

## إقرار

أنا الموقع أدناه مقدم الرسالة التي تحمل العنوان:

### **COST ESTIMATION OF CONSTRUCTION PROJECTS AT GAZA STRIP USING FUZZY LOGIC**

#### **حساب التكاليف لمشاريع التشييد في قطاع غزة باستخدام المنطق الغامض**

أقر بأن ما اشتملت عليه هذه الرسالة إنما هي نتاج جهدي الخاص، باستثناء ما تمت الإشارة إليه حيثما ورد، وإن هذه الرسالة ككل، أو أي جزء منها لم يقدم من قبل لنيل درجة أو لقب علمي أو بحث لدى أية مؤسسة تعليمية أو بحثية أخرى.

#### **DECLARATION**

The work provided in this thesis, unless otherwise referenced, is the researcher's own work, and has not been submitted elsewhere for any other degree or qualification.

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**M.Sc. Thesis**

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AT GAZA STRIP USING FUZZY LOGIC**

**حساب التكاليف لمشاريع التشييد في قطاع غزة باستخدام المنطق الغامض**

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A Thesis Submitted In Partial fulfillment of the requirement for the degree of Master of  
Science in Civil Engineering

The Islamic University of Gaza-Palestine

December, 2013



مكتب نائب الرئيس للبحث العلمي والدراسات العليا هاتف داخلي 1150

الرقم.....ج.ش.غ/35/Ref

التاريخ.....2013/12/23>Date

## نتيجة الحكم على أطروحة ماجستير

بناءً على موافقة شئون البحث العلمي والدراسات العليا بالجامعة الإسلامية بغزة على تشكيل لجنة الحكم على أطروحة الباحث/ نضال صلاح جميل الشيخ لنيل درجة الماجستير في كلية الهندسة قسم الهندسة المدنية- إدارة المشروعات الهندسية وموضوعها:

### COST ESTIMATION OF CONSTRUCTION PROJECTS AT GAZA STRIP USING FUZZY LOGIC

وبعد المناقشة التي تمت اليوم الاثنين 20 صفر 1435هـ، الموافق 2013/12/23م الساعة الثانية عشرة ظهراً، اجتمعت لجنة الحكم على الأطروحة والمكونة من:

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واللجنة إذ تمنحه هذه الدرجة فإنها توصيه بتقوى الله ولزوم طاعته وأن يسخر علمه في خدمة دينه ووطنه.

والله ولي التوفيق،،،

مساعد نائب الرئيس للبحث العلمي والدراسات العليا

أ.د. فؤاد علي العاجز



﴿ وَقُلْ اَعْمَلُوا فَسَيَرَى اللهُ عَمَلَكُمْ

وَرَسُولُهُ وَالْمُؤْمِنُونَ ﴾ (التوبة: 105)

## ***Dedication***

***This thesis is lovingly dedicated to my  
parents soul***

***To my wife for her unlimited encouragement  
To my children whom were missing my direct care  
during my study  
To all my brothers, sister, colleagues and friends  
for their sustainable support***

***Eng. Nedal Al Sheikh***

# *Acknowledgement*

- ❖ Coming this far is not in anyway by chance, but the special design of Almighty Allah. Allah alone deserves all praises for making everything possible.
- ❖ My sincere appreciation goes to Dr. Nabil El Sawalhi, for all assistance, advice, encouragement and invaluable support given as my advisor. Dr Sawalhi careful check and useful response have made a great contribution to the production of this thesis in its final form.
- ❖ I would like to express my appreciation to the academic staff of The Construction Management Program at the Islamic University-Gaza, especially Dr. Kamalin Shaat, Prof. Dr. Rifat Rustom for their academic and scientific supervision.
- ❖ Careful acknowledgment to my colleagues Eng. Hossam Shaheen for his advices during the study and for his assistance in preparing the model.
- ❖ My grateful thanks to all contractors, consultants and clients who participated in the structured interviews and provided important information for this study.
- ❖ Finally I would like to thank my wife and lovely children for their love, support and for tolerating the time I spent working with my research.

## Abstract

Construction industry is considered an important sector for the development in Gaza Strip. Cost estimation process is an important element of the construction industry. Early stage cost estimate plays significant role in the success of any construction project. Conceptual estimating is the process of establishing a project's cost, often before any graphical representation of a facility has been developed. This research aims to predict the parametric cost estimation in construction building projects in Gaza Strip using Fuzzy logic Model.

This research has been conducted through literature reviews of the cost estimating process, followed by a field survey done by 21 structured interviews in order to define the building factors which is effected the parametric cost estimation.

The result of the survey and literature review shows that ten factors are affecting construction cost. The main factors are the area of typical floor, number of stories and the building type. Data from 169 case studies from real executed construction project in Gaza Strip were collected for the most important ten factors to build up Fuzzy Logic Model.

Fuzzy Logic Model was developed to predict the parametric cost estimation. It is a computerized system which uses MATLAB program as a tool box. The results revealed the ability of Fuzzy Model to predict cost estimate to an acceptable degree of accuracy reached to 88%.

One of the main recommendations of this research is to encourage local contracting companies to do estimation for project cost using software package. The fuzzy logic model will provide more accurate estimates, save time, minimize error, and hopefully to have better chance to win bids.

## ملخص البحث

يعتبر قطاع صناعة الإنشاءات من القطاعات الهامة في قطاع غزة، وتعتبر عملية تقدير التكلفة من أهم عناصر صناعة الإنشاءات. تقدير التكلفة للمشاريع الإنشائية في المراحل المبكرة يلعب دورا هاما في نجاح أي مشروع إنشائي. التقدير الابتدائي هو عملية تقدير تكلفة المشروع وغالبا ما تكون هذه التقديرات قبل عمل أي مخططات للمشروع.

يهدف هذا البحث إلى تطوير نموذج لتقدير حساب التكاليف الابتدائية لمشاريع التشييد في قطاع غزة باستخدام منطق الغموض.

اعتمد البحث على مراجعة الدراسات السابقة في المواضيع ذات العلاقة بعملية تقدير التكلفة، تبع ذلك بحث ميداني بإجراء إحدى وعشرون مقابلة متشابهة لتحديد العوامل التي تؤثر على تقدير حساب التكلفة في المراحل الأولى من المشروع.

لقد أوضحت الدراسة بأنه يوجد عشرة عوامل تؤثر على تكلفة الإنشاءات، واهم هذه العوامل هي مساحة الطابق المتكرر و عدد الطوابق و نوع المبنى. ومن أجل بناء نموذج المنطق الغامض فقد تم جمع 169 مشروع من المشاريع التي تم تنفيذها في قطاع غزة وتحديد العوامل العشرة المهمة لكل مشروع من هذه المشاريع.

تم تطوير نموذج المنطق الغامض، و هذا النموذج عبارة عن نظام كمبيوتر لتقدير التكلفة باستخدام برنامج الماتلاب. وقد أظهرت النتائج أن نموذج المنطق الغامض لديه القدرة على إعطاء نتائج مقبولة عند تقديره للتكلفة، ووصلت دقة النتائج إلى 88% عند مقارنتها بالتكلفة الفعلية.

كان من التوصيات الأساسية لهذا البحث، تشجيع المقاولين المحليين لاقتناء برنامج محوسب متخصص في تقدير التكلفة و استخدامه في تقدير الأعمال للحصول على تقدير أدق للتكلفة وتوفير الوقت وتقليل الأخطاء وإعطاء فرصة أفضل للفوز بالعطاءات.



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## List of Abbreviations

AACE	Association for the Advancement of Cost Engineering
CBR	Case-Based Reasoning
CER's	Cost Estimating Relationships
CFE	Capacity Factored Estimate
CTC	County Transportation Commission
FIS	Fuzzy Inference System
FL	Fuzzy Logic
GAO	United States Government Accountability Office
GA	Genetic Algorithm
GAs	Genetic Algorithms
GNP	Gross National Product
GUI	Graphical User Interface
HVAC	Heating, Ventilation and Air Conditioning
LIFE	Laboratory for International Fuzzy Engineering
MAE	Mean Absolute Error
MF	Membership Function
NNs	Neural Networks
PNA	Palestinian National Authority
RMSE	The Root Mean Square Error
SCEA	Society of Cost Estimating and Analysis
Trapmf	Trapezoidal Membership Function
Trimf	Triangular Membership Function
USA	United State of America

# CHAPTER 1

## INTRODUCTION

### 1.1 Background and Rationale

Construction industry plays a major role in development and achievement of the goals of the society. Construction is one of the largest industries and contributes to about 10% of the gross national product (GNP) in industrialized countries (Barrie and Paulson, 1993). Construction industry has complexity in its nature because it contains large number of parties as clients, contractors, consultants, stakeholders, shareholders and regulators. Construction is a unique industry that by nature is risky since most projects must be priced before they are constructed, whereas in other industries the selling price is based on known manufacturing costs (Kern and Formoso, 2006). The success or failure of a project relies on the accuracy of several estimates done throughout the course of the project (Navon, 2005). The performance of the construction industry is affected by national economies. The development of construction industry is a measurement tool of countries development, it's give indicators about the economic situation (Langford et al., 2000).

Generally, the process of awarding any construction contract is based on competitive bidding. Contractors will be invited to submit their bids to the owner who normally awards the lowest bid to construct the project. Previously, both the owner and contractor have to access the construction cost of the proposed project. This is achieved through a construction cost estimate (Popescu et al., 2003).

The preparation of any type of cost estimate depends on the experience of the estimator, the tools used, the time spent, and the information available. Usually the preparation of an estimate starts by breaking down the project into components, then taking off the quantities of the elements of each package and next pricing them all (Popescu et al., 2003). The success of a contractor depends upon cost obtain a job estimates of projects, not only of, but also to construct to lose the job; the result of a low estimate could be to win the job, but to lose money in the construction process (Hendrickson, 2000).



Computers are expanding increasingly into all aspects of daily life. The cheaper computer hardware today has boosted the rush of using the computers. However, the accounting early uses of computers by construction companies were limited to functions. With the advances in micro-computing, increased knowledge of computer capabilities, and the development of user-friendly software, computers have been used every day at construction to make quick and accurate decisions through estimating software which have reduced the amount of manual work necessary for preparing an estimate (Bhatnagar and Ghose, 2012).

As a result of the limited availability information during the early stages of a project construction managers used their knowledge experience and standard estimators to estimate project costs. Therefore, personal judgment plays a significant role in decision making. Researchers have worked to develop cost estimators that improve the accuracy and reliability of cost estimation work. Today, estimating technologies used by contractors vary tremendously from contractor to contractor. Some might still be using simple tools such as paper and pencil, while others are more technologically advanced and use computers for activities such as quantity take off, calculations and estimating report generation and use digitizing tablets, others used statistical methods to develop cost estimating models like regression models (Han et al., 2008 ; Ganiyu and Zubairu, 2010). Artificial intelligence approaches are applicable to cost estimation problems related to expert systems, case-based reasoning (CBR), Neural Networks (NNs), Fuzzy Logic (FL), Genetic Algorithms (GAs) and derivatives of such (Cheng et al., 2010). Many research studies have been done in this area; this research aim is to investigate the potential use of fuzzy logic as a tool for cost estimation modeling.

## **1.2 Problem Statement**

In general, it can be stated that the current estimating methods for construction projects at Gaza Strip are traditional methods. Cost estimation for building projects traditionally starts with quantification – a time intensive process-. From these quantities, estimators utilize methods from spreadsheets to costing applications to produce the project cost estimate. This process is prone to human error and tends to propagate inaccuracies that creep into the tallies. Currently, quantification is also time consuming – it can require 50% to 80% of a cost estimator’s time on a project (Sabol, 2008). Computer-based estimating systems have gained a wide acceptance in the construction industry. It's

widely used in construction management in the developed countries. In the developing countries using computers is still at the early stages special at construction cost estimations. The majority of local contractors in Gaza Strip have poor experience in using estimating software programs. Software systems are not quite available and there is a shortage in qualified persons to use these software packages. This study is looking for rising an estimating software system for construction cost estimation applicable for all construction concerned parties.

### **1.3 Study Questions**

The purpose of this study is to examine the use of fuzzy logic in cost estimating system by Gaza Strip contractors for conceptual estimating, this aim generates:

Hypothesis 1: The fuzzy logic costing systems in the Gaza Strip can provide competent tool for conceptual estimating.

Hypothesis 2: The contractors at Gaza Strip do not implement fuzzy logic costing system.

### **1.4 Research Aim**

The aim of this research is to develop a computerized cost estimating system using fuzzy logic that may improve the local practice.

### **1.5 Research Objectives**

The aim of this research may be divided into the following objectives:

1. To explore the existing common practices in cost estimating.
2. To establish key parameters and key cost drivers in the building cost estimating.
3. To develop a computerized system in cost estimating by using fuzzy logic.

## 1.6 Limitations

This thesis is restricted by the following items:

1. Due to time constraint, this research is concerned with construction building projects only (housing, schools, hospitals, etc.), and will not take into account the other categories of engineering projects like civil projects (tunnels, highways, bridges), or utilities projects (sewage and water supply), and industrial projects (factories and workshops).
2. Only the contractors registered in the Palestinian Contractors Union and the consultants who are registered in the Engineering Association were involved in this study.
3. Contractors of first, second and third class represent the contractors population in this research, while contractors of fourth and fifth category will be excluded according to their experiences.

## 1.7 Outline Methodology

The research was conducted in three main stages. The first stage included identifying the research problem, setting out the research's aim and objectives and developing the research plan. The second phase included reviewing the literature related to cost estimate, based on the initial literature {reports, thesis, scientific papers and the own experiences} related to identify the main topics to be handled in this research. This stage includes also review of available fuzzy logic software packages.

The third phase was the model formulation and development. The model was preceded by using Matlab programming language where Fuzzy is built in Matlab Toolbox. Discussion for the obtained results was also made. Finally, conclusion of research and recommendations were then drawn up.

## CHAPTER 2

### Literature Review

## CONSTRUCTION COST ESTIMATING AND FUZZY LOGIC

### 2.1 Introduction

Construction is a unique industry, which is essentially risky because most projects must be priced before they are constructed.

Cost estimating is an essential task for budgeting and bid preparation for any construction project. To adequately define the project scope and to ensure sufficient construction funds are available, cost estimates are required during the various stages of project development. As the project progresses, the estimates are refined to ensure the project is still cost effective, sufficient funds are available for construction, and the contractor's bid price is reasonable.

A good estimate depends on many factors including time given to the estimator, estimator's experience, and a wide range of assumptions regarding the project (Jrade and Alkass, 2007). Construction cost estimating involves collecting, analyzing, and summarizing all available data for a project (Holm et al., 2005).

Researchers have worked to develop cost estimators that maximize the practical value of limited information in order to improve the accuracy and reliability of cost estimation work and thus enhance the suitability of resultant designs and project execution work (Cheng et al., 2010). The purpose of pre-tender price estimating is to provide an indication of the probable costs of construction at a very early stage in the life of a construction project. It is one of the most important factors influencing the client's decision to build or not.

This chapter will focus on conceptual estimates, the information needed for a preliminary estimate. Today's conceptual estimating technologies and the difficulties associated with conceptual estimates are also reviewed.

### 2.2 Definition of Cost Estimating

Cost estimating has different definition, Carr (1989) defines estimate is to produce a statement of the approximate quantity of material, time, or cost to perform construction. On the other hand, Steward (1991) reported a definition of cost estimation from the Society of Cost Estimating and Analysis (SCEA), as "the art of approximating the probable worth or cost of an activity based on information available at the time".

Also GAO (2009) said that cost estimating combines science and art to predict the future cost of something based on known historical data that are adjusted to reflect new materials, technology, software languages, and development teams. Al Hamidi and Mohammed (2009); Butcher and Demmers (2003) and Ahuja et al., (1994) give another definition which is, "the estimate at best is an approximation of the expected cost of the project". Dysert (2006) defined a cost estimate as, "the predictive process used to quantify, cost, and price the resources required by the scope of an investment option, activity, or project. The output of the estimating process, the cost estimate, is typically used to establish a project budget". While, Akintoye (2000) defined cost estimate as, "is crucial to construction contract tendering, providing a basis for establishing the likely cost of resources elements of the tender price for construction work". Turochy et al., (2001) distinct that cost estimation is the process by which, based on information available at a particular phase of project development, the ultimate cost of a project is estimated.

While Hendrickson (2000) specifies that are design, bid and control. Furthermore, he defines that at the very early stage of design, the screening estimate or order of magnitude estimate is made before the facility is designed, and therefore it relies on the cost data of similar facilities built in the past. While preliminary or conceptual estimate is based on the conceptual design of the facility at the state when the basic technologies for the design are known. Moreover, the detailed or definitive estimate is made when the scope of work is clearly defined and the completed plans and specification when they are ready for the owner to solicit bids from construction contractors. Uppal (1997) quotes a definition of cost estimation from Association for the Advancement of Cost Engineering (AACE) International define the cost estimation to provide the basis for project management, business planning, budget preparation and cost and schedule control. Included in these costs are assessments and an evaluation of risks and uncertainties. ElSawy et al. (2011) consider cost estimation as the lifeblood of the firm and can be defined as the determination of quantity and the prediction or forecasting, within a defined scope, of the costs required to construct and equip a facility.

