20	37	23	**	**	**	0	3	7	84	10
6	2	111	34	**	**	**	0	3	7	84	77
7	2	111	29	**	**	**	0	3	7	84	72
8	2	59	53	**	**	**	0	3	7	84	44
9	2	71	70	**	**	**	0	3	7	84	73
10	2	71	70	**	**	**	0	3	7	84	73
11	3	45	12	**	**	**	0	3	7	84	2
12	3	45	9	**	**	**	0	3	7	84	2

13	4	53	139	**	**	**	0	3	7	84	126
14	4	53	25	**	**	**	0	3	7	84	12
15	4	53	128	**	**	**	0	3	7	84	115
16	4	53	108	**	**	**	0	3	7	84	95
17	4	53	37	**	**	**	0	3	7	84	24
18	4	53	106	**	**	**	0	3	7	84	93
19	18	64	153	**	**	**	1	3	7	0	165
20	18	64	127	**	**	**	1	3	7	0	139
21	18	64	127	**	**	**	1	3	7	0	139
22	18	64	118	**	**	**	1	3	7	0	130
23	18	64	116	**	**	**	1	3	7	0	128
24	20	37	20	**	**	**	0	3	7	84	7
25	18	64	15	**	**	**	1	3	7	0	27
26	4	71	85	**	**	**	1	3	7	0	90
27	4	71	85	**	**	**	1	3	7	0	90
28	4	71	25	**	**	**	1	3	7	0	30
29	15	56	126	**	**	**	0	4	5	86	127
30	7	63	76	**	**	**	0	4	5	74	76
31	7	63	76	**	**	**	0	4	5	74	76
32	11	102	175	**	**	**	0	4	5	131	218
33	7	63	74	**	**	**	0	4	5	74	74
34	6	34	311	**	**	**	0	4	5	44	281
35	6	34	304	**	**	**	0	4	5	44	274
36	15	56	136	**	**	**	0	4	5	131	137
37	7	21	62	**	**	**	0	4	5	36	20
38	7	21	70	**	**	**	0	4	5	36	28
39	15	**56**	22	**	**	**	0	4	5	131	23
40	15	**56**	21	**	**	**	0	4	5	131	22

41	6	50	0	**	**	**	0	4	5	58	0
42	2	48	59	**	**	**	1	4	5	74	39
43	6	50	83	**	**	**	0	4	5	58	69
44	6	50	92	**	**	**	0	4	5	58	78
45	2	48	125	**	**	**	1	4	5	74	105
46	5	69	133	**	**	**	0	4	5	81	137
47	5	69	136	**	**	**	0	4	5	81	140
48	5	69	136	**	**	**	0	4	5	81	140
49	5	69	45	**	**	**	0	4	5	81	49
50	5	69	71	**	**	**	0	4	5	81	75
51	5	69	52	**	**	**	0	4	5	81	56
52	2	36	122	**	**	**	0	4	5	81	90
53	2	36	122	**	**	**	0	4	5	86	90
54	2	36	112	**	**	**	0	4	5	86	80
55	2	36	94	**	**	**	0	4	5	86	62
56	2	36	65	**	**	**	0	4	5	86	33
57	28	56	24	**	**	**	0	10	7	113	38
58	28	56	181	**	**	**	0	10	7	113	195
59	28	56	6	**	**	**	0	10	7	113	20
60	28	56	152	**	**	**	0	10	7	113	166
61	10	63	76	**	**	**	0	10	7	66	79
62	10	63	8	**	**	**	0	10	7	66	11
63	10	63	3	**	**	**	0	10	7	66	6
64	15	42	113	**	**	**	0	10	7	54	100
65	15	42	13	**	**	**	0	10	7	54	0
66	15	42	39	**	**	**	0	10	7	76	26
67	15	42	24	**	**	**	0	10	7	76	11

68	12	29	15	**	**	**	0	10	7	43	0
69	12	29	19	**	**	**	0	10	7	43	0
70	12	29	19	**	**	**	0	10	7	43	0
71	9	69	1	**	**	**	0	10	7	72	9
72	9	69	2	**	**	**	0	10	7	72	10
73	38	44	40	**	**	**	0	10	7	55	52
74	8	42	13	**	**	**	0	10	7	66	0
75	8	42	18	**	**	**	0	10	7	66	0
76	28	56	16	**	**	**	0	4	4	86	30
77	28	56	13	**	**	**	0	4	4	86	27
78	14	90	49	**	**	**	0	4	4	104	83
79	14	90	36	**	**	**	0	4	4	104	70
80	10	63	27	**	**	**	0	4	4	75	30
81	10	63	22	**	**	**	0	4	4	75	25
82	15	42	34	**	**	**	0	4	4	72	21
83	3	63	36	**	**	**	0	4	4	66	32
84	10	56	146	**	**	**	0	4	4	71	142
85	10	56	67	**	**	**	0	4	4	71	63
86	10	56	87	**	**	**	0	4	4	71	83
87	10	56	40	**	**	**	0	4	4	71	36
88	38	44	71	**	**	**	0	4	4	82	83
89	38	44	56	**	**	**	0	4	4	82	68
90	38	44	57	**	**	**	0	4	4	82	69
91	38	44	7	**	**	**	0	4	4	82	19

Appendix 4

nntool Code for Data Entry and Normalization

This section includes the code used in MATLAB nntool for the data input and normalization:

"d" is equal to the full data set, "t" is the target set and P" is the input set.

The matrix of the data set “d ”includes the data of the following factors:

For Model I the independent variable are in (column 1 to 11), while the dependent variable is in column 12:

The independent variables in column 1 to 11, respectively are: Delay in submitting valuation or claim by contractor, Valuation review, Payment processed by owner, Variations occurrence, Extension of time occurrence, Contractor experience, Consultant experience, External funding entity, Local funding entity, Work progress, and Payment amount.

The dependent variable in column 12 is the delay in interim payment in days.

For Model V the independent variables are in (column 1 to 10), while the dependent variable is in column 11:

The independent variables in column 1 to 10, respectively are: Valuation review, Payment process by owner, Variation orders evaluation and approval, Amount paid for variation, Balance of contingency, Available contingency in the contract, Extension of time, Contractor experience, Consultant experience, and Work progress.

The dependent variable in column 11 is the delay in variation payment in days.

d = [3	3	80	0	0	4	5	1	0	0	29031.103	41
9	5	49	0	0	4	5	1	0	0	162968.464	16
4	7	63	1	0	4	5	1	0	0	104457.89	25
12	9	89	0	0	4	5	1	0	140	41457.923	59
18	11	102	1	0	4	5	1	0	140	61796.63	78
15	15	56	1	0	4	5	1	0	140	28086.78	44
8	7	21	1	0	4	5	1	0	70	50142.5	0
5	7	63	0	0	4	5	1	0	84	78086.6	26
4	6	34	1	0	4	5	1	0	84	37473.65	0
29	1	40	0	0	4	5	1	0	84	61402.47	27
12	10	75	0	0	4	5	1	0	86.1	25307.61	45
2	6	50	1	0	4	5	1	0	143.5	93807.12	10
24	2	48	1	1	4	5	1	0	140	37656.27	30
4	6	62	0	0	4	5	1	0	0	121340.25	24
9	5	41	0	0	4	5	1	0	0	176734.08	8
7	5	69	1	0	4	5	1	0	90	93301.11	34
12	12	78	0	1	4	5	1	0	90	304296.03	48
8	7	56	0	0	4	5	1	0	90	211899.78	22
39	23	56	0	0	4	5	1	0	90	518299.327	76
48	2	36	1	0	4	5	1	0	90	300048.993	42
58	2	41	0	0	4	5	1	0	90	97051.041	57
0	19	148	0	0	10	8	0	1	19	24327	125
0	20	48	0	0	10	8	0	1	0	171873	26
4	20	26	0	0	10	8	0	1	2.67	124101	8
3	18	28	0	0	10	8	0	1	0	193176	7
2	22	21	0	0	10	8	0	1	0	138069	3
5	23	21	0	0	10	8	0	1	16.02	191907	7
0	31	29	0	0	10	8	0	1	64.08	203382	18
0	30	62	0	0	10	8	0	1	53.4	276066	50

1	37	56	0	0	10	8	0	1	42.72	333261	52
1	21	38	1	0	10	8	0	1	37.38	505035	18
0	15	48	1	0	10	8	0	1	42.72	264888	21
0	18	42	1	1	10	8	0	1	5.34	251055	18
0	14	45	1	0	10	8	0	1	0	225765	17
0	18	42	1	0	10	8	0	1	0	89766	18
0	74	14	1	0	10	8	0	1	3.204	49518	46
0	151	43	0	0	10	8	0	1	2.67	44442	152
0	246	37	0	0	10	8	0	1	2.67	107740.5	241
0	10	134	0	0	8	5	1	0	0	104230.755	92
0	18	87	0	0	8	5	1	0	0	27207.54	63
3	9	63	0	0	8	5	1	0	0	43455.807	24
8	21	90	0	0	8	5	1	0	0	41261.145	77
30	3	90	0	0	8	5	1	0	0	48151.148	78
6	6	89	0	0	8	5	1	0	0	48396.768	53
21	8	64	0	0	8	5	1	0	0	59720.519	43
7	5	49	0	0	8	5	1	0	0	82735.809	14
9	8	60	0	0	8	5	1	0	0	45098.055	27
9	9	92	0	0	8	5	1	0	0	112754.5	59
13	5	43	0	0	8	5	1	0	112	88937.993	14
18	11	69	0	0	8	5	1	0	130	138974.895	45
11	7	49	0	0	8	5	1	0	130	25341.268	18
13	5	43	0	0	8	5	1	0	130	145489.042	14
18	4	43	0	0	8	5	1	0	130	72038.94	19
13	9	51	0	0	8	5	1	0	130	302675.115	22
19	5	42	0	0	8	5	1	0	56	403595.993	19
18	4	62	1	0	8	5	1	0	56	375331.958	38
0	43	67	1	0	8	5	1	0	91	792115.565	68
0	94	59	1	1	8	5	1	0	0	202537.057	111