The construction cost estimate is a prediction and foreseeing of the total cost of a construction project before it actually exists.

## 2.3 Qualities of a Good Cost Estimate

In general, a cost estimate should answer a series of questions as shown in Table 2.1 below:

**Table 2.1: Questions should be answered for good cost estimation (Alameda CTC, 2011)**

<b>Group</b>	<b>questions</b>
<b>Scope</b>	What is included? What is excluded? Does the scope of the estimate match the scope of defining documents? Any variations must be identified and the reason for the deviation explained.
<b>Quantities</b>	Are the quantities reasonable? Is the method clear and easy to follow? Has the math been checked? Do the totals come forward to the summaries? A good technique is to use parametric checks from other experience, e.g. 1000 kg of reinforcing steel per cubic meter of concrete would be extraordinary
<b>Pricing</b>	Are the unit prices reasonable? Are the explanations reasonable? Does the pricing cover the type and quality of materials contemplated? Are incidentals like sales tax and freight covered? Have unusual working conditions been factored into the pricing?
<b>Support and other soft costs</b>	Did you consider work by others? Are environmental studies considered? Are preliminary engineering and final design included? Is the construction staking and construction management covered?
<b>Presentation</b>	Is the estimate presentation clear? Is it easy to follow? Is the basis of the estimate documented in a concise fashion so that it will be readily understood by an unfamiliar party?

### 2.3.1 Estimator Responsibility

Enshassi et al. (2007) said that the success or failure of a project is dependent on the accuracy of several estimates throughout the course of the project, which can influence issues ranging from project feasibility to profitability. It's the estimator's responsibility to assist the owner of the project to plan and budget for the construction of the project (Choi, 2004). For early estimates, the estimator is often working directly with the business unit in gaining alignment on the project scope to be estimated. It is the estimator responsibility to make early communication between him and the project team or business unit on the expectations for the estimate. It is the estimator responsibility to ensure that a project team understands the information needs for the estimate, then ensure that a

project team understands the information needs for the estimate, then ensure that the information provided is suitable to produce the quality of estimate desire (Dysert, 2005). The estimator responsibility is to produce an estimate that is an accurate reflection of reality, before the completion of the design he must have the vision to see beyond the obvious components and their primary costs of construction (Carr, 1989).

### **2.3.2 Estimator Skills**

The best contractor in the area cannot make a profit or stay in business for long if taken contracts are below the real cost, so to be a good competitors at the construction industry the best contractor needs a good estimator. Dysert (2005), Popescu et al., (2003) and Carr (1989) stated that an effective estimating organization requires highly knowledgeable personnel, possessing technical skills. Moreover they define a set of skills as estimating core competencies as follows:

1. Ability to read and understand contract documents, with special skills in reading construction drawings for all specialties and related specifications.
2. Ability to accurately take off the quantities of construction work for which he or she is preparing the detail estimate.
3. Ability to visualize the future building from drawings, which usually requires some years of construction site experience.
4. Knowledge of arithmetic, basic geometry, and statistics.
5. Familiarity with estimating software in depth and with available building cost databases.
6. Knowledge of building construction methods.
7. Knowledge of labor productivity, crew composition, and impacts of various forecasted site conditions on crew output.
8. Possession of office managerial skills in organizing project-related cost information.
9. Ability to work under pressure and to meet all bid requirements and deadlines.

## **2.4 The Importance of Cost Estimating**

Most public owners are obliged to select the lowest bidder. In addition, the contractor must successfully pass a qualification screening, in this situation the contractor must be prepared to lower the bid cost, reduce the project completion date, or accept additional owner requirements, but not to lose money. This can be achieved through a good cost estimation done by qualified estimator. Cost estimates allow owners and planners to evaluate project feasibility and control costs effectively in detailed project design work

(Feng et al., 2010). Estimating purpose is to provide information to construction decisions. Typical decisions include procurement and pricing of construction, establishing contractual amounts for payment and controlling actual quantities by project management (Carr, 1989). Dysert (2006) said that the cost estimate, is typically used to establish a project budget, but may also be used for other purposes, such as:

- determining the economic feasibility of a project;
- evaluating between project alternatives; and
- providing a basis for project cost and schedule control.

While GAO (2009) believes that cost estimates have two general purposes:

- (1) To help managers evaluate affordability and performance against plans, as well as the selection of alternative systems and solutions.
- (2) To support the budget process by providing estimates of the funding required to efficiently executing a work.

## **2.5 Types of Cost Estimate**

Popescu et al. (2003) said that there are many ways of classifying building cost estimates. The most significant of these are the degree of project definition, the end usage of the estimate, and the estimate generating methodology.

The first classification, the degree of project definition, is based upon the percentage of completed architectural and engineering designs. It defines available input information to the estimator.

The second classification, the end usage of the estimate, is based on available data progress and covers conceptual estimates for investment feasibility, and studies funding authorization, budgets, and contractor detail estimates for lump-sum bidding.

The third classification, the estimate generating methodology, is based on processes employed to forecast building costs that are stochastic and deterministic.

While Carr (1989) and Sabol(2008) concede that the type of estimate and its accuracy depends up on many factors including the purpose of the estimates, how much is known about the project, and how much time and effort is spent in preparing the estimate as shown in the Table 2.2 below:



**Table 2.2: Cost estimating classification matrix (Sabol, 2008).**

Estimate Phasde			Detailed		
			Budget		
	Conceptual				
Estimate Class	5	4	3	2	1
<b>Level of Project</b>	0% to 2%	1% to 15%	10% to 40%	30% to 70%	50% to 100%
<b>Definition</b>					
% of complete definition					
<b>End Usage</b> Typical purpose of estimate	Screening or feasibility	Concept study or feasibility	Budget, Authorization or control	Control or bid tender	Check estimate or bid tender
<b>Expecting Accuracy Range</b>	Hi				
Typical variations in low and high ranges	Lo				
<b>Preparation Effort</b> Typical degree of effort relative of least cost index of 1	1	2 to 4	3 to 10	5 to 20	10 to 100

Butcher and Demmers (2003) said cost estimates fall into two groups: conceptual estimates and detailed estimates. The difference between these two methods is in terms of their speed, quantity of required information, costs, and areas of use. The global cost prediction methods are useful in early determination of costs and where no time and means are available for determination of costs. On the other hand, the detailed cost prediction methods are useful in the precise cost analysis of the finished product (Ray et al., 2010). Each can be broadly defined as follows:

### 2.5.1 Conceptual Estimate

Conceptual estimating or parametric estimating is the process of establishing a project's cost, often before any graphical representation of a facility has been developed (Butcher and Demmers, 2003). Conceptual estimate is usually performed as part of project feasibility analysis at the beginning of the project. In this way, the estimate is made with limited information on project scope, and is usually made without detailed design and engineering data. The accuracy range is expected to be -25% to +50% (Popescu et al., 2003). Conceptual Cost Estimates are used for project justification, analysis of alternatives, approval, and for programming. At the conceptual stage of design, the owner is trying to decide whether to continue with facility procurement and the designer is working with the owner to establish the scope and general characteristics of the facility. An order of magnitude estimate is sufficient for decisions, particularly if it is sensitive to changes in scope (Carr, 1989).

### 2.5.2 Detailed Estimate

Detailed estimates, also known as bottom up, fair cost, or bid estimates, are prepared from well defined design and engineering data. These estimates are generally carried out for bid evaluations, contract changes, work scoping, permits and approvals (Sabol, 2008). The detailed construction estimate is the product of a process whereby the cost of a proposed construction project is predicted. The estimate is prepared by breaking down the items of work in an orderly and logical basis, determining the cost of each item from experience, and summarizing the total (Butcher and Demmers, 2003). Detailed estimates are the most accurate estimate because the available information consists of working drawings, detailed specifications, and subcontractors and supplier price quotations. Detailed estimates include direct and indirect cost estimates of materials, labor, equipment, engineering, support staff, insurance, bonds, taxes, allowances, contingencies, and profit (Ahuja et al., 1994). It can be performed only when work items are identified and a takeoff of their quantities is possible. The expected accuracy for a detailed or definitive estimate is within a range of -5% to +10 % (Popescu et al., 2003).

## 2.6 Conceptual Estimating Methods

There are many order-of-magnitude or conceptual estimating methods that have been developed over the years and each is useful in certain situations. Some of these methods and techniques are:

### 2.6.1 Capacity Factoring Technique

A capacity factored estimate (CFE) is one in which the cost of a new proposed project is derived from the cost of a similar project of a known capacity. The basic estimating algorithm relies on the typical non-linear relationship between capacity and cost shown in the following equation:

$$\$/B/\$/A = (CapB/CapA)^e \quad \text{..... (Equation 1)}$$

Where \$A and \$B are the costs of the two similar projects, CapA and CapB are the capacities of the two projects, and "e" is the exponent (or capacity factor) that drives the non-linear relationship. Capacity factored estimating techniques can be applied to a wide range of industries and projects to prepare quick feasibility and project screening estimates. This technique is very common in the process industries where the exponent "e" typically has a value between 0.5 and 0.85, depending on the type of plant; and in

fact yet another name for this estimating technique is the "sixteenths rule" because of a common reliance on using an exponent value of 0.6 if no better information is available (Dysert, 2005).

This method is most effective when the new (to be estimated) and completed projects are near-duplicates, and are reasonably close in size. If the capacity factor used in the estimating algorithm is reasonable, and the project being estimated is relatively close to the size of a similar project of known cost, then the potential error from the CFE is well within the level of accuracy of an order-of-magnitude estimate (Dysert, 2005).

### 2.6.2 Parametric Modeling

A parametric cost model can be an extremely useful tool for the preparation of early conceptual estimates. A parametric estimating model is a mathematical representation of one or more cost estimating relationships (CER's) that provide a logical and predictable correlation between the functional or physical characteristics of a project and its costs (Ray et al., 2010). A capacity factored estimate can be thought of as a simple parametric model (using capacity as a single independent variable); however, sophisticated parametric models will often involve several independent variables and cost drivers.

Derivation of a parametric estimating model can be a daunting and complicated undertaking. The model should be based on the collection and analysis of actual cost data from completed projects, along with key engineering and design data. The key is to identify the significant project design parameters that can be defined with reasonable accuracy early in project scope development, and that are correlated with statistical significance to project costs. The model should also provide the capability for the estimator to make adjustments for specific factors affecting a particular project. Usually, a CER will take one of the following forms:

$$Cost = a + bV_1x + cV_2y \quad \dots\dots\dots (Equation 2)$$

Where V1 and V2 represent the values of input design variables; a, b, and c are constants derived from the regression analysis; and x and y are exponents (also derived from the regression analysis). Often a single estimating algorithm will involve both linear and non-linear cost relationships (Dysert, 2005).

Parametric models can be much more complex than the single CER. In addition to several CER's, a complex parametric model may include an extensive database of

technical and cost history and require extensive documentation to communicate the assumptions, ground rules, and logic incorporated in the model. Parametric models have been created to prepare estimates for everything from commercial construction projects to the space shuttle to software development.

Parametric models can be a valuable resource in the preparation of early, order-of-magnitude estimates. Effective parametric models can be developed using basic skills in estimating, mathematics, and statistical analysis; and implemented using sophisticated programming application or simple spreadsheets. The quality of the results from a parametric model are obviously no better than the quality and analysis of the input data used in creation of the model. Great care should be taken during the data collection stage to gather appropriate and accurate project scope and cost data, and the model should be thoroughly tested to ensure that the results are logical, consistent, and meet the expected accuracy levels (Dysert, 2005).

### **2.6.3 End-Units Method**

This conceptual estimating methodology is generally used when enough historical data exists to from similar projects in order to relate the end-product (capacity units) of a project to its costs. This techniques allows an estimate to be prepared relatively Quickly, requiring only the end-product units of the proposed project (Henry et al., 2007).

Examples of the relationship between costs and end-product units are:

- The cost of building an electric generating plant and the plant's capacity in kilowatts;
- The construction cost of a hospital and the number of patient beds;
- The construction cost of a parking lot and the number of parking spaces required.

Very similar in concept to the end-product units estimating methodology is the physical dimensions method. This estimating technique uses the physical dimensions (length, area, volume, etc.) of the item being estimated as the driver of costs. For example, the estimate for constructing a building may be based on the square meters or cubic volume of the building, and similarly the cost of an oil pipeline or a highway may be based on a linear basis. As with the end-product unit's method, this technique also depends on historical information from comparable facilities (Dysert, 2005).

### **2.6.3.1 Area Estimate**

This method is prepared depending on the basis of the area of building, the rate being deducted from the cost of similar building having similar specification, heights and construction in the locality. It is calculated by finding the area of the building and multiplying by the unit area rate. The area is calculated from the covered area by taking external dimension of the building at the floor level (Ray et al., 2010).

### **2.6.3.2 Cubic Estimate**

It is an approximate estimate and it is prepared based on cubical contents of the building. The cube rate being deducted from the cost of similar building having similar specifications and construction, in the locality. Cubic rate is more accurate than the area because it considers the height of the building (Ray et al., 2010).

### **2.6.4 Analogy Method**

An analogy estimate is typically characterized by the use of a single historical data point serving as the basis for the estimate. Analogy estimating methods are often used when a parametric model or other estimating algorithms (capacity factors, equipment factors, etc.) cannot be applied. This may be because of a lack of adequate historical data to support the development of conceptual estimating algorithms, or perhaps because the proposed project differs significantly from those projects that existing estimating algorithms can address (Dysert, 2005).

In analog methods, costs are evaluated on the basis of similarity with other products; an analogy estimate is typically prepared by selecting a completed project as a base case, and then adjusting the historical costs for the technical, performance, complexity, physical, and other differences between the new project and the base case (Ray et al., 2010).

### **2.6.5 Expert Judgment**

As its name implies, expert judgment (or expert opinion) is an estimating technique that relies almost solely on the experience, knowledge and assessment of one or more experts (Ray et al., 2010).

Dysert (2005) see that any single expert may be subject to biases that are difficult to discern. To avoid this inherent bias when using a single expert to provide an estimated cost, a group of experts will often be used to develop an expert judgment estimate. A common technique applied to reaching group consensus is called the "Delphi Method."

## 2.7 Accuracy of Cost Estimates

Popescu et al. (2003) said that "all building estimates are probably either higher or lower than the true cost. The word "accuracy" is defined as 1) the condition or quality of being true, correct, or exact; precision; exactness. 2) The extent to which a given measurement agrees with the standard value for that measurement. The conceptual estimate accuracy is defined as a percentage difference between the engineering estimates compared to the price of the contract award". Accuracy is the degree to which a measurement or calculation varies to its actual value; thus estimate accuracy is an indication of the degree to which the final cost outcome of a project may vary from the single point value used as the estimated cost for the project. Estimate accuracy is traditionally represented as a +/- percentage range around the point estimate; with a stated confidence level that the actual cost outcome will fall within this range (Dysert, 2006).

In early pre-construction stage, accuracy degree is relatively low because of insufficient information. But, as project is going on and amounts of information are more gained, it is generally improved (Han, et al., 2008).

### 2.7.1 Factors Affecting the Accuracy of Cost Estimates

A key factor for a successful project is the preparation of an accurate estimate, which can influence by many factors that affecting this accuracy. Yong and Mustaffa, (2012) find that the financial capability of the clients is the major factor critical to the success of a construction project at Malaysia. All three groups of participants in the industry opined that apart from financial capability, "project stakeholders' factors" such as competence, cooperation in solving problems, commitment and communication are significant factors ensuring the success of a construction project. External factors such as availability of resources and weather conditions also played a crucial role in contributing to the success of a construction project. While Odeyinka and Lowe, (2002) find the major factors at the UK are client's changes to initial design, inclement weather, architect's variation to works, labour shortage, production target slippage, delay in agreeing variation/ day works, delay in settling claims, problems with foundations, underestimating project complexity, estimating error and undervaluation.

Various studies indicate to these factors affecting the construction cost estimation at Gaza Strip. Abdal-Hadi (2010) conclude that the main factors affecting accuracy of pre-

tender cost estimate are: material (prices /availability /supply /quality /imports ), closure and blockade, project team's experience in the construction type, the experience and skill level of the consultant, clear and detail drawings and specifications, quality of information and flow requirements, completeness of cost information, accuracy and reliability of cost information, currency exchange fluctuation, and finally clear contract conditions. Enshassi, et al. (2005) conclude that the main factors affecting the accuracy of cost estimation are: location of the project, segmentation of Gaza Strip and limitation of movements between areas, political situation, financial status of the owner, increase in unit cost of construction materials, experience of consultant engineer, clarity of project drawings, and clarity of information before execution and tender currency.