0	16	119	0	0	3	7	1	0	56	53902.125	93
11	7	86	0	0	3	7	1	0	77	32785.2693	55
3	70	1	0	0	3	7	1	0	84	88726.7409	32
0	21	50	0	0	3	7	1	0	84	61987.23	29
8	3	29	0	0	3	7	1	0	84	70778.16	0
11	20	37	1	0	3	7	1	0	84	88723.26	26
0	2	111	1	0	3	7	1	0	84	78928.0524	69
6	32	45	0	0	3	7	1	0	84	125279.8965	41
2	2	59	1	0	3	7	1	0	84	80944.5294	19
5	2	71	1	0	3	7	1	0	84	44082.7974	34
0	3	45	1	0	3	7	1	0	84	80518.6152	3
0	14	59	0	0	3	7	1	0	84	138916.3581	31
0	14	60	0	0	3	7	1	0	84	61787.0799	32
0	23	147	0	0	3	7	1	0	84	144282.6999	128
6	4	53	1	0	3	7	1	0	84	227964.9321	17
0	18	48	0	0	3	7	1	0	84	225050.391	24
0	9	34	0	0	3	7	1	0	84	233674.4988	0
0	13	36	0	1	3	7	1	0	84	238669.0614	0
0	18	64	1	1	3	7	1	0	0	267094.3887	40
0	25	127	1	1	3	7	1	0	0	498721.1562	110
0	4	71	1	1	3	7	1	0	0	313592.5368	29
0	11	63	0	1	3	7	1	0	0	243748.263	21
8	9	85	0	0	10	7	1	0	0	26386.721	51
3	3	54	0	0	10	7	1	0	42	80300.824	15
5	2	106	1	0	10	7	1	0	42	34793.427	69
0	2	52	0	0	10	7	1	0	42	269139.163	10
2	0	39	0	0	10	7	1	0	42	153412.69	0
4	5	36	0	0	10	7	1	0	42	165911.534	0
0	1	75	1	0	10	7	1	0	42	125869.271	33

0 2 42 0 0 10 7 1 0 42 307620.525 0

0 1 66 0 0 10 7 1 0 56 227692.896 24

0 5 38 1 0 10 7 1 0 63 343657.057 0

0 13 42 0 0 4 4 1 0 175 37150.655 0

0 12 29 0 1 4 4 1 0 154 98184.42 0

0 8 42 0 0 4 4 1 0 182 202190.13 0

5 4 44 0 0 10 7 1 0 42 67050.011 7

5 7 54 1 0 10 7 1 0 42 84677.51 17

0 24 30 1 0 10 7 1 0 42 128291.315 12

0];

>> t = d(:,12)';

>> p = d(:,1:11)';

>> [pn,ps] = mapminmax(p); [tn,ts] = mapminmax(t);

>> test = [1 22 43 1 0 10 7 1 0 77 356129.338
24

0 43 63 0 0 4 4 1 0 35 31006.8 64

3 26 128 0 0 4 4 1 0 175 36854.217 115

8 4 60 1 0 10 7 1 0 77 342564.17 26

10 4 41 1 0 10 7 1 0 77 430038.314 9

0 14 90 1 0 4 4 1 0 196 81624.35 62

2 10 63 0 0 4 4 1 0 196 132674.41 23

15 15 42 0 0 4 4 1 0 196 104566.51 30

0 3 63 0 0 4 4 1 0 196 72056.4 21

0 71 38 1 1 4 4 1 0 196 38087.013 67

4 15 42 0 1 4 4 1 0 140 44661.758 19

9 14 79 0 0 4 4 1 0 140 36565.65 60

5 10 56 1 0 4 4 1 0 140 67409.46 19

25 48 59 0 0 10 7 1 0 77 154312.339 90

0 9 69 0 1 4 4 1 0 182 68080.77 27

```
0    38   44   1    0    4    4    1    0    182  209526.65  40
25   2    42   0    1    4    4    1    0    35   129459.05  25
10   15   47   0    1    4    4    1    0    49   255946.23  30
];
>> testt = test(:,12)';
>>  testp = test(:,1:11)';
[testpn,testps] = mapminmax(testp); [testtn,testts] = mapminmax(testt);
```

Appendix 5

Model I nntool Performance for The Training and Validation Samples

This section includes the performance of the training set and validation set for Model I using MATLAB nntool for 33 trial models by presenting the following results: MSE value, R and number of epochs.

Performance of The Training and Validation Samples For Model I Using (nntool)

Levenberge-Marquardt algorithm						Bayesian regulation				Scaled regulation					
Model no	Epochs	Training		Validation		Model no	Epochs	Training		Model no	Epochs	Training		Validation	
		MSE	R	MSE	R			MSE	R			MSE	R	MSE	R
I-1	184	0.003	0.987	0.002	0.969	I-12	29	0.003	0.984	I-23	32	0.012	0.943	0.017	0.858
I-2	3	0.178	0.215	0.141	0.214	I-13	144	0.001	0.997	I-24	4	0.089	0.282	0.056	0.485
I-3	27	0.003	0.976	0.005	0.973	I-14	401	1.90E-04	0.999	I-25	23	0.019	0.860	0.050	0.689
I-4	17	2.00E-04	0.999	0.211	0.254	I-15	289	1.35E-04	0.999	I-26	21	0.012	0.897	0.050	0.910
I-5	5	0.002	0.999	0.020	0.906	I-16	581	2.30E-04	0.998	I-27	26	0.137	0.590	0.178	0.250
I-6	4	0.001	0.995	0.005	0.957	I-17	592	1.78E-04	0.999	I-28	19	0.019	0.909	0.022	0.801
I-7	4	0.007	0.970	0.046	0.832	I18	423	2.30E-04	0.999	I-29	1	0.074	0.566	0.044	0.087
I-8	2	0.007	0.970	0.007	0.951	I-19	394	1.10E-04	0.999	I-30	9	0.083	0.022	0.169	0.635
I-9	2	1.80E-01	0.087	0.421	0.186	I-20	236	2.70E-04	0.999	I-31	17	0.018	0.879	0.042	0.908
I-10	4	0.050	0.806	0.094	0.783	I-21	561	3.31E-04	0.998	I-32	14	0.022	0.808	0.007	0.945
I-11	5	0.001	0.996	0.043	0.951	I-22	111	2.20E-04	0.999	I-33	36	0.008	0.962	0.019	0.857

Appendix 6

Performance of Test Sample for Model I Using nntool

This section includes the performance of the test set for Model I using MATLAB nntool and Levenberg-Marquardt Algorithm, Bayesian regulation and scaled algorithm for 33 trial models by presenting the following results: RMSE, RMAE and MAPE values.

Performance of Model I Using (nntool And Levenberg-Marquardt)

Target Output	Model no										
	I-1	I-2	I-3	I-4	I-5	I-6	I-7	I-8	I-9	I-10	I-11
24	93.926	16.347	18.564	47.799	84.902	9.000	9.587	23.127	9.290	18.129	9.030
64	108.677	70.601	22.939	90.319	23.740	9.000	47.781	61.102	46.180	81.232	10.813
115	110.088	89.622	21.427	101.665	81.242	9.000	110.794	92.930	111.864	67.441	12.330
26	83.865	18.498	11.685	22.032	56.276	9.000	9.787	16.891	9.234	16.818	9.083
9	73.282	15.401	9.351	15.665	71.975	9.000	9.427	15.090	9.040	17.718	9.021
62	99.628	30.891	15.924	27.368	59.572	9.000	19.359	39.711	72.656	28.263	9.298
23	83.656	14.148	9.662	22.776	20.156	9.000	9.843	13.769	9.657	17.860	9.171
30	92.402	17.910	11.388	46.329	42.942	9.002	12.262	17.058	10.964	19.864	9.162
21	66.304	12.149	9.095	15.370	13.162	9.000	9.304	11.876	9.143	14.054	9.100
67	111.414	85.159	38.883	95.597	70.507	115.000	41.300	85.708	114.942	22.385	10.651
19	81.262	16.529	9.486	32.908	15.742	42.112	9.037	11.526	9.469	16.128	9.072
60	100.861	37.379	21.576	81.598	46.593	9.000	26.135	26.630	22.316	37.781	9.846
19	85.120	16.330	11.005	23.567	21.826	9.000	10.057	18.099	15.728	40.426	9.185
90	111.703	99.130	73.742	79.411	114.824	9.000	114.522	97.386	86.420	93.317	11.746
27	82.551	16.895	9.884	37.069	12.130	102.353	9.081	15.074	10.148	11.927	9.100
40	104.370	34.955	13.028	28.716	46.556	9.011	12.229	29.401	34.874	61.210	9.277
25	85.087	16.934	16.915	75.928	25.854	9.703	9.063	28.015	9.511	33.411	11.083
30	91.991	16.283	15.627	41.114	13.617	9.044	9.016	25.425	9.300	31.308	9.503
hidden neurons	1	5	10	20	30	40	50	60	70	80	100
RMSE	218.027	13.810	31.130	20.4822	26.828	45.812	20.506	13.557	18.902	20.792	41.708
MAE	51.389	11.468	22.862	16.30862	18.928	36.039	17.906	10.699	14.863	15.832	31.921
MAPE	205.458	31.410	50.304	48.51195	81.979	82.667	49.334	29.252	42.434	41.700	66.498