### **2.7.2 Common Errors and Omissions in Cost Estimation**

Developing a good cost estimate requires stable program requirements, access to detailed documentation and historical data, well-trained and experienced cost analysts, a risk and uncertainty analysis, the identification of a range of confidence levels, and adequate contingency and management reserves. During the estimating process, errors occur. The magnitude of these errors in an estimating department can spell disaster (GAO, 2009).

Popescu et al. (2003) organize the causes of possible estimating errors and omissions while at the same time associating these with possible procedures for minimizing their chances of occurrence during estimating and bid proposal preparation as shown at the Table 2.3 below.

**Table 2.3: Possible estimating errors and possible procedures for minimizing their chances of occurrence (Popescu et al. 2003)**

<b>Errors</b>	<b>Possible estimating errors</b>	<b>Procedures for reducing errors</b>
<b>Ordinary</b>	Arithmetic, location of decimal point	Standardization of estimating forms
	Unit of measure, unit price relation	
	Errors in data input in estimating software	Quiet environment and adequate work station for estimators
	Errors in transferring data from quantity take off to cost summary	
<b>Shortcuts/rush/short time to prepare the estimate</b>	Estimating quantities	Use of known average ratios to check relationship between quantities
	Failure to check the estimate	
	Guessing the site overhead cost	Review finished pricing sheets and computer printouts
	Filling in for missing subcontractor costs	
<b>Carelessness</b>	Omitting work items	Use summary checklist for each type of building
	Omitting subcontractor quotes	
	Using obsolete productivity data files	
	No allowance for waste of materials	List of subcontractor specialty for the project
	No allowance for possible major construction equipment breakdown	
	Omitting profit	
<b>Poor estimating management</b>	Not attending the prebid conference	Selection of the best estimator
	Missing addenda	New estimators in-house training
	Missing the time/date of the bid	Acquire state-of-the-art estimating software
	Incomplete proposal	Updating internal files related to labor productivity
	Not visiting the project site	
	Not reviewing historical	Update subcontractor files
	Not considering the time faster for pricing labor and materials	Last call to A/E office to check number of addenda issued
	Not having a summary schedule	Develop bid day checklist

## 2.8 Fuzzy Logic

The past few years have witnessed a rapid growth in the number and variety of applications of fuzzy logic (FL). The applications range from consumer products such as cameras, washing machines, and microwave ovens to industrial process control, medical instrumentation, decision-support systems and robotics (Idri, et al., 2001). This section of the research will focus on FL definition, history and its applications.



### 2.8.1 Fuzzy Logic Definition

The word "fuzzy", according to the dictionary, is defined as "blurred, indistinct, vaguely ". The term "fuzzy logic" refers to logic of approximation. Zadeh (1994) said fuzzy logic (FL) is a problem-solving control system methodology that lends itself to implementation in systems ranging from simple, small, embedded micro-controllers to large, networked, multi-channel PC or workstation-based data acquisition and control systems. It can be implemented in hardware, software, or a combination of both. FL provides a simple way to arrive at a definite conclusion based upon vague, ambiguous, imprecise, noisy, or missing input information. FL's approach to control problems mimics how a person would make decisions, only much faster.

Simon (2003) said that fuzzy logic imitates the logic of human thought, which is much less stiff than the calculations computers generally perform.

While Sivanandam et al. (2007) defined fuzzy logic is a mathematical tool for dealing with uncertainty and also it provides a technique to deal with imprecision and information granularity.

Fuzzy logic has two different meanings. In a narrow sense, fuzzy logic is a logical system, which is an extension of multivalued logic. But in a wider sense, which is in predominant use today, fuzzy logic (FL) is almost synonymous with the theory of fuzzy sets, a theory which relates to classes of objects with unsharp boundaries in which membership is a matter of degree. In this perspective, fuzzy logic in its narrow sense is a branch of FL. What is important to recognize is that, even in its narrow sense, the agenda of fuzzy logic is very different both in spirit and substance from the agendas of traditional multivalued logical systems (Math works, 2010).

### 2.8.2 Fuzzy Logic History

The precision of mathematics owes its success in large part to the efforts of Aristotle and the philosophers who preceded him. In their efforts to devise a concise theory of logic, and later mathematics, the so-called "Laws of Thought" were posited. One of these, the "Law of the Excluded Middle," states that every proposition must either be true or false. Even when Parmenides proposed the first version of this law (around 400 B.C.) there were strong and immediate objections: for example, Heraclitus proposed that things could be simultaneously true and not true. It was Plato who laid the foundation for what would become fuzzy logic, indicating that there was a third region

(beyond True and False) where these opposites "tumbled about." Other, more modern philosophers echoed his sentiments, notably Hegel, Marx, and Engels. But it was Lukasiewicz who first proposed a systematic alternative to the bi-valued logic of Aristotle. In the early 1900's, Lukasiewicz described a three-valued logic, along with the mathematics to accompany it. The third value he proposed can best be translated as the term "possible" and he assigned it a numeric value between True and False. Eventually, he proposed an entire notation and axiomatic system from which he hoped to derive modern mathematics. Later, he explored four-valued logics, five-valued logics, and then declared that in principle there was nothing to prevent the derivation of an infinite-valued logic. Lukasiewicz felt that three- and infinite-valued logics were the most intriguing, but he ultimately settled on a four-valued logic because it seemed to be the most easily adaptable to Aristotelian logic (Hajek, 1998).

Knuth proposed a three-valued logic similar to Lukasiewicz's, from which he speculated that mathematics would become even more elegant than in traditional bi-valued logic. His insight, apparently missed by Lukasiewicz, was to use the integral range  $[-1, 0, +1]$  rather than  $[0, 1, 2]$ . Nonetheless, this alternative failed to gain acceptance, and has passed into relative obscurity. It was not until relatively recently that the notion of an infinite-valued logic took hold (Hajek, 1998).

The concept of Fuzzy Logic (FL) was first conceived by Lotfi Zadeh, a professor at the University of California at Berkeley, in 1965 to describe, mathematically, classes of objects that do not have precisely defined criteria of membership. His contention is that meaning in natural language is a matter of degree. Zadeh gave the examples, the class of all beautiful women and the class of all tall men (Nguyen, et al., 2003). Jantzen (2007) said that professor Zadeh reasoned that people do not require precise, numerical information input, and yet they are capable of highly adaptive control. If feedback controllers could be programmed to accept noisy, imprecise input, they would be much more effective and perhaps easier to implement.

Zadeh elaborated on his ideas in a 1973 paper that introduced the concept of "linguistic variables", which in this article equates to a variable defined as a fuzzy set. Other research followed, with the first industrial application, a cement kiln built in Denmark, coming on line in 1975 (Faqs, 2011).

While the United State of America (USA) and certain parts of Europe ignored it, fuzzy logic was accepted with open arms in Japan, China and most Oriental countries. It may be surprising to some that the world's largest numbers of fuzzy researchers are in China with over 10,000 scientists. Fuzzy systems were largely ignored in the US because they were associated with artificial intelligence, a field that periodically oversells itself and which did so in a big way in the mid-1980s, resulting in a lack of credibility in the commercial domain. The Japanese did not have this prejudice. Interest in fuzzy systems was sparked by Seiji Yasunobu and Soji Miyamoto of Hitachi, who in 1985 provided simulations that, demonstrated the superiority of fuzzy control systems for the Sendai railway. Their ideas were adopted, and fuzzy systems were used to control accelerating, braking, and stopping when the line opened in 1987 (Faqs, 2011).

Another event in 1987 helped promote interest in fuzzy systems. During an international meeting of fuzzy researchers in Tokyo that year, Takeshi Yamakawa demonstrated the use of fuzzy control, through a set of simple dedicated fuzzy logic chips, in an "inverted pendulum" experiment. This is a classic control problem, in which a vehicle tries to keep a pole mounted on its top by a hinge upright by moving back and forth (Faqs, 2011).

Following such demonstrations, the Japanese became infatuated with fuzzy systems, developing them for both industrial and consumer applications. In 1988 they established the Laboratory for International Fuzzy Engineering (LIFE), a cooperative arrangement between 48 companies to pursue fuzzy research. Japanese companies developed a wide range of products using fuzzy logic, ranging from washing machines to autofocus cameras and industrial air conditioners (Faqs, 2011).

Some work was also performed on fuzzy logic systems in the US and Europe, and a number of products were developed using fuzzy logic controllers. However, little has been said about the technology in recent years, which implies that it has either become such an ordinary tool that it is no longer worth much comment, or it turned out to be an industrial fad that has now generally died out (Faqs,2011).

### 2.8.3 Fuzzy Logic Applications

Fuzzy logic is used in system control and analysis design, because it shortens the time for engineering development and sometimes, in the case of highly complex systems, is the only way to solve the problem (Sachdeva, et al., 2012).

Today, Fuzzy Logic concept used widely in many implementations like automobile engine & automatic gear control systems, air conditioners, automatic focus control, video enhancement in TV sets, washing machines, behaviour-based mobile robots, sorting and handling data, Information Systems, Pattern Recognition (Image Processing, Machine Vision), motion control systems, decision support (Adaptive HMI, Sensor Fusion), traffic control systems and many, many others (Ordoobadi, 2009 and Metaxiotis et al., 2003).

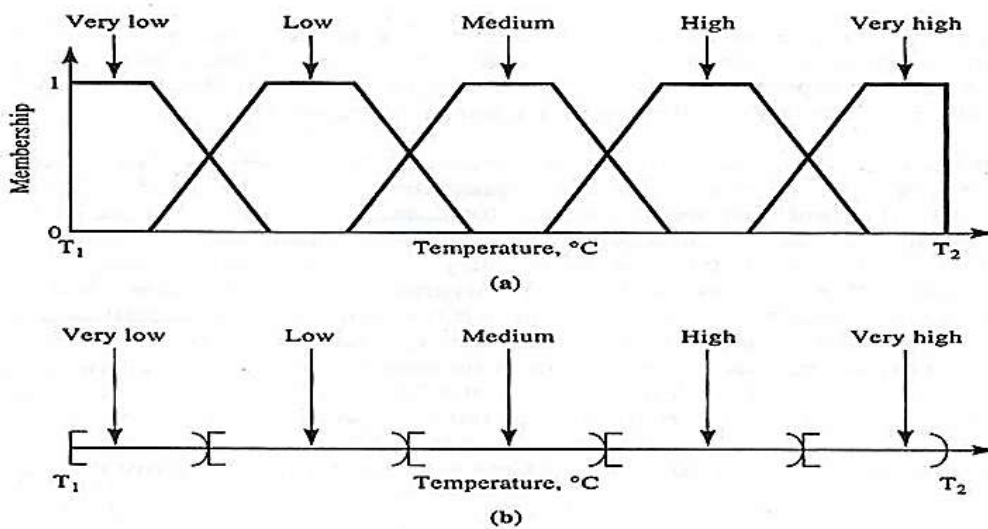
Dell'Acqua (2012) said that fuzzy inference systems have been successfully applied in fields, because of their multidisciplinary nature, fuzzy inference systems have a number of names, such as fuzzy-rule-based systems, fuzzy expert systems, fuzzy modeling, fuzzy associative memory, fuzzy logic controllers, and simply (and ambiguously) fuzzy systems.

### 2.8.4 Fuzzy Sets and Membership Functions

Fuzzy logic starts with the concept of a fuzzy set. A fuzzy set is a set without a crisp, clearly defined boundary. It can contain elements with only a partial degree of membership, rather than having to belong completely or not at all. Fuzzy set theory therefore begins with an assignment of grade of membership values which are not restricted to 0 (non membership) or 1 (full membership). In classical set theory, membership is binary, since there are only two possible states, membership and non membership. Conventionally, these are assigned the values 1 and 0 respectively as shown in the figure below (Teodorovic, 1999).

Fuzzy set is more advantageous than the classical set because it is more general, it mimics the way in which the human-mind interprets linguistic values, and the transition from one linguistic value to a contiguous linguistic value is gradual rather than abrupt (Idri, et al., 2001).

A membership function (MF) is a curve that defines how each point in the input space is mapped to a membership value (or degree of membership) between 0 and 1. The input space is sometimes referred to as the universe of discourse, a fancy name for a simple concept (Reddy, et al., 2011 and Math works, 2010). The degree of the fuzzy membership function  $\mu(x)$  can be define as possibility function not probability function. The notion central to fuzzy systems is that truth values (in fuzzy logic) or membership values (in fuzzy sets) are indicated by a value on the range  $[0.0, 1.0]$ , with 0.0 representing absolute Falseness and 1.0 representing absolute Truth (Idri and Abran, 2001).



**Figure 2.1: Temperature in the range  $[T_1, T_2]$  conceived As (a) a fuzzy variable; (b) a traditional crisp. ( Jantzen, 1998).**

A fuzzy set or a fuzzy number  $\tilde{A}$  has a number of fuzzy members or outcomes  $x_1, x_2, x_i$ , and a membership value can be assigned to each member. In order to define the membership value  $x_i$ , the membership function  $\mu_{\tilde{A}}(x)$  is used. Then, the fuzzy number  $\tilde{A}$  is denoted as  $\tilde{A} = \{(x, \mu_{\tilde{A}}(x)) \mid x \in X\}$ , where  $X$  denotes the domain of fuzzy members  $x$ . A membership value  $\mu_{\tilde{A}}(x_i)$  is allocated within the domain  $[0, 1]$ , indicating the degree of association of a fuzzy member to a fuzzy number. If a member  $x$  more likely belongs to the fuzzy number  $\tilde{A}$ , its membership value will be closer to 1. For example, if there are five fuzzy members in a fuzzy number  $\tilde{A}$ , namely,  $x_1, x_2, x_3, x_4, x_5$ , and their membership values are defined, respectively, as 0.4, 0.7, 0.5, 0.8 and 0.1, then, we can

write the fuzzy number as  $\tilde{A} = \{(x_1, 0.4), (x_2, 0.7), (x_3, 0.5), (x_4, 0.8), (x_5, 0.1)\}$ , where  $x_4$  mostly belongs to the fuzzy set (Tan and Shen, 2010).

#### 2.8.4.1 Features of Membership Function

Sivanandam, et al. (2007) specifies the feature of the membership function by three properties. They are:

- (1) Core: If the region of universe is characterized by full membership (1) in the set  $\tilde{A}$  then this gives the core of the membership function of fuzzy at  $\tilde{A}$ . The elements, which have the membership function as 1, are the elements of the core.
- (2) Support: If the region of universe is characterized by nonzero membership in the set  $\tilde{A}$ , this defines the support of a membership function for fuzzy set  $\tilde{A}$ . The support has the elements whose membership is greater than 0.
- (3) Boundary: If the region of universe has a nonzero membership but not full membership, this defines the boundary of a membership; this defines the boundary of a membership function for fuzzy set  $\tilde{A}$ . The boundary has the elements whose membership is between 0 and 1.

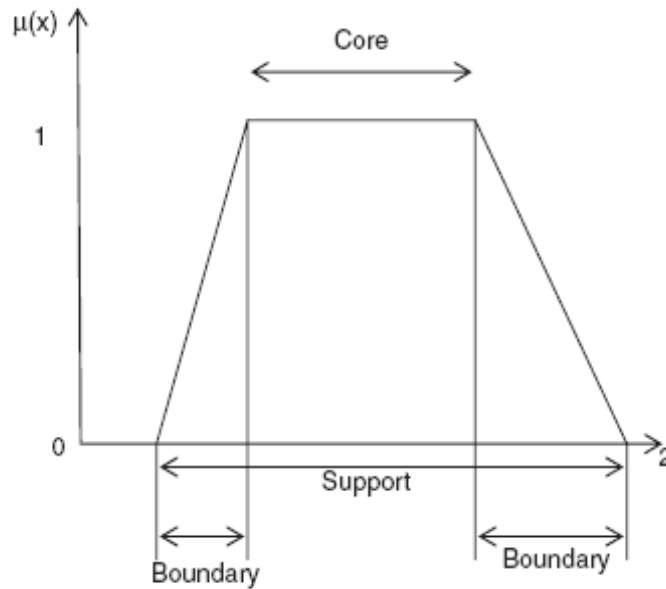


Figure 2.2: Features of membership function (Sivanandam, et al. 2007)

### 2.8.4.2 Classification of Fuzzy Sets

Mittal and Bhatia (2007) said the fuzzy sets can be classified based on the membership functions as:

**Normal fuzzy set:** If the membership function has at least one element in the universe whose value is equal to 1, then that set is called as normal fuzzy set.

**Subnormal fuzzy set:** If the membership function has the membership values less than 1, then that set is called as subnormal fuzzy set.

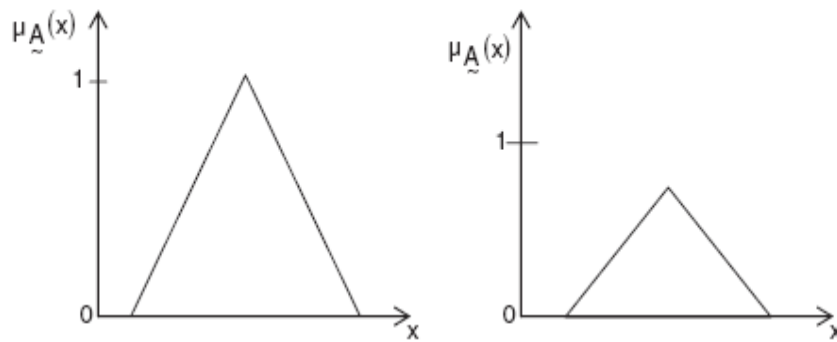


Figure 2.3: Normal fuzzy set and subnormal fuzzy set (Sivanandam, et al. 2007)

**Convex fuzzy set:** If the membership function has membership values those are monotonically increasing, or, monotonically decreasing, or they are monotonically increasing and decreasing with the increasing values for elements in the universe, those fuzzy set  $\tilde{A}$  is called convex fuzzy set.

**Nonconvex fuzzy set:** If the membership function has membership values which are not strictly monotonically increasing or monotonically decreasing or both monotonically increasing and decreasing with increasing values for elements in the universe, then this is called as nonconvex fuzzy set.

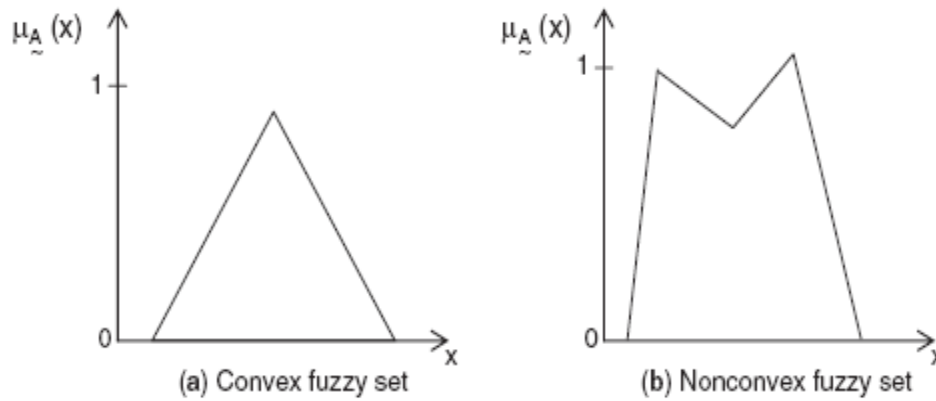


Figure 2.4: (a) Convex set and (b) Nonconvex set (Sivanandam, et al. 2007)

### 2.8.4.3 Membership Values Determination

Kumar et al. (2011) identifying some of the uncertainties present in the crisp values, is form the fuzzy values. The conversion of fuzzy values is represented by the membership functions. There are various methods to assign the membership values or the membership functions to fuzzy variables. The assignment can be just done by intuition or by using some algorithms or logical procedures. The methods for assigning the membership values are:

#### 1. Intuition

It is based on the human's own intelligence and understanding to develop the membership functions. The thorough knowledge of the problem has to be known, the knowledge regarding the linguistic variable should also be known. This method is called Subjective evaluation and elicitation (Sivanandam et al., 2007).

#### 2. Inference

This method involves the knowledge to perform deductive reasoning. The membership function is formed from the facts known and knowledge. Many applications of fuzzy logic use physical measurement, but almost none measure the membership grade directly. Instead, a membership function is provided by another method, and then the individual membership grades of data are calculated from it (Sivanandam et al. 2007).



### 3. Rank Ordering

The polling concept is used to assign membership values by rank ordering process. This method is called Converted frequencies or probabilities, where sometimes information taken in the form of frequency histograms or other probability curves are used as the basis to construct a membership function. There are a variety of possible conversion methods, each with its own mathematical and methodological strengths and weaknesses. However, it should always be remembered that membership functions are NOT (necessarily) probabilities (Sivanandam et al., 2007).

### 4. Angular Fuzzy Sets

The angular fuzzy sets are different from the standard fuzzy sets in their coordinate description. These sets are defined on the universe of angles, hence are repeating shapes every  $2\pi$  cycles. Angular fuzzy sets are applied in quantitative description of linguistic variables known truth-values. When membership of value 1 is true and that of 0 is false, then in between '0' and '1' is partially true or partially false.

The linguistic values are formed to vary with  $\theta$ , the angle defined on the unit circle and their membership values are on  $\mu(\theta)$ . The membership of this linguistic term can be obtained from  $\mu_t(\theta) = t \tan \theta$ , where  $t$  is the horizontal projection of the radial vector and is given as  $\cos \theta$ , i. e.,  $t = \cos \theta$ . When the coordinates are in polar form, angular fuzzy sets can be used (Sivanandam et al., 2007).

### 5. Neural Networks

Neural networks are used to simulate the working network of the neurons in the human brain. The concept of the human brain is used to perform computation on computers (Sivanandam et al., 2007).

### 6. Genetic Algorithm

Genetic algorithm (GA) uses the concept of Darwin's theory of evolution. Darwin's theory is based on the rule, "survival of the fittest." Darwin also postulated that the new classes of living things came into existence through the process of reproduction, crossover, and mutation among existing organisms (Sivanandam et al., 2007).

## 7. Inductive Reasoning

The membership can also be generated by the characteristics of inductive reasoning. The induction is performed by the entropy minimization principle, which clusters the parameters corresponding to the output classes. For inductive reasoning method, there should be a well-defined database for the input–output relationships. This method can be suited for complex systems where the data are abundant and static. When the data are dynamic, this method is not suited, since the membership functions continually change with time (Sivanandam et al., 2007).

### 2.8.5 Membership Functions Shapes

One of the key issues in all fuzzy sets is how to determine fuzzy membership functions (MF), membership functions can take any form, but there are some common examples that appear in real applications.

Mendel (1995) said membership functions can either be chosen by the user arbitrarily, based on the user's experience MF chosen by two users could be different depending upon their experiences, perspectives, etc.). Or be designed using machine learning methods (e.g., artificial neural networks, genetic algorithms, etc.).

There are two alternative ways to represent a membership function in a computer: continuous or discrete. In the continuous form the membership function is a mathematical function, possibly a program. A membership function is for example bell-shaped, s-shaped, a reverse, triangular, or trapezoidal. In the discrete form the membership function and the universe are discrete points in a list (vector). Sometimes it can be more convenient with a sampled (discrete) representation (Jantzen, 1998).

The simplest membership functions are formed using straight lines. Of these, the simplest is the triangular membership function, and it has the function name *trimf*. It is nothing more than a collection of three points forming a triangle. The trapezoidal membership function, *trapmf*, has a flat top and really is just a truncated triangle curve. These straight line membership functions have the advantage of simplicity (Kumar et al., 2011 and Nguyen et al., 2003).

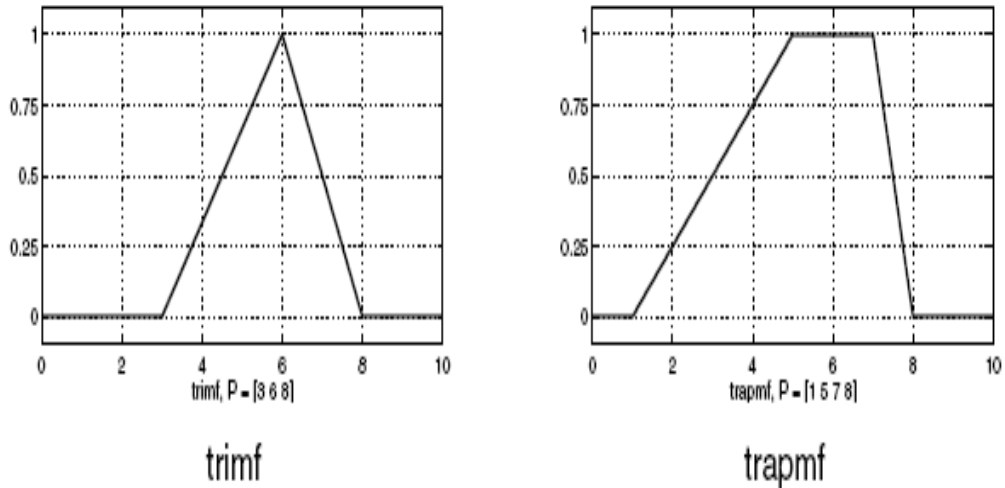


Figure 2.5: Triangular and trapezoidal membership function (Nguyen, et al. 2003).

Two membership functions are built on the Gaussian distribution curve: a simple Gaussian curve and a two-sided composite of two different Gaussian curves. The two functions are `gaussmf` and `gauss2mf`. The generalized bell membership function is specified by three parameters and has the function name `gbellmf`. The bell membership function has one more parameter than the Gaussian membership function, so it can approach a non-fuzzy set if the free parameter is tuned. Because of their smoothness and concise notation, Gaussian and bell membership functions are popular methods for specifying fuzzy sets. Both of these curves have the advantage of being smooth and nonzero at all points (Mittal and Bhatia 2007).

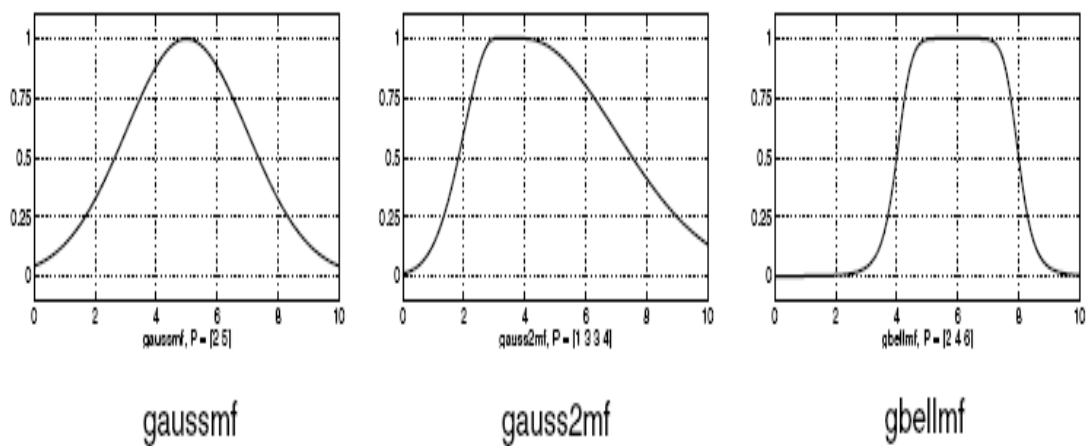


Figure 2.6: Simple Gaussian and two-sided Gaussian membership functions and bell membership

Function, which is either open left or right. Asymmetric and closed (i.e. not open to the left or right) membership functions can be synthesized using two sigmoidal functions, so in addition to the basic sigmf, we also have the difference between two sigmoidal functions, dsigmf, and the product of two sigmoidal functions psigmf (Math works 2010).

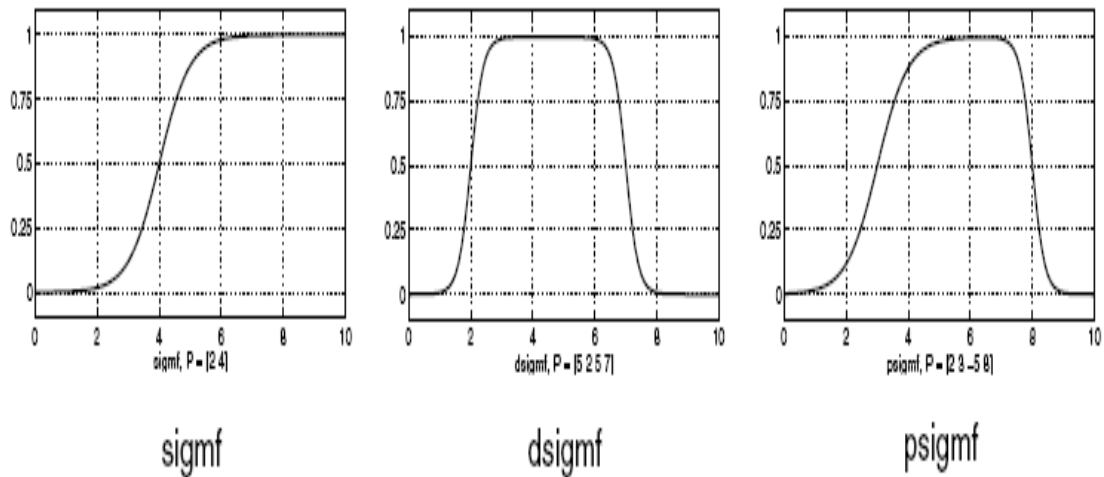


Figure 2.7: Sigmoidal membership functions (Math works 2010).

Polynomial based curves account for several of the membership functions like the Z, S, and Pi curves, all named because of their shape. The function zmf is the asymmetrical polynomial curve open to the left, smf is the mirror-image function that opens to the right, and pimf is zero on both extremes with a rise in the middle (Math works 2010).

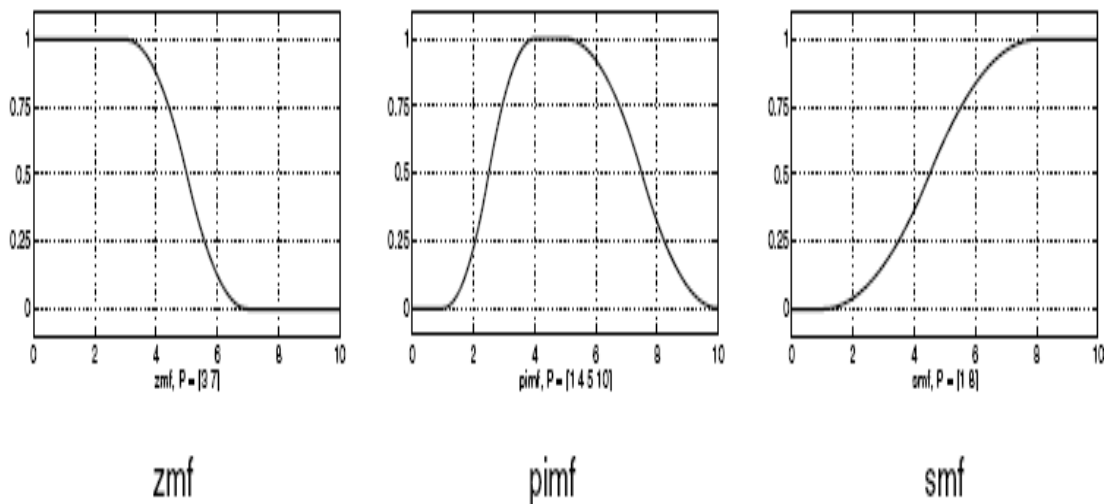


Figure 2.8: Z membership function, P membership function and S membership function (Math works 2010).

### 2.8.5.1 Triangular Membership Function

The most common types of membership functions are triangular, Lets a, b and c represent the x coordinates of the three vertices of  $\mu_A(x)$  in a fuzzy set A (a: lower boundary and c: upper boundary where membership degree is zero, b: the centre where membership degree is 1) (Kumar et al., 2011; Reddy et al., 2011 and Tan and Shen, (2010)).

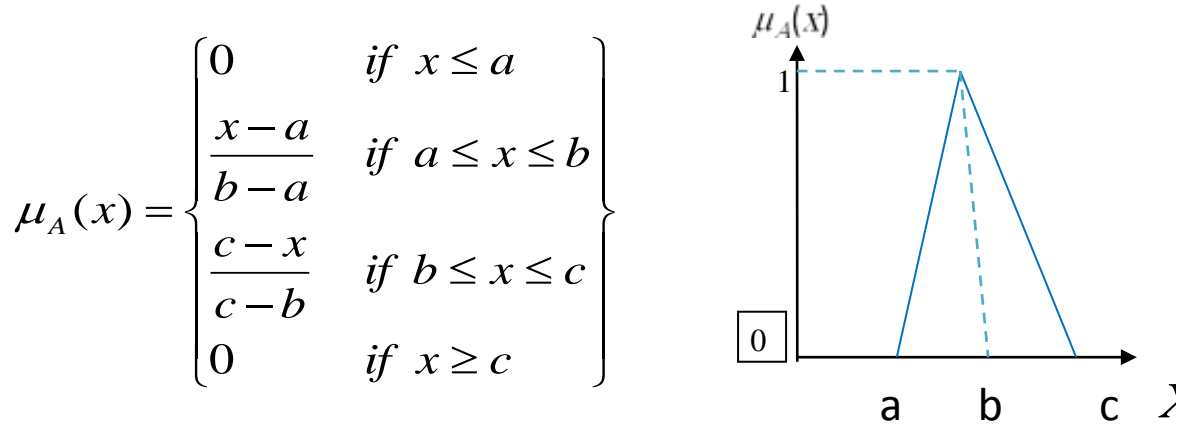


Figure 2.9: Triangular membership function

### 2.8.5.2 Trapezoidal Membership Function

Jamkhaneh and Gildeh (2011) reported that the trapezoidal function B with endpoints (a, 0) and (b, 0), and high points (c,  $\alpha$ ) and (d,  $\alpha$ ) is defined by

$$\mu_A(x) = \left\{ \begin{array}{ll} 0 & \text{if } x \leq a \\ \frac{x-a}{b-a} & \text{if } a < x < b \\ 1 & \text{if } b < x \leq c \\ \frac{d-x}{d-c} & \text{if } c < x < d \\ 0 & \text{if } x \geq d \end{array} \right\}$$

### 2.8.6 Fuzzy Set Operation

The variety of operators for the aggregation of fuzzy sets can be confusing. If fuzzy set theory is used as a modeling language for real situations or systems, it is not only

important that the operators satisfy certain axioms or have certain formal qualities (such as associativity and commutativity), that are certainly of importance, but the operators must also be appropriate models of real-system behavior, and this can normally be proven only by empirical testing. In practice, numerical efficiency in computations can also be an important consideration (Nguyen et al., 2003).