Performance of Model I Using nntool And Bayesian Algorithm

Target Output	Model no										
	I-12	I-13	I-14	I-15	I-16	I-17	I-18	I-19	I-20	I-21	I-22
24	25.050	17.477	17.475	22.959	21.383	20.648	22.289	16.727	22.282	23.640	22.437
64	76.232	71.928	72.772	85.897	79.351	107.301	74.319	93.546	81.607	74.358	78.327
115	89.302	102.356	100.520	104.348	99.893	98.212	99.983	102.968	100.353	98.495	100.758
26	19.825	15.884	14.868	17.636	18.606	13.133	20.411	14.338	18.297	19.976	19.830
9	15.448	12.559	12.067	11.584	14.447	10.147	14.753	11.071	14.115	15.385	15.146
62	42.727	50.226	35.396	52.817	39.717	58.123	52.465	47.741	38.248	40.325	42.057
23	19.643	17.461	15.024	15.086	19.186	17.315	19.443	14.671	16.765	19.287	20.024
30	24.349	27.808	18.937	20.667	25.132	19.253	24.373	19.959	20.138	23.407	27.859
21	14.585	12.032	11.726	10.926	14.460	12.777	12.906	10.843	12.419	14.435	14.773
67	89.108	110.309	103.360	113.464	99.467	111.220	111.275	109.050	97.999	97.019	100.660
19	16.325	12.340	13.649	12.529	18.061	11.350	13.976	11.310	13.569	16.808	18.573
60	45.082	49.173	41.040	58.139	45.657	55.474	57.677	52.892	42.640	42.018	48.129
19	20.027	15.499	15.101	15.363	20.781	16.564	18.023	14.409	16.863	20.172	21.849
90	93.144	110.842	110.099	111.836	106.787	113.813	113.157	111.676	109.472	104.770	108.350
27	18.219	16.023	15.805	15.196	19.733	15.354	17.236	13.349	15.533	19.069	20.350
40	50.062	52.785	35.539	59.895	42.697	65.444	62.444	45.880	41.659	43.907	44.993
25	19.217	14.468	17.203	17.662	24.776	19.428	14.807	14.547	17.832	20.655	26.631
30	23.748	15.021	18.524	19.716	26.168	14.291	18.746	16.065	21.967	24.160	26.703
hidden neurons	1	5	10	20	30	40	50	60	70	80	100
RMSE	11.370	14.410	14.737	15.626	12.367	18.609	14.828	15.953	13.566	12.035	12.106
MAE	8.947	11.314	12.138	11.702	9.098	13.722	10.812	12.911	11.052	9.241	8.748
MAPE	23.266	30.338	31.552	30.222	21.641	33.271	28.205	34.039	28.431	23.076	20.971

Performance of Model I Using nntool And Scaled Conjugate Gradient Algorithm

Target Output	Model no										
	I-23	I-24	I-25	I-26	I-27	I-28	I-29	I-30	I-31	I-32	I-33
24	24.468	38.676	72.700	13.371	9.000	13.261	19.457	16.430	13.271	15.700	17.107
64	24.468	67.849	79.639	65.637	9.000	54.326	20.435	25.524	73.443	9.008	77.222
115	24.441	29.830	73.966	45.037	9.000	95.218	59.256	85.607	82.595	9.073	91.380
26	24.468	27.826	63.047	13.780	9.000	12.923	15.316	19.672	12.213	13.580	18.825
9	24.468	44.792	43.650	12.521	9.000	12.344	14.499	16.513	10.895	12.654	12.634
62	24.464	22.396	65.081	11.535	9.000	42.805	19.218	15.063	54.661	9.756	23.561
23	24.467	22.931	38.960	14.451	9.000	13.030	20.867	36.970	15.396	9.007	24.668
30	24.409	26.903	52.285	18.403	9.000	12.115	15.030	42.269	28.508	9.011	61.278
21	24.468	21.030	24.811	12.171	9.000	11.640	17.373	29.075	12.404	9.005	12.622
67	13.515	81.315	101.656	10.623	9.000	99.980	18.569	34.116	91.751	15.688	92.479
19	24.169	20.615	20.484	10.897	9.000	14.642	12.318	13.559	10.214	9.002	14.976
60	24.465	20.554	69.885	27.818	9.000	23.020	21.688	41.135	27.797	9.007	73.410
19	24.467	22.269	48.151	12.510	9.000	14.448	13.371	11.348	24.344	9.043	23.409
90	24.468	27.047	109.669	93.571	9.000	94.829	33.885	42.551	103.444	25.854	101.353
27	24.009	19.234	45.916	11.737	9.000	28.766	16.715	13.587	10.531	9.002	17.842
40	24.435	58.476	76.284	11.640	9.000	24.962	15.611	18.608	67.143	9.954	53.418
25	14.574	12.936	20.646	39.263	9.000	9.737	20.137	33.524	9.922	9.008	21.831
30	18.609	29.059	34.882	18.270	9.000	10.194	17.247	39.251	10.130	9.008	12.698
hidden neurons	1	5	10	20	30	40	50	60	70	80	100
RMSE	33.685	30.397	25.716	27.606	42.865	16.717	29.029	23.196	17.000	40.456	16.568
MAE	22.288	19.164	21.194	19.653	32.722	13.811	21.723	18.633	14.243	30.886	13.113
MAPE	45.545	51.649	77.948	46.400	68.027	37.630	44.857	45.060	38.214	65.931	33.694

Appendix 7

Model I nftool Performance for The Training and Validation Samples

This section includes the performance of the training set and validation set for Model I using MATLAB nftool for 36 trial models by presenting the following results: MSE value, R and number of epochs.

Performance Of The Training And Validation Samples For Model I Using (nftool)

Levenberge						Bayesian				Scaled					
Model no	Epochs	Training		Validation		Model no	Epochs	Training		Model no	Epochs	Training		Validation	
		MSE	R	MSE	R			MSE	R			MSE	R	MSE	R
I34	9	11.144	0.996	10.312	0.955	I46	13	9.176	0.997	I58	20	204.886	0.935	298.847	0.851
I35	10	8.838	0.997	13.465	0.997	I47	117	4.105	0.999	I59	30	45.46	0.98	93.259	0.992
I36	6	8.664	0.999	20.214	0.979	I48	120	1.547	0.999	I60	51	21.179	0.993	198.394	0.923
I37	11	1.222	0.999	54.578	0.988	I49	578	2.742	0.998	I61	238	1.882	0.999	44.813	0.989
I38	7	1.258	0.983	51.612	0.995	I50	92	3.558	0.998	I62	100	6.374	0.998	33.656	0.959
I39	2	44.047	0.999	550.376	0.804	I51	218	2.376	0.999	I63	77	12.841	0.996	302.472	0.846
I40	4	1.033	0.999	70.970	0.942	I52	274	2.68	0.999	I64	37	107.036	0.965	368.595	0.556
I41	3	7.573	0.999	283.597	0.888	I53	460	3.171	0.988	I65	42	45.873	0.983	988.993	0.452
I42	4	8.96E-08	0.999	1247.964	0.692	I54	340	1.567	0.999	I66	20	288.789	0.909	1945.822	0.511
I43	2	12.124	0.999	1584.250	0.714	I55	328	7.157	0.999	I67	44	144.177	0.946	4384.275	0.616
I44	2	17.672	0.995	5558.658	0.133	I56	1000	1.297	0.999	I68	44	90.937	0.966	668.094	0.771
I45	5	4.362	0.999	2631.215	0.703	I57	334	7.549	0.999	I69	60	38.033	0.988	3189.804	0.383

Appendix 8

Performance of Test Sample for Model I Using nftool

This section includes the performance of the test set for Model I using MATLAB nftool and Levenberg-Marquardt Algorithm, Bayesian regulation and scaled algorithm for 36 trial models by presenting the following results: RMSE, RMAE and MAPE values.

Performance Of test sample of Model I Using (nftool And Levenberg-Marquardt)

Target Output	Model no											
	I-34	I-35	I-36	I-37	I-38	I-39	I-40	I-41	I-42	I-43	I-44	I-45
24	22.018	23.048	22.650	24.206	24.001	30.422	18.560	29.923	24.000	20.883	25.316	5.170
64	60.013	62.369	60.456	64.012	61.526	62.663	64.055	64.109	42.801	62.648	59.724	64.000
115	111.773	113.039	112.733	115.049	115.001	118.119	125.750	115.176	80.798	81.705	106.993	115.000
26	26.713	27.564	27.781	26.205	26.001	30.942	25.994	26.138	30.271	9.556	17.512	58.999
9	11.526	12.253	11.827	9.257	9.001	14.780	9.019	9.122	9.000	5.697	10.802	9.000
62	57.748	58.260	56.397	62.055	62.001	71.629	62.020	82.456	62.000	54.458	60.729	62.000
23	28.245	27.862	30.198	28.467	23.979	32.895	32.147	28.646	47.297	29.090	20.304	22.340
30	26.208	26.469	27.753	30.097	30.002	40.995	29.995	29.950	30.000	28.255	28.146	30.000
21	19.340	18.712	21.390	20.751	15.544	31.587	21.006	20.984	56.105	22.375	17.355	20.996
67	65.145	66.801	65.292	67.015	66.999	70.707	67.003	67.059	67.000	67.249	109.164	67.000
19	14.369	14.824	17.637	18.959	19.001	19.130	19.001	19.036	19.000	-37.528	10.937	30.250
60	54.662	55.451	54.364	59.848	60.001	65.389	54.438	37.725	60.000	57.332	84.021	60.000
19	25.617	25.803	23.755	19.191	21.324	28.758	19.030	19.127	19.000	14.075	19.111	19.000
90	88.385	89.436	90.345	90.001	90.001	70.238	89.977	90.061	90.000	30.053	127.978	57.105
27	29.533	30.057	33.956	36.664	32.251	30.749	27.012	6.144	27.000	27.638	16.195	27.000
40	37.879	40.233	36.174	39.959	40.001	51.679	24.885	40.080	40.000	35.383	52.265	40.000
25	21.596	21.618	23.713	35.960	25.001	23.858	50.190	25.037	25.000	24.570	17.986	25.000
30	24.814	24.722	26.966	30.038	30.000	22.066	30.004	30.118	30.000	27.588	23.503	30.000
No of hidden neurons	1	5	10	20	30	40	50	60	70	80	90	100
RMSE	3.719	3.410	3.744	3.679	1.970	8.424	7.898	8.872	13.865	21.536	15.645	12.139
MAE	3.371	2.890	3.118	1.539	0.916	6.998	3.966	4.238	6.615	11.482	10.126	5.369
MAPE	12.031	11.641	10.899	6.183	3.657	23.501	12.236	11.156	19.561	34.086	23.205	16.890