### 2.8.6.1 Union

Beheshti and Lollar (2008) reported that the membership function of the Union of two fuzzy sets A and B with membership functions  $\mu_A$  and  $\mu_B$  respectively is defined as the maximum of the two individual membership functions. This is called the *maximum* criterion.

$$\mu_{A \cup B} = \max(\mu_A, \mu_B)$$

The Union operation in Fuzzy set theory is the equivalent of the **OR** operation in Boolean algebra (Jantzen, 1998).

### 2.8.6.2 Intersection

Beheshti and Lollar (2008), reported that the membership function of the Intersection of two fuzzy sets A and B with membership functions  $\mu_A$  and  $\mu_B$  respectively is defined as the minimum of the two individual membership functions. This is called the *minimum* criterion.

$$\mu_{A \cap B} = \min(\mu_A, \mu_B)$$

The Intersection operation in Fuzzy set theory is the equivalent of the **AND** operation in Boolean algebra (Jantzen, 1998).

### 2.8.6.3 Complement

The membership function of the Complement of a Fuzzy set A with membership function  $\mu_A$  is defined as the negation of the specified membership function. This is called the *negation* criterion.

$$\mu_{\bar{A}} = 1 - \mu_A$$

The Complement operation in Fuzzy set theory is the equivalent of the **NOT** operation in Boolean algebra (Jantzen, 1998).

#### 2.8.6.4 De Morgans Law

Nguyen, et al. (2003) said that there is an important relation that exists among these previous three operations, known as the De Morgan Laws.

$$\overline{(A \cup B)} = \overline{A} \cap \overline{B}$$

$$\overline{(A \cap B)} = \overline{A} \cup \overline{B}$$

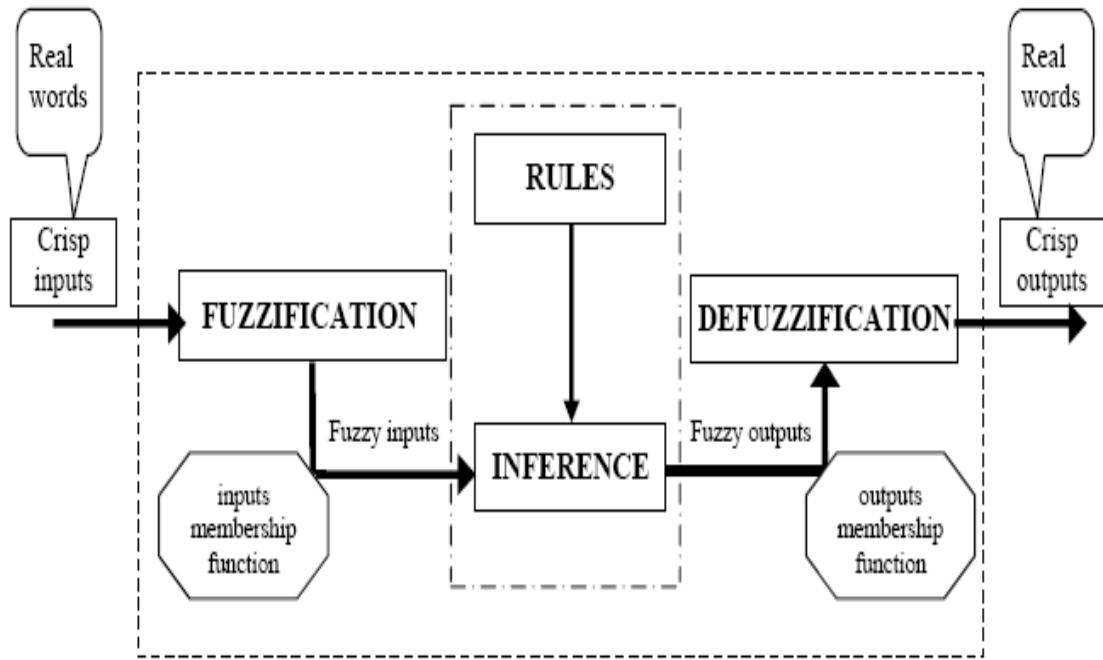
#### 2.8.7 Fuzzy Control Systems

The purpose of control is to influence the behavior of a system by changing an input or inputs to that system according to a rule or set of rules that model how the system operates. The system being controlled may be mechanical, electrical, chemical or any combination of these.

Fuzzy control, which directly uses fuzzy rules, is the most important application in fuzzy theory. Using a procedure originated by Ebrahim Mamdani in the late 70s, three steps are taken to create a fuzzy controlled machine as shown in Figure 2.10.

##### 2.8.7.1 Linguistic Variables

Linguistic Variable - Linguistic means relating to language, in our case plain language words. A fuzzy variable becomes a linguistic variable when we modify it with descriptive words, such as somewhat fast, very high, real slow, very strong, strong, average, weak, poor, and very poor etc (Verma, 1997).



**Figure 2.10: A Fuzzy Logic System.**

The main function of linguistic variables is to provide a means of working with the complex systems as being too complex to handle by conventional mathematics and engineering formulas. Linguistic variables appear in control systems with feedback loop control and can be related to each other with conditional, "if-then" statements. Example: If the speed is too fast, then back off on the high accelerator setting (Beheshti and Lollar, 2008).

### **2.8.7.2 Fuzzification**

Fuzzification is an important concept in the fuzzy logic theory. Fuzzification is the process where the crisp quantities are converted to fuzzy (crisp to fuzzy). By identifying some of the uncertainties present in the crisp values, we form the fuzzy values. The conversion of fuzzy values is represented by the membership Functions (Majeed, 2010).

In any practical applications, in industries, etc., measurement of voltage, current, temperature, etc., there might be a negligible error. This cause imprecision in the data. This imprecision can be represented by the membership functions. Hence fuzzification is performed. Thus fuzzification process may involve assigning membership values for the given crisp quantities.



### **2.8.7.3 Fuzzy Rules**

Fuzzy machines, which always tend to mimic the behavior of man, work the same way. However, the decision and the means of choosing that decision are replaced by fuzzy sets and the rules are replaced by fuzzy rules. Fuzzy rules also operate using a series of if-then statements. For instance, if X then A, if Y then b, where A and B are all sets of X and Y. Fuzzy rules define fuzzy patches, which is the key idea in fuzzy logic (Surmann and Selenschtschikow, 2002).

### **2.8.7.4 Defuzzification**

Defuzzification means the fuzzy to crisp conversions. The fuzzy results generated cannot be used as such to the applications, hence it is necessary to convert the fuzzy quantities into crisp quantities for further processing. This can be achieved by using defuzzification process. The defuzzification has the capability to reduce a fuzzy to a crisp single-valued quantity or as a set, or converting to the form in which fuzzy quantity is present. Defuzzification can also be called as “rounding off” method. Defuzzification reduces the collection of membership function values in to a single sealer quantity. Ordoobadi (2008) cited by Ross there are seven methods employed to convert the fuzzy quantities into crisp quantities as shown in Figure 2.11.

#### **1. Max-membership principle**

This method is also referred as height method.

#### **2. Centroid method**

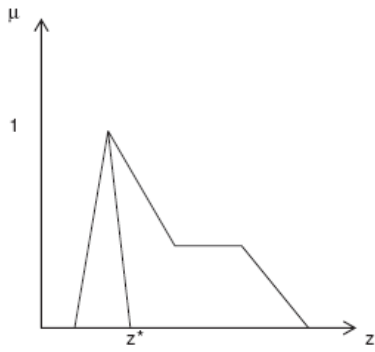
This is the most widely used method. This can be called as center of gravity or center of area method.

#### **3. Weighted average method**

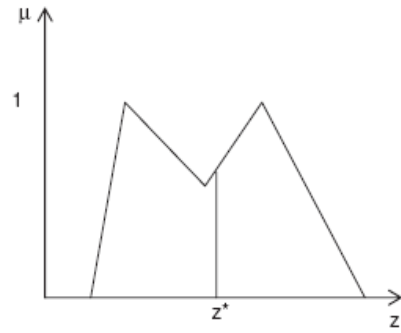
This method can be used only for symmetrical output membership functions. Weighting each membership function in the obtained output by its largest membership value forms this method.

#### **4. Mean-max membership**

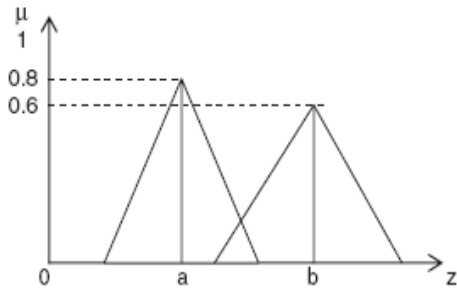
This method is related to max-membership principle, but the present of the maximum membership need not be unique, this method is also called as middle of maxima method.



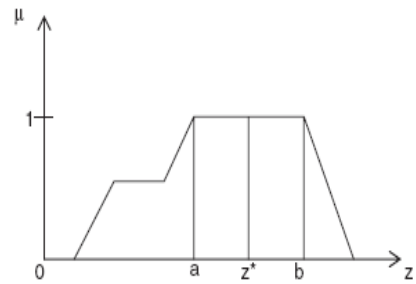
1. Max-membership method



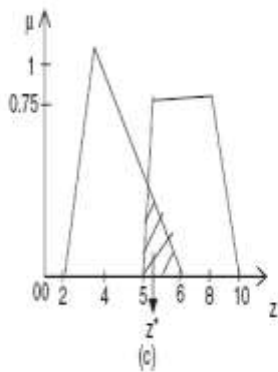
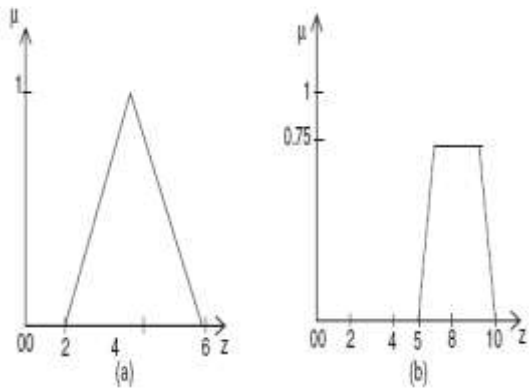
2. Centroid method



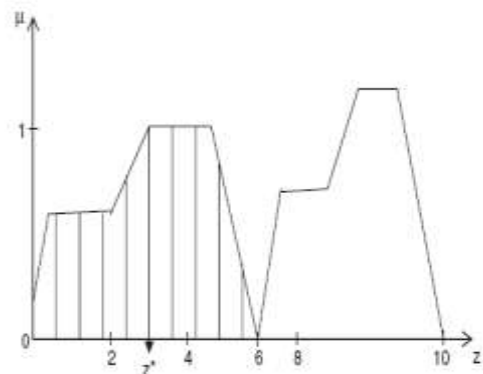
3. Weighted average method



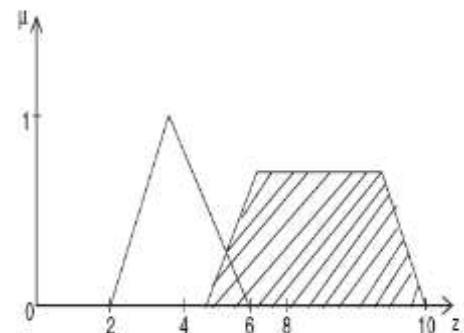
4. Mean-max method



5. the center of sums method (a) First membership, (b) second membership and (c) defuzzification step.



6. Centre of largest area



7. First of or last of maxima

Figure 2 .11: Defuzzifying the fuzzy output functions methods (Math works 2010).

### **5. Centre of sums**

It involves the algebraic sum of individual output fuzzy sets, it is noted that the intersecting areas are added twice. This method is similar to the weighted average method, but in center of sums, the weights are the areas of the respective membership functions whereas in the weighted average method, the weights are individual membership values.

### **6. Centre of largest area**

If the fuzzy set has two convex subregions, then the entire of gravity of the convex subregion with the largest area can be used to calculate the defuzzification value.

### **7. First of maxima or last of maxim**

## **2.9 Construction Cost Estimating Previous Researches**

Several researches have studied the cost estimating in general, the accuracy of cost estimate, factors affecting cost estimating and the computer applications in cost estimating.

Globally there many researches such as Zheng and Guang (2012); Bhatnagar and Ghose (2012); Bo and Albert (2011); Memon et al., (2010); Ray et al., (2010); Cheng et al., (2010) and Adeli and Jiang, (2003).

Zheng and Guang (2012) said the main factors influencing the construction engineering cost at China are:

- (1) Geological conditions of the engineering and hydrological geological conditions.
- (2) Structural features of the building.
- (3) Construction techniques and mechanical equipment.
- (4) Influence of the construction unit.

In their study they found that the computational speed and accuracy have been more significantly improved by using the global random search capability of genetic algorithm and the learning ability and robustness of neural network than the traditional methods.

While Bo and Albert (2011) study the key parameters that measure the degree of project complexity at China, they identified that the Six key measures of project complexity include, (1) building structure & function; (2) construction method; (3) the urgency of the project schedule; (4) project size/scale; (5) geological condition; and (6) neighboring environment.

While Memon et al. (2010) study the factors affecting construction cost at MARA which is one of the government agencies of Malaysia. They present the results of a questionnaire survey conducted among the personnel of Project Management Consultant. They concluded that cash flow and financial difficulties faced by contractors, contractor's poor site management and supervision, inadequate contractor experience, shortage of site workers, incorrect planning and scheduling by contractors are most severe factors while changes in scope of project and frequent design changes are least affecting factors on construction cost.

Ray et al. (2010) reported that the results show that the quality of predictions made by the intelligent system is comparable to the quality assured by the experienced expert. The proposed expert system is superior to traditional cost accounting system and assists inexperienced users in predicting the optimum process cost within the shortest possible time.

While Bhatnagar and Ghose (2012) reported that fuzzy logic is the best model for predicting early stage effort estimation, they have been found that Mamdani FIS was able to predict the early stage efforts more efficiently in comparison to the neural network models based models.

On the other hand Cheng et al. (2010) find a conceptual cost estimate model by the Evolutionary Fuzzy Neural Inference, they presents Evolutionary Web-based Conceptual Cost Estimators which can be deployed to estimate conceptual construction cost more precisely during the early stages of projects.

Adeli and Jiang (2003) developed neuro-fuzzy logic model for estimation of the freeway work zone capacity, the new model in general provides a more accurate estimate of the work zone capacity.

Locally many searches were done for the accuracy of cost estimate, factors affecting cost estimating and the computer applications in cost estimating, like Shehatto (2013), Arafa and Alqedra (2011); Abdal-Hadi (2010); Aljarosha (2008); Al-Najjar (2008); Abu Shaban (2008); Al-Shanti (2003); Madi (2003); El-Sawalhi (2002).

Shehatto (2013) study the significant parameters that effect the cost estimation of construction projects in Gaza at the early stage. Shehatto reported that the factors affecting the cost of construction projects are divided into two main groups' structural skeleton and finishes.

The structural skeleton groups were including 13 factors, he founded the degree of importance for each factors and the most significant factors at this group were:

- 1- Area of the typical floor.
- 2- Number of stories.
- 3- Area of the retaining wall.
- 4- Type of the building (residential, schools, hospital, mosque, university).
- 5- Type of footing (isolated, combined, raft, piles).
- 6- Number of elevators.
- 7- Type of the slab (hollow, solid, drop beam).

The finishes groups were include 18 factors, he founded the degree of importance for each factors and the most significant factors at this group were:

- 1- External finishing (plaster, Tyrolean, oixus. composites).
- 2- Type of Tiles (terrazzo, ceramic, porcelain, marble).
- 3- Area of glassed elevations.
- 4- HVAC volume.
- 5- Type of electrical works.
- 6- Type of mechanical works.
- 7- False ceiling area.

Arafa and Alqedra (2011) developed a model for early cost estimation of construction projects at Gaza. The model were built using artificial neural network depends on seven significant factors for the structural skeleton namely ground floor area, typical floor area, number of stories, number of columns, type of footing, number of elevators and number of rooms.