Performance of test sample of Model I Using nftool And Bayesian Algorithm

	Model no											
Target Output	I-46	I-47	I-48	I-49	I-50	I-51	I-52	I-53	I-54	I-55	I-56	I-57
24	21.998	22.997	24.308	23.997	22.428	24.644	23.532	23.446	24.247	20.883	24.430	24.150
64	59.487	66.006	63.592	64.568	65.084	64.206	62.675	64.476	64.106	62.648	63.472	64.195
115	112.003	113.070	115.238	122.962	115.408	115.128	114.020	114.699	114.847	81.705	115.300	115.354
26	26.956	26.231	25.258	26.186	25.901	25.857	25.179	27.197	25.384	9.556	25.216	25.566
9	11.273	9.953	9.386	9.639	10.269	8.706	9.825	9.892	9.350	5.697	9.085	6.199
62	57.501	59.505	61.349	60.860	60.992	61.966	60.352	61.129	62.307	54.458	60.882	61.333
23	27.490	25.875	26.534	27.994	26.766	33.938	26.163	26.204	25.150	29.090	24.518	26.087
30	25.365	26.615	29.170	28.321	28.628	26.150	26.936	29.143	29.488	28.255	13.309	22.256
21	18.501	16.032	16.505	17.814	16.547	20.710	17.537	17.519	18.470	22.375	18.298	19.493
67	65.008	66.694	67.269	67.113	66.817	66.969	67.231	67.175	66.928	67.249	66.954	66.368
19	13.712	17.217	18.840	17.184	17.508	18.921	17.434	19.659	18.858	-37.528	16.152	18.933
60	54.372	56.285	57.974	55.221	55.207	59.405	51.776	57.507	59.115	57.332	48.144	58.053
19	24.800	23.558	20.108	21.449	23.154	19.438	22.881	21.312	31.688	14.075	20.904	20.311
90	89.389	89.251	89.674	89.407	89.365	89.881	88.971	89.218	89.556	30.053	89.389	89.743
27	29.313	27.910	27.672	27.376	27.898	26.999	37.567	44.904	27.188	27.638	27.040	26.936
40	36.977	39.274	40.054	38.758	39.528	39.775	39.108	38.824	39.625	35.383	31.259	19.750
25	21.032	26.471	25.576	25.596	25.312	24.942	25.314	24.977	25.039	24.570	25.098	25.252
30	24.145	27.264	29.338	29.532	25.167	29.952	29.644	16.375	29.917	27.588	30.003	29.751
No of hidden neurons	1	5	10	20	30	40	50	60	70	80	90	100
RMSE	3.871	2.469	1.520	2.770	2.469	2.746	3.631	5.512	3.110	21.536	5.373	5.252
MAE	3.519	2.044	0.969	1.822	1.822	1.007	2.379	2.832	1.216	11.482	2.795	2.332
MAPE	12.442	7.388	3.767	5.535	7.078	4.089	8.221	10.460	5.714	34.086	8.426	8.108

Performance of test sample of Model I Using nftool And Scaled Conjugate Gradient Algorithm

Target Output	Model no											
	I-58	I-59	I-60	I-61	I-62	I-63	I-64	I-65	I-66	I-67	I-68	I-69
24	33.096	12.537	24.233	25.095	24.195	25.007	10.533	16.304	2.009	-5.154	20.993	25.280
64	66.278	53.469	63.008	77.050	82.479	57.345	72.820	61.306	41.515	65.922	72.758	127.234
115	136.012	110.106	117.389	115.567	112.932	117.213	125.198	119.275	120.705	106.863	161.911	118.284
26	30.125	20.901	27.583	26.872	21.741	28.228	31.621	21.762	17.526	12.018	23.289	30.290
9	22.263	8.225	10.540	8.918	10.211	18.246	19.023	20.785	38.770	-14.778	9.990	37.232
62	76.235	63.679	63.711	60.525	61.483	67.082	62.676	61.657	67.828	47.470	51.187	-18.605
23	35.309	30.002	32.020	27.362	26.008	26.182	27.279	19.822	41.607	44.601	25.762	22.017
30	22.727	24.976	32.056	28.682	26.147	29.055	23.556	34.030	1.169	13.711	8.466	32.861
21	31.107	23.206	19.928	16.488	21.051	20.633	21.974	11.974	50.438	36.203	3.843	3.549
67	57.491	55.502	61.495	78.401	77.008	61.870	29.601	71.658	42.579	68.239	74.133	69.878
19	19.618	15.910	8.412	18.510	17.756	10.390	31.989	24.514	16.583	8.614	-21.701	18.608
60	45.820	57.022	58.318	57.694	57.882	58.345	57.527	48.253	37.809	57.266	49.567	57.471
19	35.356	25.321	25.285	20.831	28.027	38.196	21.130	27.613	19.651	6.359	83.835	-3.124
90	40.081	82.132	88.663	88.869	86.937	121.852	68.468	89.184	71.764	87.537	94.066	30.887
27	28.603	31.772	32.478	27.493	25.836	28.038	21.539	25.804	2.381	39.040	38.107	22.675
40	52.779	30.428	40.477	40.610	39.403	34.237	34.620	37.118	25.640	28.440	38.854	45.224
25	14.988	23.513	16.695	25.530	24.764	1.877	49.733	57.464	14.747	39.079	36.354	-4.814
30	22.016	24.738	11.134	29.802	38.703	28.417	8.815	29.173	46.499	34.721	31.358	72.067
No of hidden neurons	1	5	10	20	30	40	50	60	70	80	90	100
RMSE	16.008	6.547	6.425	4.453	6.074	11.144	14.371	9.657	19.257	14.214	22.936	31.920
MAE	12.037	5.640	4.396	2.573	3.878	7.160	10.766	6.443	16.932	12.025	14.821	20.594
MAPE	36.611	16.810	16.702	6.522	11.112	25.718	34.679	28.003	64.145	53.859	52.962	63.630

Appendix 9

Model V nntool Performance for the Training and Validation Samples

This section includes the performance of the training set and validation set for Model V using MATLAB nntool for 36 trial models by presenting the following results: MSE value, R and number of epochs.

Performance of The Training and Validation Samples for Model V Using (nntool)

Levenberge						Bayesian				Scaled					
Model no	Epoches	Training		Validation		Model no	Epoches	Training		Model no	Epoches	Training		Validation	
		MSE	R	MSE	R			MSE	R			MSE	R	MSE	R
V1	191	0.003	0.993	0.004	0.994	V13	27	0.004	0.991	V25	25	0.023	0.923	0.009	0.983
V2	8	0.001	0.999	0.001	0.999	V14	145	1.50E-05	0.999	V26	49	0.005	0.987	0.004	0.988
V3	3	0.007	0.983	0.005	0.977	V15	336	1.64E-05	0.999	V27	64	0.002	0.995	0.006	0.990
V4	4	0.002	0.995	0.022	0.957	V16	230	3.64E-05	0.999	V28	23	0.007	0.984	0.007	0.938
V5	8	0.000	0.999	0.022	0.997	V17	685	1.18E-05	0.999	V29	40	0.002	0.992	0.01	0.983
V6	5	0.002	0.998	0.009	0.976	V18	393	1.48E-05	0.999	V30	36	0.002	0.993	0.004	0.993
V7	3	3.00E-03	0.989	0.073	0.945	V19	237	3.46E-05	0.999	V31	28	0.005	0.986	0.004	0.993
V8	21	1.97E-05	0.999	0.003	0.983	V20	665	6.46E-05	0.999	V32	32	0.004	0.989	0.012	0.951
V9	6	0.08	0.817	0.017	0.949	V21	190	3.40E-05	0.999	V33	42	0.003	0.987	0.018	0.897
V10	8	0.001	0.998	0.022	0.922	V22	164	1.89E-05	0.999	V34	14	0.009	0.978	0.012	0.852
V11	3	0.012	0.982	0.070	0.864	V23	125	1.00E-03	0.997	V35	20	0.001	0.971	0.025	0.834
V12	7	0.005	0.986	0.005	0.986	V24	364	3.85E-05	0.999	V36	20	0.005	0.986	0.008	0.980

Appendix 10

Performance of Test Sample for Model V using nntool

This section includes the performance of the test set for Model V using MATLAB nntool and Levenberg-Marquardt Algorithm, Bayesian regulation and scaled algorithm for 36 trial models by presenting the following results: RMSE, RMAE and MAPE values.

Performance of Model V Using (nntool And Levenberg-Marquardt)

Target Output	Model no											
	V-1	V-2	V-3	V-4	V-5	V-6	V-7	V-8	V-9	V-10	V-11	V-12
83	79.231	**82.993**	82.420	80.163	85.582	79.402	73.975	87.433	79.206	89.006	67.767	80.566
70	64.408	**70.983**	68.253	54.387	69.670	64.714	66.201	70.006	70.135	72.784	56.567	69.511
30	31.830	**29.235**	33.269	26.865	29.885	24.314	41.527	27.719	28.212	30.726	31.193	30.005
25	28.659	**25.325**	30.682	24.021	26.463	21.922	38.390	24.930	25.780	27.233	28.673	26.913
21	24.578	**19.324**	24.197	19.491	21.321	26.884	25.041	21.001	22.137	21.558	20.571	21.300
32	31.272	**32.141**	30.827	24.655	37.789	25.773	33.890	32.021	85.717	32.481	28.113	31.482
142	154.527	**142.571**	155.404	208.993	142.137	135.629	134.201	142.000	142.327	146.535	131.751	141.964
63	59.514	**62.735**	58.692	57.749	63.535	47.855	68.314	63.065	56.961	62.224	57.138	62.127
83	81.404	**84.138**	79.109	90.493	82.813	67.706	85.468	82.953	82.259	86.097	74.039	83.390
36	35.357	**35.595**	36.788	32.878	34.780	28.002	46.212	35.605	36.553	36.301	33.739	36.515
83	81.389	**82.489**	85.607	88.508	86.468	81.196	82.646	96.706	83.769	85.408	73.995	81.833
68	64.147	**64.906**	69.638	64.647	64.816	61.051	63.276	68.002	68.235	69.837	59.715	67.996
69	65.128	**66.618**	71.203	65.184	67.114	62.344	65.188	70.712	68.023	71.345	61.533	67.890
19	24.512	**20.238**	35.351	19.060	21.556	19.164	20.984	18.987	39.120	31.516	28.656	35.001
No of hidden neurons	1	**5**	10	20	30	40	50	60	70	80	90	100
RMSE	4.709	**1.292**	6.288	18.816	2.340	7.652	6.909	3.926	15.466	4.243	8.308	4.392
MAE	3.732	**0.964**	4.346	9.072	1.698	6.439	5.739	1.625	6.508	2.900	7.114	1.840
MAPE	8.062	**2.295**	12.405	11.490	4.217	13.050	14.432	2.402	21.997	7.900	13.477	7.492