Arafa and Alqedra reported that the results obtained from the trained models indicated that neural networks rationally succeeded in predicting the early stage cost estimation of building using basic information of the projects and without need for more detailed design.

Abdal-Hadi (2010) reported that the factors affecting accuracy of pre-tender cost estimate at Gaza Strip. An exploration of 85 factors affecting the accuracy of pre-tender cost estimate was conducted in order to find the degree of importance for each factor. The 85 factors where divide into five main groups which are:

1. Factors related to clients characteristics,
2. Factors related to consultants, design parameters and information,
3. Factors related to project characteristics,
4. Factors related to contract requirement and procurement method.
5. External factors and market conditions.

Abdal-Hadi said that the factors that are related to consultants, design parameters and information were ranked in the first position among other groups. The factors that are related to external factors and market conditions were ranked in the second position. The factors that are related to contract requirement and procurement method were ranked in the third position. The factors that are related to clients characteristics were ranked in the fourth position, while the factors that are related to project characteristics were ranked in the last position. Which emphasized that, the consultants, design parameters and information are crucial in accurate estimation of construction costs at the pre-tender stage.

Aljarosha (2008) explored the impact of conditions of contract for construction on the cost estimating. He investigated the using of computer applications to deal with liabilities and risks associated with the construction projects. He found the majority of contractors do not use formalized techniques for estimating contingencies when preparing tenders. They do not use computerized tools to evaluate and manage responsibilities and risks and, in general, there is no commitment to employ an experienced person or team for evaluating and managing responsibilities and risks.

Abu Shaban (2008) identified 17 cost factors that affecting the performance of construction projects. He recommended the construction companies to have a structured methodology and technique should be identified to overcome the effect of local political and economic situations on the performance of construction projects in the Gaza Strip.

Al-Najjar (2008) study the factors influencing time and cost overruns on construction projects in the Gaza Strip, he said that it is well known that most construction projects in Gaza Strip exposed to time and cost overrun or both. So the cost estimator must be more accuracy and take the factors affecting the cost estimation at his consideration.

Al-Shanti (2003) explored the project cost estimation in Gaza strip. He investigated the using of computer applications in cost estimating. He concluded that most of contracting companies are still estimating the projects manually. Shortage of user

friendly estimating software packages and lack of available qualified personnel in using computer-based estimating systems are considered the main obstacles in using computer in construction estimating.

Madi (2003) investigated the essential factors affecting the accuracy of cost estimating in Gaza Strip to show the degree of importance of 51 factors in cost estimation practice. Madi classified the 51 factor into 8 groups:

1. Group 1 related to project complexity.
2. Group 2 related to project information and resources.
3. Group 3 related to technological requirements.
4. Group 4 related to contract requirements.
5. Group 5 related to efficiency and resources of company.
6. Group 6 related to market requirements.
7. Group 7 related to project and its duration.
8. Group 8 related to project risks.

Madi found that the most important group in cost estimating practice is group 8 related to project risks. This group is ranked first. Group 2 related to project information and resources is ranked second and group 6 related to market requirements is ranked third. He found that the main factors are: location of the project, segmentation of the Gaza Strip and limitation of movements between areas, political situation and closure of the Gaza Strip, financial status of the owner and increase in unit costs of construction materials (Enshassi et al., 2007).

Also Madi investigated the using of computer in tender estimation. He concluded that the main reasons for not using computer in estimating is lack of suitable software for estimating, shortage of qualified employees, the wrong belief that using computer gives inaccurate results, and difficulty in operating computer software.

Al-Shanti (2003) quoted in El-Sawalhi (2002) explored the project management practice by public owners and contractors in Gaza Strip. He investigated the using of computer applications in supporting implementation of project management in cost estimating. He concluded that the main reason for low using of computer applications in cost estimating may be referred to the inefficient using in estimating computer applications. He also referred this partly for the lack of efficient training for using such programs.

## **CHAPTER 3**

### **METHODOLOGY**

#### **3.1 Introduction**

In this chapter, the research methodology utilized in the current study is described and it provides the information about the research strategy, research design population, various approaches to data collection and data analysis.

#### **3.2 Research Strategy**

Research strategy can be defined as the way in which the research objectives can be questioned, there are two types of research strategies, namely, quantitative research and qualitative research (Naoum, 2007). Data may take the form of narrative information (qualitative data) or numerical values (quantitative data). Quantitative researchers collect facts and study the relationship of one set of facts to another. They use techniques that are likely to produce quantified and, if possible, generalizable conclusions. Researchers adopting a qualitative perspective are more concerned to understand individuals' perceptions of the world. They seek insights rather than statistical perceptions of the world. They doubt whether social 'facts' exist a question whether a 'scientific' approach can be used when dealing with human beings (Bell, 2005). In this study both Quantitative and Qualitative approaches are used.

The structured interviews for this study is designed to get the factual information about the factors affecting the construction cost estimating as well as the opinions of stakeholders about this factors.

#### **3.3 Research Design**

The purpose of this research is to explore the significant factors affecting the cost estimating of construction projects at Gaza Strip and develop a computerized cost estimating system using fuzzy logic to be used in early cost estimation.

This research consists of eight phases, the first one is the proposal for identifying and defining the problems and establishment of the objectives of the study and development of research plan. The second phase of the research includes literature review. Literatures of construction cost estimation and fuzzy logic were reviewed.



The third phase of the research included a field survey which included of owners, contractors and consultants through personal interview which be used in this research because it's a technique for collecting factual information as well as opinions (Naoum, 2007). It was decided that the most appropriate approach was to carry out a structured interview which mean questions are presented in the same order and with the same wording to all interviewees.

The fourth phase of the research includes data collection of real construction projects. 169 construction projects were collected, these projects were residential, schools, mosque and organization buildings.

The fifth phase of the research includes fuzzy logic model built by using Matlab.

The sixth phase of the research focused on model validity by comparing the model results of 30 projects by real cost of these projects. The seventh phase of the research focused data analysis and discussion the results of the accuracy of cost estimation. The last phase of the research includes the conclusions and recommendations. Figure 3.1 shows the research flow chart.

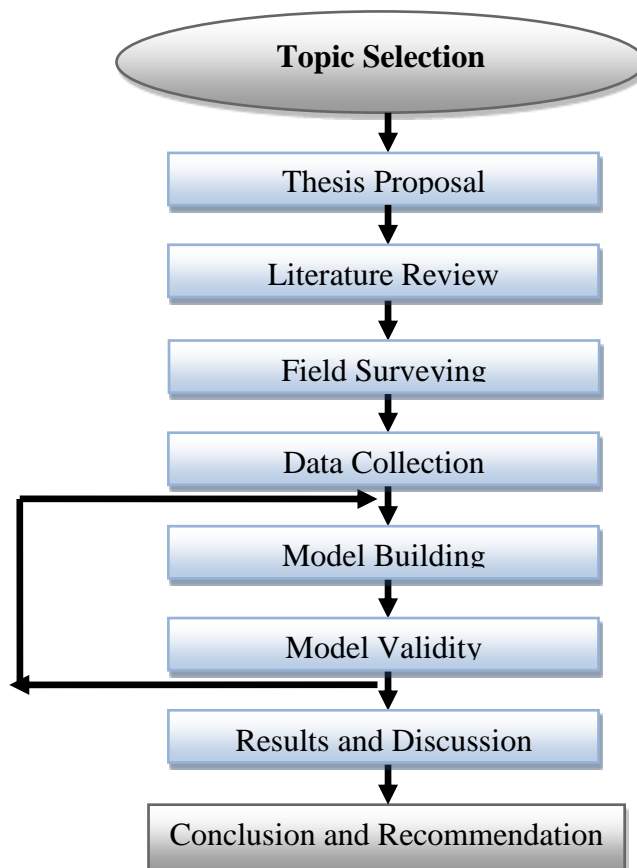


Figure 3.1: Research methodology flowchart

### **3.4 Research Population and Sample Size**

The studied population consists of experts, engineers, and managers from different organizations with experience and with direct contacts in their jobs to the cost estimation process, preparing estimates, and to supervisions and management of construction projects in Gaza strip. The targeted sample was divided into three categories:

- 1- Clients: this category includes ministries, municipalities, governmental bodies, donors and NGOs. The total numbers of interviews with this category were five.
- 2- Consultants: this category can be hired by some clients because of their experiences. The total numbers of interviews with this category were four.
- 3- Contractors: the first, second and third category who have valid registration by the Contractors Union were include in this category. The total numbers of interviews with this category were twelve.

### **3.5 Research Location**

The research was carried out in Gaza Strip, which consists of five governorates, the North, Gaza, the middle, Khan Younus and Rafah. These five governorates are considered the southern governorates of Palestinian National Authority (PNA).

### **3.6 Limitation of the Research**

This thesis is restricted by the following items:

1. Due to time constraint, this research is concerned with construction building projects only (housing, schools, etc.), and will not take into account the other categories of engineering projects like civil projects (tunnels, highways, bridges), or utilities projects (sewage and water supply), and industrial projects (factories and workshops).
2. As a result of model training the type of construction buildings that were included in the final model were residential, schools, mosques and organization buildings. The hospitals and universities were excluded because there is a big gap in the cost of these types.
3. Only registered contractors in the Palestinian Contractors Union and the consultants who are registered in the Engineering Association will be involved in this study.

4. Contractors of first, second and third class represent the population in this research, while contractors of fourth and fifth category will be excluded.

### 3.7 Defining the Factors Affecting Cost Estimating Project in Gaza Strip

A thorough literature review was conducted to identify the factors that affecting cost estimating by researchers and practitioners in this field. Combining this literature review as discussed in chapter 2 with researcher experience, the factors affecting cost estimating were identified. They are categorized into two groups (main factors). Each group is divided into sub-factors as shown in Table 3.1.

**Table 3.1: Factors affecting cost estimating of the construction building project**

No.	Main Factor	Sub-factors
1	Structural skeleton works	Type of the building
		Type of soil
		Type of the foundation in the building
		Area of ground floor
		Area of typical floor
		Type of the slab
		Number of stores in the building
		Number of columns
		Number of rooms in the building
		Number of elevators
		location of the project
2	Finishing works	Type of external finishing
		Type of tiles
		Type of painting
		Volume of HVAC works
		Type of electrical works
		Type of mechanical works
		False ceiling and gypsum board area
		Type of aluminum works
		Type of metal works
		Type of carpentry works

### 3.8 Structured Interviews

It was decided that the most appropriate approach was to carry out structure interviews with a number of experts, engineers, and managers in order to get a better understanding of most important factors affecting the cost estimating of construction projects.

Since the Arabic language is much effective and easier to be understood to get more realistic results the structure interviews was conducted in Arabic language.

The structured interviews schedule also sought information regarding the following areas:

1. Characteristics of responding organizations in term of position of respondent, years of experience for the organization and total number of employees.
2. Factors affecting cost estimating.
3. Suggestions regarding any other factors and improvements required in estimating.

The following structured interviews were conducted and lasted for 30 to 40 minutes for each one.

#### 3.8.1 The Relative Importance Index

The relative index technique has been widely used in construction research for measuring attitudes with respect to surveyed variables. Several researches such as Abdal-Hadi (2010); Al-Najjar (2008); Madi (2003) and Akintoye (2000) used the relative importance index in their analysis of factors affecting the accuracy of cost estimate. At this study used this technique to determined factors affecting cost estimating. Likert scaling was used for ranking questions that have an agreement levels. The respondents were required to rate the importance of each factor on a 5-point Likert scale using 1 for not important, 2 for of little importance, 3 for somewhat important, 4 for important and 5 for very important. Then, the relative importance index was computed using the following equation:

$$\text{Relative Importance Index} = \frac{\sum W}{AN} = \frac{5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1}{5N}$$

Where W is the weighting given to each factor by the respondent, ranging from 1 to 5, (n1 = number of respondents for not important, n2 = number of respondents for little importance, n3 = number of respondents for somewhat important, n4 = number of respondents for important, n5 = number of respondents for very important). "A" is the highest weight (i.e 5 in the study) and N is the total number of samples. The relative importance index ranges from 0 to 1 (Tam and Le, 2006).

### **3.9 Reliability and Validity of Research**

Reliability is the extent to which a test or procedure produces similar results under constant conditions on all occasions (Bell, 2005). Reliability can be equated with the stability, consistency, or dependability of a measuring tool. There are a number of devices for checking reliability in scales and tests, such as ‘test–retest’ (administering the same test some time after the first), the ‘alternate forms method’ (where equivalent versions of the same items are given and results correlated) or the ‘split-half method’ (where the items in the test are split into two matched halves and scores then correlated) (Bell, 2005).

Validity refers to the degree to which an instrument measures what it is supposed to be measured. When an instrument is valid, it truly reflects the concept it is supposed to measure (Bell, 2005).

Checking validity can be done by telling other people (colleagues, pilot respondents) what you are trying to find out or to measure and ask them whether the questions or items you have devised are likely to do the job.

The validity content of the structured interviews was tested by three experts. Each of them has full information about the research objectives. Each of them was requested to evaluate validity content for each item.

The three experts do agree that the structured interview was valid and suitable enough to measure the concept of interest with some amendments.

### **3.10 Development of the Research Model**

The results of this study show that the existing common practice in estimating is simple where most of contractors were still estimating the construction cost manually or by using a personal excel sheets. The computer applications were rarely used for bid analysis in construction companies. This superior the goal of this study to develop a computerized estimating system.

Based on the main factors and sub-factors affecting cost estimating generated from combining the results of gathering structured interviews and literature review, a research model was developed to facilitate the research study.

The selected factors for the model were ten factors they are: area of typical floor, number of stories, type of the building, type of the foundation, type of the slab, number

of elevators, type of external finishing, volume of HVAC works, type of tilling and type of electro-mechanic works.

The developed model in this research based on MATLAB version 7.12.0. ( R2011a) program. It was selected for its easy to install and operate. The selected shape of the memberships functions is the triangular membership function.

Adding rules is last step to completely defined the fuzzy inference system.

### **3.10.1 First Trial Model Development**

The first trial model was built according to the **169** real project were collected from ministries, consultants, municipalities, NGO's and international institutions. This first trial run for model composed of ten factors and 665 rules.

A validation technique is applied on FL model by run the model by two of my colleagues for twenty projects chosen randomly from the 169 collected projects.

A continuity testing and degeneracy testing done to check the model reliability, the FL model degeneracy test was done by running the model many times with all inputs entries the result where responsible and satisfactory. While the FL model was exposed to continuity test, the area of typical floor factor entries were introduced with slight increase or decrease, the results obtained were reasonable and have the same value.

After checking the model logic and the rules, it's found that the rules build were insufficient to meet the required accuracy. This is because the required rules for the model are where **1244160** rules, where the rules at the built model where **665** rules.

### **3.10.2 The Second Modified Model Development**

Develop a computerized cost estimating system using fuzzy logic is the research main goal, to meet this goal a second modified model built. This model composed of three factors and 288 rules. The selected factors were the area of typical floor, numbers of stories and the building type. From the collected real project the average cost were calculated for every type of buildings, the area were divided every 200 m<sup>2</sup> and started from 100 m<sup>2</sup>, accordingly the construction cost was calculated for every type of building to find the output membership function and the 228 rules were written.

A validation and reliability tests were done for this model the result where responsible and satisfactory.

## **CHAPTER 4**

### **DATA COLLECTION**

#### **4.1 Introduction**

This chapter discusses the results that have been deduced from a field survey of twenty one structured interviews. The interviews were conducted with five clients, four consultants and twelve contractors. Section one presents the clients, consultants and contractors profiles. Section two was designed to attain the first and second objectives in this research. These objectives intend to study the perspectives of interviewed persons of the methods of estimating and key parameters and main factors affecting the building cost estimating in Gaza Strip. The third section was designed to attain the third objective in this research. This objective intends to develop a computerized system in cost estimating by using fuzzy logic. This model was built according to a real projects collected from local construction market.

#### **4.2 Study Population Characteristics**

This section mainly designed to provide general information about the respondents in terms of the major type of work involved, position and experience of respondent.

##### **4.2.1 Type of Works**

Figure 4.1 shows that, 19% (4) consultants, 57% (12) contractors and 24% (5) clients, such as ministries, municipalities, NGO's and International Institutions were participated in the structured interviews.

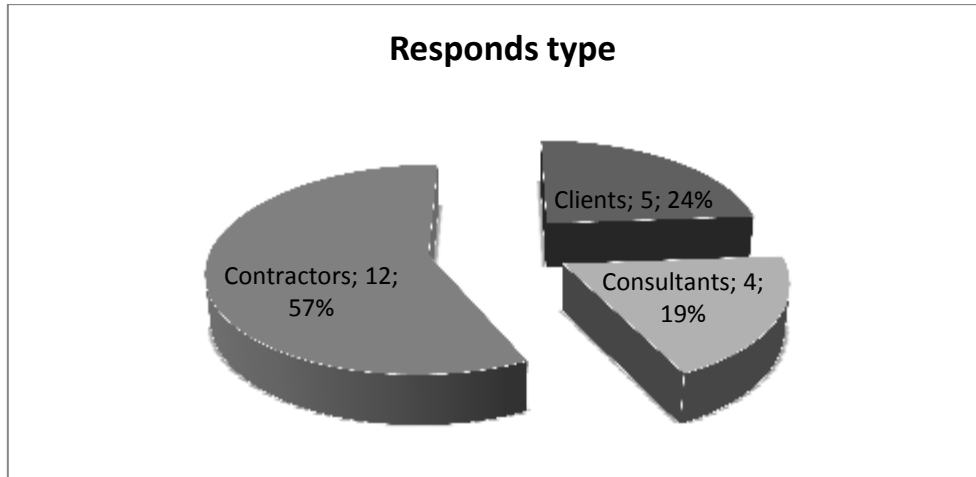


Figure 4.1: The type and the percent of the targeted groups

#### 4.2.2 Position of Respondent

Table 4.1 shows that, 40% (2) of the clients' respondents, 50% (2) of the consultants respondents and 33.3 % (4) of contractors respondents were project managers. 20% (1) of the clients' respondents, 25% (1) of the consultants' respondents and 41.7 % (5) of contractors' respondents were office or site engineers. 20% (1) of the clients' respondents, 25% (1) of the consultants' respondents and 16.7 % (2) of contractors' respondents were estimators. 20% (1) of clients respondents and 8.3% (1) of the contractors' respondents were others such as firm owner and general manager. It can be seen that more than 90% of the respondents have key positions that insure quality information.

Table 4.1: Position of respondent in organization

<i>Position of respondent</i>	<i>Clients</i>		<i>Consultants</i>		<i>Contractors</i>		<i>Total</i>	
	Freq.	Percent. (%)	Freq.	Percent. (%)	Freq.	Percent. (%)	Freq.	Percent. (%)
Project managers	2	40	2	50.0	4	33.3	8	<b>38.1</b>
Office or site engineers	1	20	1	25.0	5	41.7	7	<b>33.3</b>
Estimators	1	20	1	25.0	2	16.7	4	<b>19.0</b>
Others	1	20	0	0.0	1	8.3	2	<b>9.5</b>
<b>Total</b>	<b>5</b>	<b>100</b>	<b>4</b>	<b>100</b>	<b>12</b>	<b>100</b>	<b>21</b>	<b>100</b>



### 4.2.3 Respondents Years of Experience

Table 4.2 shows that, 20% (2) of the clients' respondents, 16.7% (2) of contractors respondents (14.3% from the total sample) have years of experience less than 3 years. 25% (1) of the consultants' respondents and 25 % (3) of contractors respondents (19% from the total sample) have years of experience between 4-6 years. 40% (2) of the clients' respondents, 50% (2) of the consultants' respondents and 16.7 % (2) of contractors respondents (23.8% from the total sample) have years of experience between 7-10 years. And 40% (2) of clients respondents, 50 % (2) of the consultants respondents and 41.7 % (5) of contractors respondents (42.9% from the total sample) have years of experience more than 10 years.

**Table 4.2: Respondents years of experience**

<i>Experience</i>	<i>Clients</i>		<i>Consultants</i>		<i>Contractors</i>		<i>Total</i>	
	Freq.	Percent. (%)	Freq.	Percent. (%)	Freq.	Percent. (%)	Freq.	Percent. (%)
Less than 3 years	1	20	0	0.0	2	16.7	3	<b>14.3</b>
4-6 years	0	0	1	25.0	3	25.0	4	<b>19.0</b>
7-10 years	2	40	1	25.0	2	16.7	5	<b>23.8</b>
More than 10 years	2	40	2	50.0	5	41.7	9	<b>42.9</b>
<b>Total</b>	<b>5</b>	<b>100</b>	<b>4</b>	<b>100.0</b>	<b>12</b>	<b>100</b>	<b>21</b>	<b>100</b>

These results illustrate that, approximately 43% of the respondents have experience more than 10 years, and more than 24% of the respondents have experience between 7-10 years. These results will also provide a level of satisfaction that the obtained data will reflect what it was designed for. Those respondents have good positions in their organizations to provide confident and specific data.

### 4.2.4 Respondents Method for Construction Cost Estimation

Table 4.3 shows that, 25% (1) of the consultants' respondents (5% from the total sample) have special package software for construction cost estimation, while 100% (5) of clients' respondents, 75% (3) of the consultants respondents and 100 % (12) of contractors respondents (95% from the total sample) didn't have special package software for construction cost estimation, they used manual techniques for quantities take off and used spreadsheets or excel sheets. They stated that shortage of suitable

estimating software and lack of qualified persons in using computerized estimating packages is considered the main obstacle for computerized estimating.

**Table 4.3: Estimating method**

<i>Estimating method</i>	<i>Clients</i>		<i>Consultants</i>		<i>Contractors</i>		<i>Total</i>	
	Freq	Percent (%)	Freq	Percent (%)	Freq	Percent (%)	Freq	Percent (%)
Manually	5	100	3	75	12	100	20	<b>95</b>
Special package software	0	0	1	25	0	0	1	<b>5</b>
<b>Total</b>	<b>5</b>	<b>100</b>	<b>4</b>	<b>100</b>	<b>12</b>	<b>100</b>	<b>21</b>	<b>100</b>

#### 4.2.5 Respondents Opinion for Construction Cost Estimation

Table 4.4 shows that, all the respondents agree that the construction cost didn't meet with the construction cost estimation. This result has many reasons like lack of time and information for construction cost estimation. Some clients said that they sometime are required to rescind some items of construction works because the total cost is exceed the construction estimation cost.

**Table 4.4: Opinion for Construction Cost Estimation**

<i>Is construction cost meet the estimation cost</i>	<i>Clients</i>		<i>Consultants</i>		<i>Contractors</i>		<i>Total</i>	
	Freq	Percent (%)	Freq	Percent (%)	Freq	Percent (%)	Freq	Percent (%)
Yes	0	0	0	0	0	0	0	<b>0</b>
No	5	100	4	100	12	100	21	<b>100</b>
<b>Total</b>	<b>5</b>	<b>100</b>	<b>4</b>	<b>100</b>	<b>12</b>	<b>100</b>	<b>21</b>	<b>100</b>

#### 4.3 Main Factors Affecting the Building Cost Estimating

The main objectives of this section are to study the perspective of clients, consultants and contractors of the essential factors affecting the building cost estimation in Gaza Strip and to study the relationship between the importance of these factors. This section contains two groups, structural (skeleton) group and finishes group.

### 4.3.1 Factors Related to Structural Group

This group contained eleven sub factors as shown in Table 4.5. During the discussion at the structured interviews some of the responds suggested that "the factor type of the foundation depends on the factor type of soil", so there is a need only of one factor and they suggested " type of the foundation" to be endorsed.

Other of the responds suggested that the factor "area of ground floor" and "the area of typical floor" in most of construction projects are the same. Therefore these two factors were dependent for that one of them should be used.

Most of the respondents agreed on the choice of the most effecting factors on building cost estimation, the final order of these effecting factors starting with the most importance factor was:

**Table 4.5: Group one sub factors & its ranks**

skeleton works sub factors	Importance degree					RII	Rank
	NI	LI	SI	I	VI		
Type of the building	0	0	1	2	18	0.96	<b>4</b>
Type of soil	0	4	6	9	2	0.69	<b>6</b>
Type of the foundation in the building	0	4	5	9	3	0.70	<b>5</b>
Area of ground floor	0	0	0	0	21	1.00	<b>1</b>
Area of typical floor		0	0	1	20	0.99	<b>2</b>
Type of the slab	1	2	10	7	1	0.65	<b>7</b>
Number of stories in the building	0	0	0	1	20	0.99	<b>3</b>
Number of columns	4	7	6	2	0	0.42	<b>9</b>
Number of rooms in the building	6	10	5	0	0	0.39	<b>10</b>
Number of elevators	3	1	7	9	1	0.64	<b>8</b>
Location of the project	8	9	3	1	0	0.37	<b>11</b>

( NI= Not Important; LI= little importance; SI= somewhat important; I= important; VI= Very important)

- Area of typical floor.
- Number of stories in the building.

- Type of the building.
- Type of the foundation.
- Type of the slab.
- Number of elevators.
- Number of columns.
- Number of rooms in the building.
- Location of the project.

This result is in line with Shehatto (2013) and Arafa and Alqedra (2011), whom had developed models for early cost estimation of construction projects at Gaza Strip.

According to previous interviews discussions, the first three factors are the most effecting factors in the construction cost estimation, the last three factors aren't have big weight on the cost of the construction building, thus these three factors were excluded from the model and the first six factors were included in the model building.

#### 4.3.2 Factors Related to Finishing Works Group

According to the structured interviews this group contained ten sub factors as shown in Table 4.6.

Table 4.6: Group two sub factors & its ranks

Finishes works sub factors	Importance degree					RII	Rank
	NI	LI	SI	I	VI		
Type of external finishing	0	0	2	3	16	0.93	1
Type of tiles	1	1	4	7	8	0.79	3
Type of painting	6	4	8	3	0	0.48	8
Volume of HVAC works	0	1	1	4	15	0.91	2
Type of electrical works	1	3	5	0	12	0.78	4
Type of mechanical works	1	3	5	1	11	0.77	5
False ceiling and gypsum board area	6	8	6	1	0	0.42	10
Type of aluminum works	6	7	6	2	0	0.44	9
Type of metal works	4	8	5	4	0	0.49	7
Type of carpentry works	3	8	7	3	0	0.50	6

According to interviews discussions, the last five factors aren't have big weight on the cost of the construction building, so the first five factors were only included in the model building. The interviewed persons see these factors can greatly less important than the factors in skeleton group.

#### 4.4 Real Building Projects at Gaza Strip

This section is very important section because the model building and validation needs a real data. The projects data were collected from ministries, consultants, municipalities, NGO's and international organizations.

The total of collected projects were 178 projects. These projects were divided as :

The first type is residential buildings which classified according to the municipalities classification. The second type is mosques buildings. This type is divided for two parts mosque and prayer. The difference between them is that mosque buildings are include minaret and dome or one of them which means more cost for construction.

The third type is school buildings. This type is divided for two parts school buildings and school extension. School buildings are include the external works like play ground, sheds, canteens and toilet blocks which mean more cost. The forth type is institutions buildings which can include public buildings and universities. The last type is hospitals as shown in Table 4.7. The final division for collected projects were as shown in Figure 4.3.

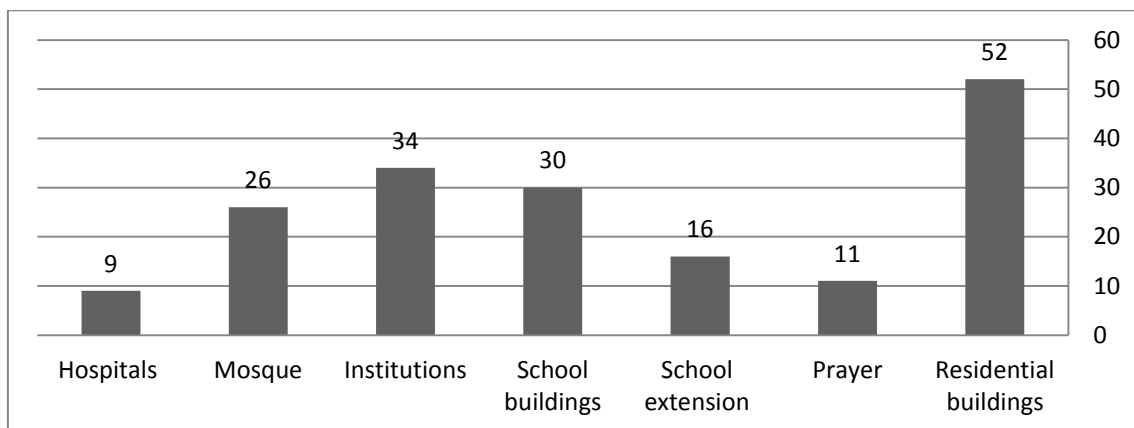


Figure 4.2: Types of collected projects

## CHAPTER 5

### MODEL DEVELOPMENT

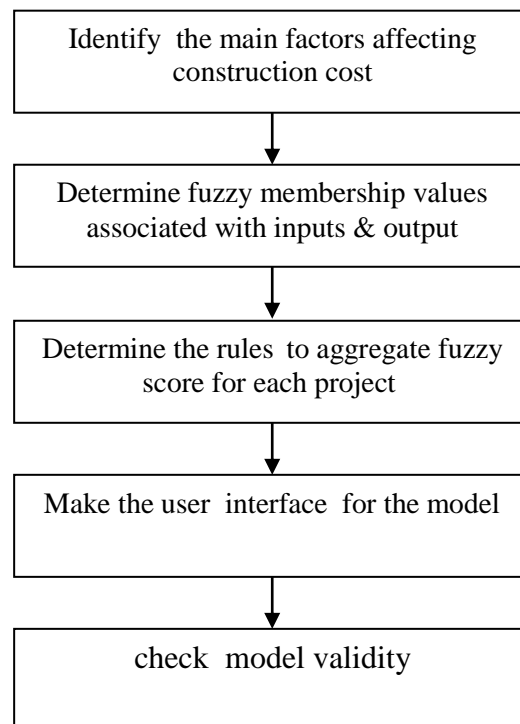
#### 5.1 Introduction

Now days computers played an important role in the construction industry, particularly in cost estimating. This chapter presents the computerized system which the researcher developed to help the Gaza Strip contractors to improve their practice in construction cost estimation.

The following sections present the steps performed to design the fuzzy logic model, the limitation of adopted model, and finally the discussion and analysis of results.

#### 5.2 Model Building

The developed model in this research based on MATLAB version7.12.0. ( R2011a) program. It was selected for its easy to install and operate, it's fully tested system and have a proven record, it's flexible and have capacity for handling many types of application and finally this system is economical in terms of installation, operation, and maintenance. The model flow chart is shown in Figure 5.1.



**Figure 5.1: Model flow chart for construction cost estimation**

### 5.2.1 Data Organization and Sets

The first step of model building is determined the inputs and the out puts of the model. The inputs of this model consist of ten inputs they are: area of typical floor, number of stories, type of the building, type of the foundation, type of the slab, number of elevators, type of external finishing, volume of HVAC works, type of tiling and type of electro-mechanic works.

The output of this model is the prediction cost of the construction project according to the inputs factors. The FIS Editor chosen for this model is mamdani as shown in Figure 5-2.

After determined of these factors their needs for Fuzzification which is the process where the crisp quantities are converted to fuzzy. Fuzzification process involve assigning membership values for the given crisp quantities.

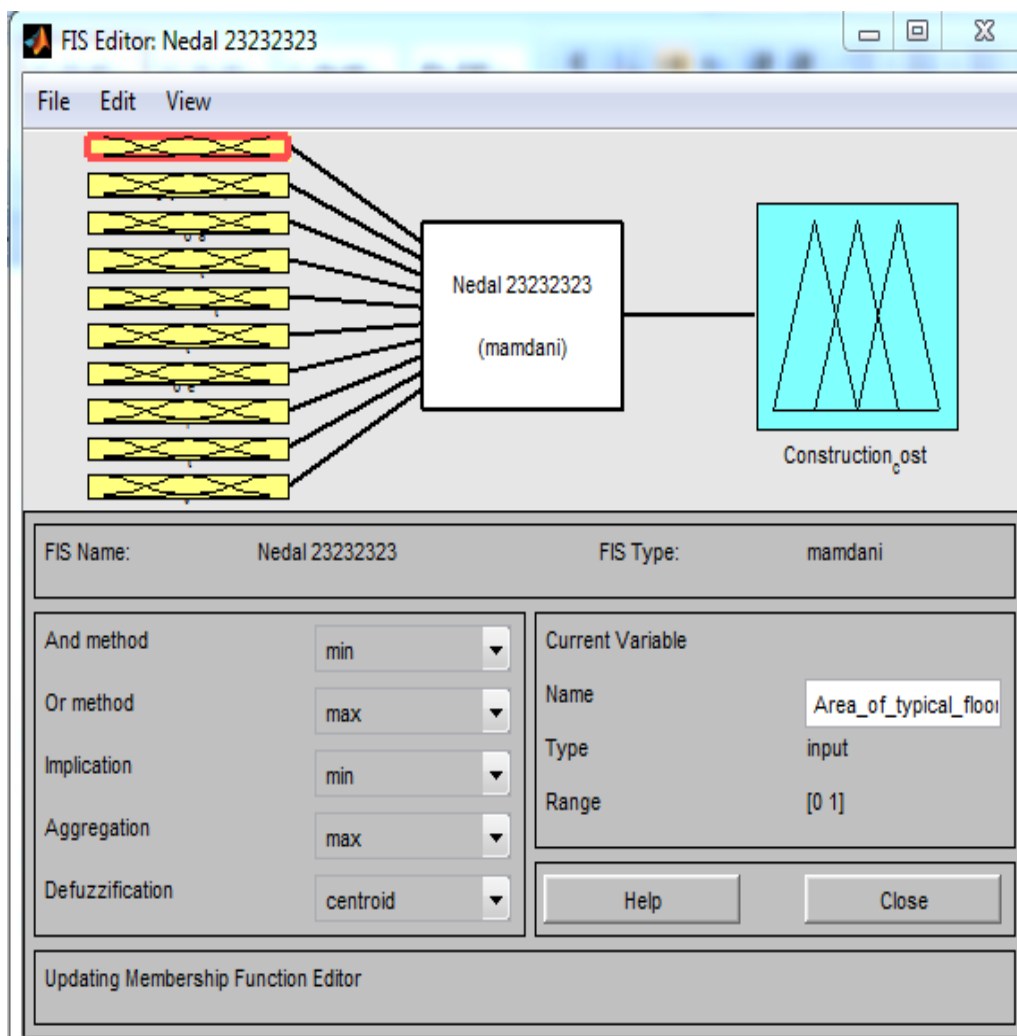


Figure 5.2: Model inputs and outputs

## Variable Normalization

According to the a viable data the variable factors are discrete values with deferent ranges, the fuzzy set needs normalization the variable data to (0-1) values.