Performance of Model V Using nntool And Bayesian Algorithm

Target Output	Model no											
	V13	**V14**	V15	V16	V17	V18	V19	V20	V21	V22	V23	V24
83	79.138	**82.778**	93.902	82.995	83.001	82.864	82.797	82.739	78.200	83.044	77.244	82.663
70	64.472	**70.368**	79.404	77.601	72.776	70.147	70.223	70.308	69.986	72.570	66.760	70.425
30	32.813	**30.407**	41.211	30.115	30.248	30.119	29.093	29.277	30.103	29.918	35.836	29.560
25	29.767	**25.445**	38.596	25.219	24.933	24.833	25.556	25.342	25.439	25.183	33.177	25.197
21	25.113	**21.176**	20.688	18.121	20.958	21.053	21.075	24.624	20.907	21.098	22.413	21.057
32	32.186	**31.822**	19.315	32.047	41.073	31.990	31.777	31.959	31.881	31.020	31.008	31.974
142	155.823	**142.036**	157.611	142.011	142.012	141.998	141.960	163.926	141.987	155.386	143.565	141.973
63	59.934	**62.633**	66.466	63.077	63.143	63.003	62.578	62.987	62.696	62.983	59.151	63.192
83	81.528	**83.064**	82.037	81.537	82.893	78.800	83.298	84.335	83.263	82.905	77.255	81.632
36	36.317	**35.910**	41.854	35.560	35.996	35.556	36.436	35.808	35.796	36.693	39.005	36.070
83	80.212	**82.642**	53.288	82.790	83.009	83.041	83.483	82.824	83.165	83.010	84.621	82.808
68	63.154	**68.628**	44.384	68.044	68.257	67.998	67.551	68.400	67.946	68.209	66.003	68.187
69	64.180	**68.969**	45.161	69.210	68.736	68.965	68.716	68.874	68.815	68.835	66.314	69.014
19	25.089	**19.104**	28.975	18.887	19.020	18.894	19.609	23.931	19.211	18.837	26.726	19.034
No of hidden neurons	1	**5**	10	20	30	40	50	60	70	80	90	100
RMSE	5.260	**0.304**	14.828	2.213	2.539	1.132	0.433	6.101	1.298	3.659	4.475	0.424
MAE	4.178	**0.248**	12.225	0.960	0.930	0.390	0.372	2.457	0.498	1.335	3.829	0.255
MAPE	9.138	**0.586**	25.067	2.165	2.491	0.620	0.999	4.747	0.839	1.512	10.392	0.464

Performance of Model V Using nntool And Scaled Conjugate Gradient Algorithm

Target Output	Model no											
	V-25	V-26	**V-27**	V-28	V-29	V-30	V-31	V-32	V-33	V-34	V-35	V-36
83	77.271	93.902	**84.097**	82.850	93.087	81.469	80.542	68.294	82.159	87.273	68.390	63.807
70	63.529	79.404	**71.313**	72.801	79.377	73.986	69.256	57.219	67.455	76.851	59.808	54.192
30	36.318	41.211	**34.296**	34.866	34.153	39.395	34.566	36.067	38.293	29.819	40.222	46.096
25	33.693	38.596	**31.604**	32.752	31.149	37.145	32.270	33.034	35.071	27.315	37.421	42.819
21	30.025	20.688	**15.400**	17.094	41.732	18.354	31.522	28.809	32.454	22.225	27.242	16.415
32	37.283	19.315	**20.766**	24.054	39.342	19.591	21.585	44.873	45.904	38.470	43.084	25.370
142	155.890	157.611	**132.813**	150.899	143.198	145.643	137.124	143.404	146.719	168.826	149.842	128.420
63	60.164	66.466	**57.980**	51.917	55.924	60.915	55.969	61.163	61.324	52.357	69.733	75.911
83	80.739	82.037	**70.353**	67.155	78.405	76.718	73.711	84.675	82.709	74.528	88.949	87.668
36	39.237	41.854	**33.995**	33.562	38.439	38.983	32.480	40.482	40.623	33.032	48.125	46.240
83	71.980	53.288	**88.054**	73.427	78.533	79.387	73.822	87.817	73.748	90.965	63.734	82.720
68	57.249	44.384	**67.493**	62.116	63.006	61.943	58.562	70.013	61.753	68.579	52.564	69.679
69	58.034	45.161	**69.785**	64.197	64.243	63.326	59.182	71.110	62.271	70.851	54.714	71.170
19	27.135	28.975	**25.709**	35.587	25.422	25.730	26.669	27.381	33.412	24.222	29.185	39.292
No of hidden neurons	1	5	**10**	20	30	40	50	60	70	80	90	100
RMSE	8.192	14.828	**6.367**	8.675	8.088	6.591	7.559	7.736	8.133	8.952	11.785	12.413
MAE	7.472	12.225	**5.147**	7.324	6.699	5.656	6.914	6.357	6.790	6.132	11.185	10.425
MAPE	17.518	25.067	**13.160**	18.501	18.819	15.532	17.576	17.147	21.120	10.407	25.540	27.862

Appendix 11

Model V nftool performance for the training and validation samples

This section includes the performance of the training set and validation set for Model V using MATLAB nftool for 39 trial models by presenting the following results: MSE value, R and number of epochs.

Performance of The Training and Validation Samples For Model V Using (nftool)

No of neurons	Levenberge						Bayesian				Scaled					
	Model no	Epochs	Training		Validation		Model no	Epochs	Training		Model no	Epochs	Training		Validation	
			MSE	R	MSE	R			MSE	R			MSE	R	MSE	R
1	V-37	26	7.80E-03	0.999	8.477	0.998	V-50	7	2.786	0.999	V-63	39	184.969	0.977	203.953	0.979
5	V-38	11	3.748	0.999	5.111	0.999	V-51	114	0.48	0.999	V-64	32	22.608	0.996	24.873	0.998
10	V-39	11	5.972	0.999	2.870	0.999	V-52	250	4.90E-27	0.999	V-65	43	14.312	0.998	193.292	0.963
15	V-40	8	2.937	0.999	94.420	0.979	V-53	255	2.70E-23	0.999	V-66	68	6.042	0.999	107.802	0.950
20	V-41	7	4.184	0.999	26.398	0.997	V-54	298	0.346	0.999	V-67	40	21.688	0.996	65.506	0.990
30	V-42	6	1.10E-25	0.999	166.670	0.971	V-55	241	5.85E-16	0.999	V-68	37	10.484	0.998	169.876	0.976
40	V-43	3	0.003	0.999	46.751	0.987	V-56	203	4.24E-16	0.999	V-69	128	1.439	0.999	461.1	0.951
50	V-44	3	4.80E-03	0.999	528.144	0.978	V-57	225	5.80E-16	0.999	V-70	60	9.806	0.998	115.455	0.970
60	V-45	4	5.90E-08	0.999	313.006	0.963	V-58	354	5.24E-16	0.999	V-71	36	34.116	0.994	92.76	0.986
70	V-46	2	2.035	0.999	274.921	0.981	V-59	279	2.320	0.999	V-72	18	208.912	0.965	562.25	0.946
80	V-47	5	2.497	1.000	2991.958	0.656	V-60	378	1.29E-11	1	V-73	45	31.001	0.994	654.758	0.930
90	V-48	3	1.30E-04	0.999	753.606	0.862	V-61	144	1.77E-16	0.999	V-74	26	125.659	0.977	3238.612	0.878
100	V-49	3	4.70E-05	0.999	111.159	0.968	V-62	347	2.04E-16	0.999	V-75	88	7.312	0.999	123.811	0.985

Appendix 12

Performance of Test Sample for Model V using nftool

This section includes the performance of the test set for Model V using MATLAB nftool and Levenberg-Marquardt Algorithm, Bayesian regulation and scaled algorithm for 39 trial models by presenting the following results: RMSE, RMAE and MAPE values.

Performance of Model V Using (nftool And Levenberg-Marquardt)

Predicted output	Model no												
	V-37	V-38	V-39	V-40	V-41	V-42	V-43	V-44	V-45	V-46	V-47	V-48	V-49
83	83.387	82.280	83.340	83.266	83.000	83.000	91.231	83.079	83.000	85.927	83.000	83.009	82.999
70	70.005	69.517	69.503	68.354	70.000	70.000	85.720	60.982	72.831	67.495	70.000	70.010	77.794
30	29.306	30.972	29.606	30.592	31.961	24.536	28.731	30.061	29.401	15.760	30.000	28.067	29.993
25	24.501	26.667	24.894	25.610	26.973	20.158	24.957	25.061	25.000	10.771	25.000	25.016	24.993
21	21.010	23.215	25.114	21.147	21.000	21.000	20.825	21.072	21.000	17.837	21.000	21.020	20.996
32	32.016	32.206	35.722	29.562	26.996	32.000	31.831	32.088	32.000	59.088	10.370	32.005	31.995
142	141.970	144.715	142.346	142.305	142.599	167.306	141.862	207.651	142.000	190.960	142.000	142.013	141.996
63	63.029	62.864	62.149	63.469	67.179	63.000	59.956	75.874	63.000	60.656	63.000	63.015	62.994
83	83.015	83.149	82.625	84.669	83.000	83.000	76.004	100.023	83.000	81.019	83.000	83.014	82.997
36	35.997	36.487	36.070	36.480	36.000	40.672	35.987	50.508	36.000	33.578	35.448	36.016	22.813
83	83.644	82.877	85.393	83.229	84.397	83.000	82.778	83.035	137.974	81.286	83.000	83.035	82.996
68	67.800	68.201	68.491	66.639	68.000	68.000	67.793	68.029	108.630	66.319	68.134	68.036	67.996
69	69.022	69.206	69.622	67.428	68.956	69.207	68.790	68.432	110.947	67.290	69.000	65.731	69.334
19	19.008	19.611	18.851	19.343	19.000	19.000	18.856	22.923	18.999	17.496	19.000	19.036	18.996
No of hidden neurons	1	5	10	15	20	30	40	50	60	70	80	90	100
RMSE	0.309	1.120	1.662	1.111	1.938	7.149	5.175	19.036	21.449	16.007	5.783	1.015	4.095
MAE	0.183	0.778	1.034	0.866	1.083	2.892	2.613	8.856	10.070	9.033	1.594	0.388	1.526
MAPE	0.437	2.163	2.972	1.862	2.777	4.906	3.798	11.648	13.773	19.531	4.952	0.840	3.456

Performance of Model V Using nftool And Bayesian Algorithm

Predicted output	V-50	V-51	V-52	V-53	V-54	V-55	V-56	V-57	V-58	V-59	V-60	V-61	V-62
83	81.178	82.563	83.000	83.000	83.031	83.000	83.727	83.000	83.000	83.000	83.000	83.000	83.000
70	68.163	70.034	70.000	70.000	70.1751	70.000	70.000	70.000	69.576	73.266	70.000	67.323	70.000
30	31.326	30.222	30.000	30.000	30.122	30.000	30.000	30.000	30.000	30.000	29.755	30.000	30.000
25	26.815	25.468	25.017	25.000	25.271	25.749	25.000	25.000	25.000	25.000	25.000	25.000	25.000
21	21.849	20.630	21.000	21.000	21.006	21.000	21.000	21.000	5.523	35.374	21.000	21.000	21.000
32	32.358	32.199	32.000	32.000	32.034	32.000	32.000	32.000	48.389	32.000	32.000	32.000	32.000
142	143.383	142.350	144.978	146.384	142.073	142.000	142.000	140.904	146.878	129.744	142.000	142.000	142.000
63	62.707	62.733	63.000	63.000	62.910	63.000	63.000	63.000	63.000	63.000	63.000	63.000	61.717
83	82.443	82.827	83.000	83.000	82.7354	83.000	83.000	83.000	83.000	83.000	83.000	83.000	83.000
36	36.759	35.833	36.000	36.000	35.819	36.000	36.000	36.000	36.000	40.100	36.000	36.000	36.000
83	81.769	83.573	84.775	83.000	83.227	83.000	83.000	83.000	83.000	83.000	83.000	83.000	83.000
68	66.681	67.934	68.000	68.000	67.851	68.000	68.000	68.000	68.000	68.000	68.000	68.000	68.000
69	67.683	69.031	69.399	69.000	68.852	69.000	69.000	69.000	69.000	69.000	69.000	69.000	69.000
19	20.509	18.957	19.000	18.083	19.114	19.000	19.000	17.471	19.000	19.000	19.000	19.000	19.000
No of hidden neurons	1	5	10	15	20	30	40	50	60	70	80	90	100
RMSE	1.275	0.296	0.933	1.197	0.157	0.200	0.194	0.503	6.165	5.239	0.066	0.715	0.343
MAE	1.170	0.243	0.369	0.379	0.135	0.054	0.052	0.188	2.655	2.428	0.018	0.191	0.092
MAPE	2.797	0.569	0.349	0.565	0.302	0.214	0.063	0.630	9.211	6.652	0.058	0.273	0.145

Performance of Model V Using nftool And Scaled Conjugate Gradient Algorithm

Predicted output	V-63	V-64	V-65	V-66	V-67	V-68	V-69	V-70	V-71	V-72	V-73	V-74	V-75
83	82.280	84.044	62.049	79.349	78.370	81.946	82.569	64.156	91.297	69.945	79.186	119.600	85.310
70	69.517	73.080	51.156	69.832	63.893	69.523	67.711	54.012	93.719	52.949	70.092	94.748	68.841
30	30.972	33.669	35.350	31.023	32.793	26.959	28.030	26.286	30.577	25.025	23.857	22.029	31.083
25	26.667	29.481	30.552	26.663	27.859	22.543	23.832	24.204	30.221	20.046	19.630	16.815	27.465
21	23.215	15.503	32.803	20.650	18.225	21.122	21.363	21.226	22.035	94.467	23.815	1.872	20.010
32	32.206	29.556	29.443	40.824	36.240	59.576	72.422	29.297	41.786	21.781	19.783	42.327	33.255
142	144.715	118.066	132.378	141.499	151.693	148.005	142.764	141.762	143.728	144.845	138.692	135.630	143.933
63	62.864	63.536	71.404	60.842	64.340	54.888	60.469	63.304	53.637	46.096	69.259	59.894	63.544
83	83.149	80.779	88.031	80.485	84.501	77.755	82.496	72.007	59.556	86.807	89.398	82.346	90.996
36	36.487	37.890	45.267	35.697	36.434	36.793	37.262	52.568	39.235	39.887	39.399	43.765	29.549
83	82.877	84.717	80.675	79.519	79.798	83.460	82.873	88.069	83.943	68.399	79.152	82.208	81.428
68	68.201	70.665	68.020	65.733	69.665	71.184	67.213	65.642	71.257	52.219	75.513	69.803	68.646
69	69.206	71.814	69.106	66.011	70.310	72.650	68.650	65.943	68.091	53.155	66.064	69.983	72.745
19	19.611	18.860	18.446	22.004	41.551	33.864	18.622	-3.368	17.902	3.952	79.332	26.864	19.351
RMSE	**1.120**	6.969	9.560	3.181	7.181	9.070	10.871	10.586	10.072	22.796	17.031	13.971	3.197
MAE	**0.778**	4.009	7.170	2.350	4.650	5.503	3.810	7.373	6.615	15.174	8.889	9.735	2.321
MAPE	**2.163**	7.576	15.301	5.662	14.313	15.933	11.111	18.734	12.038	46.103	33.226	24.308	4.746

Appendix 13

Simulation Function for Model I-48

This Section includes the chosen model Model-I-48 from MATLAB nftool with all the weights values and the procedure built in the MATLAB program.

```
function [Y,Xf,Af] = myNeuralNetworkFunction(X,~,~)
%MYNEURALNETWORKFUNCTION neural network simulation function.
%
% Generated by Neural Network Toolbox function genFunction, 08-
Oct-2017 09:53:41.
%
% [Y] = myNeuralNetworkFunction(X,~,~) takes these arguments:
%
%   X = 1xTS cell, 1 inputs over TS timesteps
%   Each X{1,ts} = 10xQ matrix, input #1 at timestep ts.
%
% and returns:
%   Y = 1xTS cell of 1 outputs over TS timesteps.
%   Each Y{1,ts} = 1xQ matrix, output #1 at timestep ts.
%
% where Q is number of samples (or series) and TS is the number
of timesteps.

%#ok<*RPMT0>

% ===== NEURAL NETWORK CONSTANTS =====

% Input 1
x1_step1.xoffset = [2;21;0;117;7878.365;176094.824;0;3;4;0];
x1_step1.gain =
[0.0555555555555556;0.0222222222222222;0.00643086816720257;1.724
45011596927e-05;9.49364072273644e-06;3.97775725652809e-
05;2;0.285714285714286;0.666666666666667;0.0152671755725191];
x1_step1.ymin = -1;

% Layer 1
b1 = [-
0.061225620644962418;0.97065894783662099;1.0632783721800454;1.67
54257655014395;0.80238644491776712;-
0.97658681944984815;0.9092619886711768;1.8596386791023125;0.1879
6235412693202;1.3322763251279426];
IW1_1 = [-0.55582944438188853 -0.5238577348054968
0.61427213544952386 0.9166532467538222 0.72403034263634403 -
0.26204975333491154 1.0933444480827397 -0.87991449872495597 -
2.3712408634271411 -2.8345595111324937;1.5831006010282582 -
0.065189598416119737 -1.4172435074728031 -0.32085474560008526 -
0.93522908576397401 3.5489921349014106 -0.062760284817336087
2.1552274034833041 1.9728723154790011 -
1.3388328587854808;0.039890736395231711 -0.044352385647088766
```

```
0.1228032431641442 3.3662950249309866 -0.47877944592801736 -
1.1541184565516802 -1.5513530113992342 0.37042783485345798
1.7831638227184876 0.52794348272840508;2.1578816149914966
1.4268111634806324 7.1149896288830785 -0.23568338010701123 -
1.7965826461394772 -0.12059528195397275 -2.4391390767910797 -
1.99649008483726 -0.034205536544567809 2.7142327618043884;-
0.87696689112209547 2.4132693384943216 0.75428854801170342 -
1.7121533015214987 0.11042146195828209 -1.0749293048857103
0.82593951925259323 3.3690519252613451 0.64150873312771728
4.6742518183998021;1.5080626176482528 2.9673606774691637
1.827284515327694 -3.6997666494132049 -0.5016214065141682 -
1.618386789384165 2.0851005599909618 -0.098361038099136724
1.2169146278700613 1.4814748530365598;1.1183136590037936 -
2.0862474828337265 2.6442914968747102 -3.2568768840854037 -
0.076954165269582736 1.3245715055067258 -0.35589702718846045
1.3298166110694358 -2.2643894969016785 -0.20325891503586546;-
0.2339739603311265 0.47333899535629648 0.22290495729025619 -
2.6562649475004303 0.53793143930008946 -0.22198643057890485 -
1.1124086790027687 -0.64017894648222851 1.0491884414005062
0.15267247124414293;0.0573279930018036 0.14016722238469886
0.53941246684054822 0.002852433903193344 0.0311787087589614
0.023389383014802229 0.025958320712316216 0.033937135454270823 -
0.032586755567896489 -0.021109261971262373;1.2601635175469783
3.6020909297790289 0.93500176853542849 -1.6155205769035179
1.1562049123583862 1.564951659991284 2.4955183368931855 -
2.1188107935236125 -0.39748682665307283 4.16557241986881];

% Layer 2
b2 = -0.10044536592696761;
LW2_1 = [-0.075043988246440888 -0.04855079350244889 -
0.0038265855891413954 0.011286237298599355 -0.038283785529466
0.0350732055436552 -0.040006719354950301 0.033687517883267397
2.1560942641126664 -0.036057430640773012];

% Output 1
y1_step1.ymin = -1;
y1_step1.gain = 0.007117437722241993;
y1_step1.xoffset = 0;

% ===== SIMULATION ========

% Format Input Arguments
isCellX = iscell(X);
if ~isCellX
    X = {X};
end
```

```
% Dimensions
TS = size(X,2); % timesteps
if ~isempty(X)
    Q = size(X{1},2); % samples/series
else
    Q = 0;
end

% Allocate Outputs
Y = cell(1,TS);

% Time loop
for ts=1:TS

    % Input 1
    Xp1 = mapminmax_apply(X{1,ts},x1_step1);

    % Layer 1
    a1 = tansig_apply(repmat(b1,1,Q) + IW1_1*Xp1);

    % Layer 2
    a2 = repmat(b2,1,Q) + LW2_1*a1;

    % Output 1
    Y{1,ts} = mapminmax_reverse(a2,y1_step1);
end

% Final Delay States
Xf = cell(1,0);
Af = cell(2,0);

% Format Output Arguments
if ~isCellX
    Y = cell2mat(Y);
end
end

% ===== MODULE FUNCTIONS ========

% Map Minimum and Maximum Input Processing Function
function y = mapminmax_apply(x,settings)
y = bsxfun(@minus,x,settings.xoffset);
y = bsxfun(@times,y,settings.gain);
y = bsxfun(@plus,y,settings.ymin);
end

% Sigmoid Symmetric Transfer Function
```

```
function a = tansig_apply(n,~)
a = 2 ./ (1 + exp(-2*n)) - 1;
end

% Map Minimum and Maximum Output Reverse-Processing Function
function x = mapminmax_reverse(y,settings)
x = bsxfun(@minus,y,settings.ymin);
x = bsxfun(@rdivide,x,settings.gain);
x = bsxfun(@plus,x,settings.xoffset);
end

% Solve an Input-Output Fitting problem with a Neural Network
% Script generated by Neural Fitting app
% Created 08-Oct-2017 09:54:35
%
% This script assumes these variables are defined:
%
%   p - input data.
%   t - target data.

x = p;
t = t;

% Choose a Training Function
% For a list of all training functions type: help nntrain
% 'trainlm' is usually fastest.
% 'trainbr' takes longer but may be better for challenging
problems.
% 'trainscg' uses less memory. Suitable in low memory
situations.
trainFcn = 'trainlm';  % Levenberg-Marquardt backpropagation.

% Create a Fitting Network
hiddenLayerSize = 10;
net = fitnet(hiddenLayerSize,trainFcn);

% Setup Division of Data for Training, Validation, Testing
net.divideParam.trainRatio = 70/100;
net.divideParam.valRatio = 15/100;
net.divideParam.testRatio = 15/100;

% Train the Network
[net,tr] = train(net,x,t);

% Test the Network
y = net(x);
e = gsubtract(t,y);
```

```
performance = perform(net,t,y)

% View the Network
view(net)

% Plots
% Uncomment these lines to enable various plots.
%figure, plotperform(tr)
%figure, plottrainstate(tr)
%figure, ploterrhist(e)
%figure, plotregression(t,y)
%figure, plotfit(net,x,t)
```

Appendix 14

Simulation Function for Model V-60

This Section includes the chosen model Model V -60 from MATLAB nftool with all the weights values and the procedure built in the MATLAB program.

```
function [Y,Xf,Af] = myNeuralNetworkFunction(X,~,~)
%MYNEURALNETWORKFUNCTION neural network simulation function.
%
% Generated by Neural Network Toolbox function genFunction, 08-Oct-2017
20:46:09.
%
% [Y] = myNeuralNetworkFunction(X,~,~) takes these arguments:
%
%   X = 1xTS cell, 1 inputs over TS timesteps
%   Each X{1,ts} = 10xQ matrix, input #1 at timestep ts.
%
% and returns:
%   Y = 1xTS cell of 1 outputs over TS timesteps.
%   Each Y{1,ts} = 2xQ matrix, output #1 at timestep ts.
%
% where Q is number of samples (or series) and TS is the number of timesteps.

%#ok<*RPMT0>

% ===== NEURAL NETWORK CONSTANTS =====

% Input 1
x1_step1.xoffset = [2;21;0;117;7878.365;176094.824;0;3;4;0];
x1_step1.gain =
[0.0555555555555556;0.0222222222222222;0.00643086816720257;1.72445011596927e-
05;9.49364072273644e-06;3.97775725652809e-
05;2;0.285714285714286;0.666666666666667;0.0152671755725191];
x1_step1.ymin = -1;

% Layer 1
b1 = [-0.0010529405777157028;-0.00092919489523521847;0.002416770990763571;-
0.00071837933874878965;-0.10917705376060564;-
0.001112774829962972;0.011805765285588974;0.010559988625575632;-
0.0028690324459927879;-
0.0058913788045857288;0.00078620835840131204;0.39561522807262961;0.0064053155
84177766;-
0.00038029244159485862;0.0022171434893285477;0.00041604357120906816;0.0890715
13622493118;-0.011446858634670322;0.0004968425658078647;-
0.013832381166202935;0.014503431000983412;-0.00072015814159455958;-
0.012208189183164967;0.01262623949811518;-
0.0037526630147197175;0.00021211444012788735;0.005044480621791466;0.004138269
3009255379;-0.010150723716462577;-
0.00096278289668044433;0.010543857486611199;-
0.0067445756491492084;3.8531792375153556e-05;-
0.01533008860148906;0.0018088334313402909;0.00010860816422640025;0.0071027694
379147419;-0.00087851702926927124;-0.0093905034669825808;-
0.012881923868792212;-1.1026602773189531;-
0.0031762972160617651;0.00021231709688386506;-0.29452266199145899;-
0.014043269788196323;0.00032059718146052412;-
0.17325748961878917;0.0047706165898770362;0.013508387141830164;-
0.0010465892415616575;0.0027938766187122718;0.0082914212381635880;0.0652470667
```

44130749;0.0010516343084541438;0.0065685617655431268;-0.0010373947887386856;-
0.00014551573022225989;0.0013248909889476584;-
0.0010554082164099599;0.0023408635569485358;-0.0074290191869863676;-
0.64630609054856569;0.0064508619367286968;-0.026801658743374496;-
0.00083287686442589217;-0.30993893238879289;-0.0016697364781711565;-
0.008613672579638413;-0.0077555032848513911;0.00062943960789704485;-
0.002767694957491964;-
0.0087808393849332887;0.0050191676589518754;0.0027320045110001195;0.005771002
7668468984;0.0050402973315742464;0.0010134211720335031;-
0.0045606353551541799;0.0066970984208906716;0.014313262309021029];
IW1_1 = [0.0053550709430997276 0.027510150798083471 0.03230394029068346
0.0015283664830560 86 -0.019912114341989758 0.016552876478765466 -
0.005983865942801923 -0.025386271292988635 0.01413791903911534 -
0.0059050124996461251;0.0060077147395687543 0.032026713849723554
0.037921045524375488 0.0015853226764008523 -0.022858306321076969
0.019563754318249436 -0.0074192133375283412 -0.029792835230767804
0.01687143887335233 -0.0070356313264738199;0.0075837397280257256
0.053366932218032452 0.065482102885311338 -0.00015076642673870035 -
0.034254654673277027 0.037405281482446713 -0.017006256689867921 -
0.053256862388026599 0.034051676872327498 -0.01269495725416126;-
0.0077474851230045823 -0.046667373072631697 -0.056709414115138218 -
0.0009098665347078797 0.031501180416427188 -0.03119607578810028
0.013189369296550808 0.045444317134268039 -0.027740684050705507
0.010543211203425232;0.19709448634570811 -0.01253241268345285 -
0.71348509919283831 0.36985643862444351 -0.39080305921206726 -
0.0097237706124777869 -0.093745200951484947 0.0037129191048883301
0.13744263313731309 0.24677993013379157;-0.0074790985571291935 -
0.048595644927083376 -0.059204837126860456 -0.00063869785427078478
0.032199336533462367 -0.032690962752005996 0.014328367586993816
0.047481174403170311 -0.029368916477427089
0.011332920107729022;0.010150152825768583 0.069310720754050065
0.090307052326721315 -0.0059793883732339684 -0.037109093876062565
0.060162194778397272 -0.032104963221649657 -0.077535133193410655
0.05442780046491151 -0.023790028005960751;0.0078727935339231812
0.068759590000207843 0.08712955428731764 -0.0056327206488758566 -
0.037011389935628851 0.057116345204439513 -0.030441479557613053 -
0.075017534335957092 0.052839214624869422 -0.021705971716821044;-
0.009016087063551028 -0.05331001729118879 -0.066739523612858481
0.00021349214978532834 0.035100884855595434 -0.038723936000704666
0.017260327229498124 0.054298839720347603 -0.034807127299117335
0.012711793082046639;-0.021392728584452 -0.05350756710363478 -
0.082886484724653695 0.0010093078389415411 0.039317349955773635 -
0.052200661683187391 0.021326469269515397 0.063497327356224292 -
0.041852893085425329 0.020662032195974428;-0.0063259718752350699 -
0.034673528559089006 -0.041263696841479541 -0.001566885362726372
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0.062511423694298657 0.077955973805882484 -0.0027820981171953643 -
0.036750935588607397 0.048079803225807898 -0.023932472714474816 -
0.065471484648969527 0.044748397237766926 -
0.01673697203188991;0.0070015330160458069 0.03953610197454091
0.047432430276871544 0.0014425553168651941 -0.027518833200104308
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0.0040569487237775625 0.0017545659806480131;-0.023444457200684551 -
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0.0078672772402156657;0.092004639409432445 0.050688949046016937
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0.01897394675720333;0.0075186133824315746 0.057919856189403082
0.071631926736560395 -0.0012588781747756069 -0.035777404227226105
0.042434779817965007 -0.020125871249137086 -0.059153991819083318
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0.063093165371078994 -0.092871635382901177 0.0023253323497257738
0.038359996761721409 -0.06076646508380959 0.029357322748415033
0.074402901315819656 -0.051529581209239061
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0.019164616819531584 -0.0071323046018871459 -0.029164981702308312
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0.037128027142877655 0.057201624608647327 -0.030317156309669826 -
0.074931260286849141 0.05268889564140463 -
0.021713377509326091;0.077895970806032333 0.049553237458162952
0.14895494197992915 0.023697243919018812 -0.019420291554257282
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0.015270847756519773 -0.072652639153760745 -0.099816303746440821
0.007831380744186293 1 0.035604562240578445 -0.068622624425901904
0.037506707911385731 0.085261109199876742 -0.058253445078335971
0.031421842153890572;0.0076622485513247541 0.051304005890415776
0.062774449297814477 0.00023962971414249857 -0.033478224543161982
0.035382422536971742 -0.015754039205018704 -0.050773477715626722
0.03198646650427367 -0.012009473858363097;0.0075677335544690767
0.043244873073626171 0.052227368261854798 0.0012372823995253255 -
0.029760284233701848 0.028267242530341078 -0.011542832692929592 -
0.041620543893994 0.02487694851360784 -
0.0095955696737110019;0.0088554146431895891 0.062591883546101346
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0.045844438733603575 -0.017608371505109788;0.0061324803531922394
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0.023513079705656904 0.020278276955307883 -0.0077880343428066868 -
0.030829814427287862 0.017535275279553529 -0.0073161948332919223;-
0.011570535999141953 -0.064672797187231346 -0.086269208169334519
0.00372751635604862 0.03789456745763483 -0.055723212834345261
0.028181914944796101 0.072010925169915543 -0.050076613450159305
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0.092427579836953364 0.0067879365703028731 0.036782406928082552 -
0.062312298684617719 0.033764091910413491 0.07981545152860485 -
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```
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0.034838766044630057 0.072893385101903227 -0.036259460897444792 -
0.085724812066130751 0.057567432387383079 -0.036662284790058744];

% Layer 2
b2 = 0.10767401426093953;
```

```
LW2_1 = [-0.058999202357750351 -0.069426865364579787 -0.12497732439857157
0.10642477686416447 0.70695680298310304 0.11137535577607587 -
0.18199198106617442 -0.17584554540773828 0.12745858344589586
0.15357272893303547 0.075693501023587156 -1.1410312065834349 -
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0.11766457778094534 0.16618265567444129 0.16173339661499175
0.081536354498308344 0.12812190635525519 0.16675196430347095 -
0.14220765770963228 -0.12783667311140398 -0.14870805054030206 -
0.14538925715733333 0.064621103187197049 0.14210663774200485 -
0.15567374458047861 -0.20544078872067012];

% Output 1
y1_step2.ymin = -1;
y1_step2.gain = 0.00711743772241993;
y1_step2.xoffset = 0;
y1_step1.xrows = 2;
y1_step1.keep = 1;
y1_step1.remove = 2;
y1_step1.constants = 0;

% ===== SIMULATION ========

% Format Input Arguments
isCellX = iscell(X);
if ~isCellX
    X = {X};
end

% Dimensions
TS = size(X,2); % timesteps
if ~isempty(X)
    Q = size(X{1},2); % samples/series
else
    Q = 0;
end

% Allocate Outputs
Y = cell(1,TS);
```

```
% Time loop
for ts=1:TS

    % Input 1
    Xp1 = mapminmax_apply(X{1,ts},x1_step1);

    % Layer 1
    a1 = tansig_apply(repmat(b1,1,Q) + IW1_1*Xp1);

    % Layer 2
    a2 = repmat(b2,1,Q) + LW2_1*a1;

    % Output 1
    temp = mapminmax_reverse(a2,y1_step2);
    Y{1,ts} = removeconstantrows_reverse(temp,y1_step1);
end

% Final Delay States
Xf = cell(1,0);
Af = cell(2,0);

% Format Output Arguments
if ~isCellX
    Y = cell2mat(Y);
end
end

% ===== MODULE FUNCTIONS ========

% Map Minimum and Maximum Input Processing Function
function y = mapminmax_apply(x,settings)
y = bsxfun(@minus,x,settings.xoffset);
y = bsxfun(@times,y,settings.gain);
y = bsxfun(@plus,y,settings.ymin);
end

% Sigmoid Symmetric Transfer Function
function a = tansig_apply(n,~)
a = 2 ./ (1 + exp(-2*n)) - 1;
end

% Map Minimum and Maximum Output Reverse-Processing Function
function x = mapminmax_reverse(y,settings)
x = bsxfun(@minus,y,settings.ymin);
x = bsxfun(@rdivide,x,settings.gain);
x = bsxfun(@plus,x,settings.xoffset);
end

% Remove Constants Output Reverse-Processing Function
function x = removeconstantrows_reverse(y,settings)
Q = size(y,2);
x = nan(settings.xrows,Q,'like',y);
x(settings.keep,:) = y;
x(settings.remove,:) = repmat(settings.constants,1,Q);
end
```

ملخص البحث

تهدف هذه الدراسة إلى دراسة العوامل التي تؤدي إلى تأخر المستحقات المالية في المشاريع الإنشائية الحكومية في مملكة البحرين والآثار المترتبة على هذه التأخير. كما تهدف إلى إيجاد حلول وطرق فعالة للتغلب على هذه المشكلة أو التقليل من حدوثها. بالإضافة إلى تطوير نموذج للتنبأ بعدد الأيام المتوقع تأخر المستحقات المالية فيها إلى حين استلامها من قبل المقاول لنوعين من المستحقات المستخدمة في وزارة الأشغال بمملكة البحرين وهما المستحقات الجزئية (نموذج ج) والمستحقات المضافة (نموذج م).

وتتحقق أهداف الدراسة من خلال مراجعة الدراسات السابقة حول ثلاثة عوامل رئيسية، أسباب تأخير المستحقات المالية؛ وتأثير تأخير المستحقات والحلول الفعالة للتغلب على التأخير. ثانيا، تم تقييم هذه العوامل باستخدام استبانة تم توزيعها على الخبراء العاملين في مجال هندسة البناء والتشييد في القطاعين الحكومي والخاص. وأخيرا، يتم تطوير نماذج للتنبؤ بتأخير المستحقات المالية لنوعين من المستحقات في وزارة الأشغال و البلديات و التخطيط العمراني.

تم ترتيب العوامل بحسب الاهمية عن طريق حساب (RII) لكل منها ومن ثم تم اختيار العوامل المستخدمة في إنشاء النماذج. تم استخدام اثناعشرة عامل لتطوير النموذج ج وعشرة عوامل لتطوير النموذج م وتم إنشاء النماذج بتطبيق التحليل (ANN) عن طريق برنامج (MATLAB) وأيضا بتطبيق التحليل (MLRN) عن طريق برنامج (Excel analysis tool). وتهدف هذه النماذج إلى الحصول على نتائج مقاربة للواقع ويمكن الاعتماد عليها من قبل المهندسين في المجال للتنبؤ بعدد الايام المتوقعة لتأخر المستحقات ، كما وتسلط الضوء على حجم المشكلة الموجودة والمساهمة في تطوير عملية معالجة المستحقات واستحقاقها في المشاريع الحكومية.

أخيرا وليس آخرا قامت الدراسة بمقارنة النتائج لكل من التحليلين (ANN) و(MLRN) وتم التوصل إلى أن نتائج التحليل (ANN) هي الأفضل حيث اعطت نتائج واعدة ومقاربة للواقع. حيث أفضل نموذج للتنبؤ بمقدار التأخر في المستحقات الجزئية هو النموذج (I-48) في حين أن أفضل نموذج للتنبؤ بالتأخير في المستحقات المضافة هو النموذج (V-60) و كلاهما تم تطويرهما باستخدام الأداة (nftool) في برنامج (MATLAB).

قامت الدراسة باقتراح توصيات للتغلب على مشكلة التاخير في المستحقات وقد تبين أن أهم ثلاثة حلول تم تقييمها من خلال الإستبانة هي: تطوير وتيسير عملية تقييم وإصدار الشهادات للمستحقات؛ منح عقود المشاريع للمقاولين الأكفاء اللذين يملكون ما يكفي من الموظفين و الخبرة لتجنب أي التأخير؛ التخطيط و الموازنة السليمة لجميع المشاريع الحكومية؛ الإدارة السليمة للتدفقات النقدية وفقا لنطاق العمل والجدول الزمني المعتمد؛ استباق و توقع الأخطار التي قد تؤدي إلى تأخر المستحقات المالية؛ الاجتماع؛ و التخطيط قبل البدأ بأي عمل لتجنب اي توابع من الممكن ان تؤدي إلى تأخر المستحقات المالية.

جامعة البحرين

كلية الهندسة الميكانيكية

قسم الهندسة

نمذجة تأخير المستحقات المالية للمقاولين العاملين في المشاريع الإنشائية للمباني في وزارة الأشغال

أطروحة مقدمة كجزء من متطلبات الحصول على درجة الماجستير في برنامج الإدارة الهندسية

إعـــــداد

سحر خالد علي فلامرزي

٢٠٠٨٣٥٤١

إشـــــراف

أ.د. سعد سليمان

أستاذ – دكتور

جامعة البحرين

مـملكة البـحرين

فبراير/٢٠١٨