The normalization can be made by the flowing equation:

$$Y = \frac{X - \min .value}{Max.value - Min.value}$$

Where: Y is the normalization value

X is the un normalization value

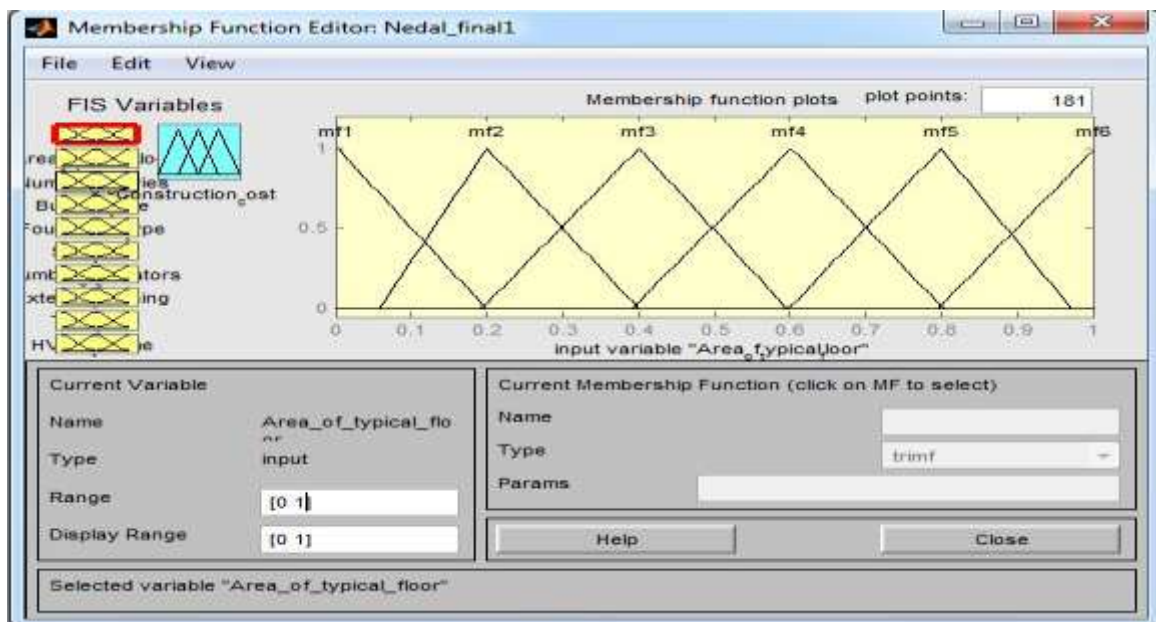
For example variable with six memberships and range from 1-6 as shown in Table 5.1.

**Table 5.1: Variables of six memberships normalization**

x	1	2	3	4	5	6
y	0	0.2	0.4	0.6	0.8	1

### 5.2.2 Adding Variables

After the defining of the inputs and out puts, the next step is to determine the range of all variables by the memberships functions. The selected shape of the memberships functions is the triangular membership function, and it has the function name trimf as shown in Figure 5.3. The range, the normalization and the type of model variables were as shown at the Table 5.2.



**Figure 5.3: Memberships function for input number 1.**



Table 5.2: Model variables

No.	Factors	Type	MF	Range	Normalization	Variable type
1	Area of typical floor	input	MF1	50 -199 m2	0	Numeric
			MF2	200-399 m2	0.2	
			MF3	400-599 m2	0.4	
			MF4	600-799 m2	0.6	
			MF5	800-999 m2	0.8	
			MF6	1000-1200 m2	1	
2	Number of stories	input	MF1	1	0	Integer
			MF2	2	0.143	
			MF3	3	0.285	
			MF4	4	0.428	
			MF5	5	0.571	
			MF6	6	0.714	
			MF7	7	0.857	
			MF8	8	1	
3	Type of the building	input	MF1	Residential	0	Linguistic
			MF2	Prayer	0.2	
			MF3	School extension	0.4	
			MF4	School	0.6	
			MF5	Institution	0.8	
			MF6	Mosque	1	
4	Type of the foundation	input	MF1	No foundation	0	Linguistic
			MF2	Isolated	0.25	
			MF3	Strap	0.5	
			MF4	Piles	0.75	
			MF5	Mat	1	
5	Type of slab	input	MF1	Solid	0	Linguistic
			MF2	Hollow	0.5	
			MF3	Drop beams	1	
6	Elevators number	input	MF1	0	0	Integer
			MF2	1	0.33	
			MF3	2	0.66	
			MF4	3	1	
7	External finishing	input	MF1	No ex. finishing	0	Linguistic
			MF2	Plastering	0.33	
			MF3	Oixus	0.66	
			MF4	Normal stone	1	
8	Tiles type	input	MF1	Ceramic	0	Linguistic
			MF2	Terrazzo tiles	0.5	

			MF3	Porcelain	1	
9	<b>HVAC volume</b>	input	MF1	No HAVC works	0	Linguistic
			MF2	Isolated units	0.5	
			MF3	Central unit	1	
10	<b>Electro-mechanic</b>	input	MF1	Normal	0	Linguistic
			MF2	Excellent	1	
11	<b>Cost estimation</b>	output	MF1	5000-25000	0	Numeric
			MF2	20000-40000	0.03	
			MF3	35000-70000	0.06	
			MF4	65000-100000	0.09	
			MF5	90000-140000	0.12	
			MF6	130000-180000	0.15	
			MF7	170000-220000	0.18	
			MF8	200000-260000	0.21	
			MF9	250000-320000	0.24	
			MF10	310000-380000	0.27	
			MF11	370000-450000	0.30	
			MF12	440000-520000	0.33	
			MF13	510000-600000	0.36	
			MF14	590000-700000	0.39	
			MF15	690000-800000	0.42	
			MF16	790000-900000	0.45	
			MF17	890000-1000000	0.48	
			MF18	990000-1100000	0.52	
			MF19	1000000-1200000	0.55	
			MF20	1190000-1300000	0.58	
			MF21	1290000-1400000	0.61	
			MF22	1390000-1500000	0.64	
			MF23	1490000-1600000	0.67	
			MF24	1590000-1700000	0.70	
			MF25	1690000-1800000	0.73	
			MF26	1790000-1900000	0.76	
			MF27	1890000-2000000	0.79	
			MF28	1990000-2300000	0.82	
			MF29	2290000-2600000	0.85	
			MF30	2590000-2900000	0.88	
			MF31	2890000-3200000	0.91	
			MF32	3190000-3750000	0.94	
			MF33	3700000-5000000	0.97	
			MF34	>50000000	1.00	

### 5.2.3 Rules Adding

After the variables have been named, and the membership functions have appropriate shapes and names, its ready to write down the rules. This step is the most important step at the model building. The fuzzy inference engine performs the mapping between the input membership functions and the output membership functions using fuzzy rules that can be obtained from expert knowledge of the relationships being modeled. The greater the input membership degree, the stronger the rule fires, thus the stronger the pull towards the output membership function. A defuzzifier carries out the defuzzification process to combine the output into a single label or numerical value as required. The required rules can be determined by  $(\text{input})^{\wedge} \text{membership}$ .

Here the required rules = **1244160** rules. This number of rules is very difficult to be done by the researcher and this number of rules need a special computer to run , so this model were depended on the previous collected projects as mentioned in chapter four. The chosen projects were fuzzification as shown at Table 5.3. The rules can be added using the rule editor as shown at Figure 5.4.

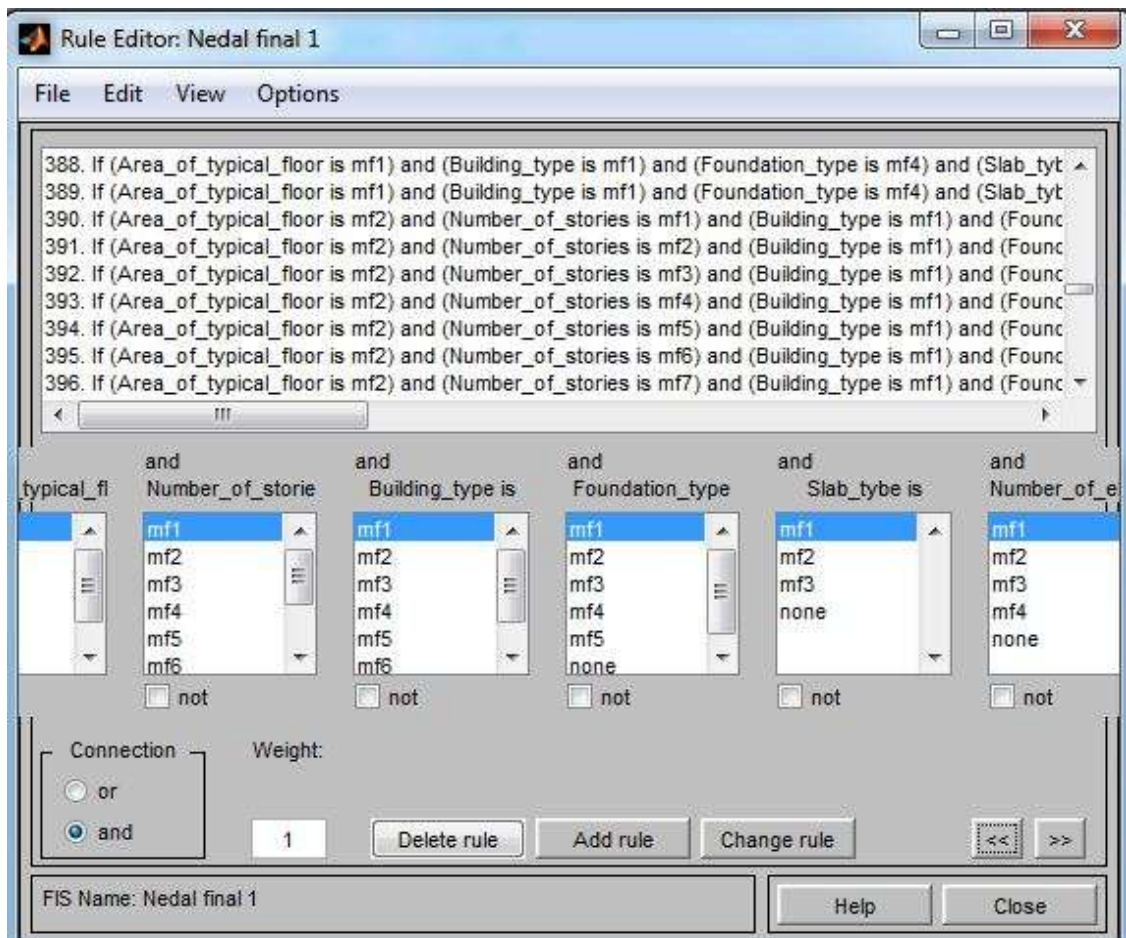


Figure 5.4: Rule Editor





Continue of Table 5.3: Model Rules

MF6	MF1	MF4	MF5	MF4	MF2	MF2	MF3	MF3	MF3	MF2
MF7	MF2	MF3	MF5	MF2	MF2	MF1	MF4	MF1	MF1	MF1
MF7	MF2	MF2	MF5	MF1	MF2	MF1	MF3	MF2	MF1	MF1
MF8	MF2	MF2	MF5	MF2	MF3	MF1	MF3	MF3	MF1	MF1
MF8	MF2	MF3	MF5	MF2	MF3	MF1	MF3	MF3	MF1	MF1
MF9	MF2	MF3	MF5	MF2	MF3	MF1	MF2	MF1	MF1	MF1
MF9	MF2	MF2	MF5	MF1	MF2	MF1	MF2	MF2	MF1	MF1
MF9	MF2	MF2	MF5	MF2	MF3	MF1	MF2	MF1	MF1	MF1
MF10	MF3	MF2	MF5	MF3	MF2	MF1	MF3	MF3	MF1	MF1
MF10	MF3	MF2	MF5	MF3	MF2	MF1	MF3	MF3	MF1	MF1
MF10	MF3	MF1	MF5	MF2	MF3	MF1	MF3	MF2	MF1	MF2
MF11	MF3	MF2	MF5	MF2	MF2	MF1	MF3	MF3	MF1	MF1
MF12	MF3	MF3	MF5	MF2	MF3	MF1	MF4	MF1	MF1	MF1
MF13	MF3	MF3	MF5	MF2	MF2	MF1	MF2	MF2	MF1	MF2
MF14	MF4	MF1	MF5	MF2	MF3	MF1	MF2	MF1	MF1	MF1
MF14	MF4	MF1	MF5	MF4	MF3	MF1	MF2	MF1	MF1	MF1
MF15	MF4	MF1	MF5	MF1	MF3	MF1	MF2	MF2	MF1	MF1
MF15	MF4	MF4	MF5	MF2	MF2	MF1	MF2	MF3	MF1	MF1
MF16	MF4	MF3	MF5	MF2	MF2	MF1	MF3	MF1	MF1	MF2
MF16	MF4	MF4	MF5	MF2	MF2	MF1	MF3	MF1	MF1	MF2
MF18	MF5	MF6	MF5	MF2	MF3	MF2	MF3	MF3	MF3	MF2
MF18	MF6	MF7	MF5	MF5	MF2	MF4	MF2	MF2	MF1	MF2
MF21	MF6	MF5	MF5	MF5	MF2	MF3	MF3	MF1	MF2	MF2
MF24	MF6	MF3	MF5	MF2	MF3	MF3	MF4	MF3	MF2	MF2
MF28	MF6	MF4	MF5	MF5	MF2	MF3	MF3	MF1	MF2	MF2
MF5	MF1	MF3	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF8	MF2	MF2	MF6	MF2	MF3	MF1	MF1	MF2	MF1	MF1
MF8	MF2	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF2
MF9	MF2	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF2
MF9	MF2	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF9	MF2	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF10	MF3	MF2	MF6	MF2	MF3	MF1	MF2	MF1	MF1	MF2
MF10	MF3	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF10	MF3	MF2	MF6	MF5	MF3	MF1	MF2	MF2	MF1	MF1
MF10	MF3	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF10	MF3	MF5	MF6	MF2	MF3	MF1	MF3	MF1	MF1	MF2
MF11	MF3	MF2	MF6	MF5	MF3	MF1	MF2	MF2	MF1	MF1
MF12	MF3	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF12	MF3	MF2	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF13	MF3	MF2	MF6	MF5	MF3	MF1	MF2	MF1	MF1	MF2
MF14	MF4	MF2	MF6	MF4	MF3	MF1	MF2	MF2	MF1	MF1
MF15	MF4	MF2	MF6	MF1	MF1	MF1	MF4	MF1	MF1	MF1
MF16	MF4	MF5	MF6	MF2	MF3	MF1	MF2	MF2	MF1	MF1
MF16	MF5	MF3	MF6	MF2	MF3	MF1	MF1	MF1	MF1	MF1
MF18	MF6	MF2	MF6	MF4	MF3	MF1	MF3	MF2	MF2	MF2
MF18	MF6	MF3	MF6	MF5	MF3	MF1	MF4	MF2	MF2	MF2
MF32	MF6	MF2	MF6	MF3	MF3	MF1	MF4	MF2	MF2	MF2

At this point, the fuzzy inference system has been completely defined, in that the variables, membership functions, and the rules necessary to calculate construction cost. The Fuzzy interface gives the user ability to see the result of the work and verify that everything is behaving the way he think by using the rule viewer and surface viewer which are read only tools, they help the user and give him ability to see if his work is correct or not.

The rule viewer displays a roadmap of the whole fuzzy inference process, the rule viewer allows you to interpret the entire fuzzy inference process at once. The rule viewer also shows how the shape of certain membership functions influences the overall result. Since it plots every part of every rule, it can become unwieldy for particularly large systems, but, for a relatively small number of inputs and outputs, it performs well, the rule viewer of our model is shown in Figure 5.5.

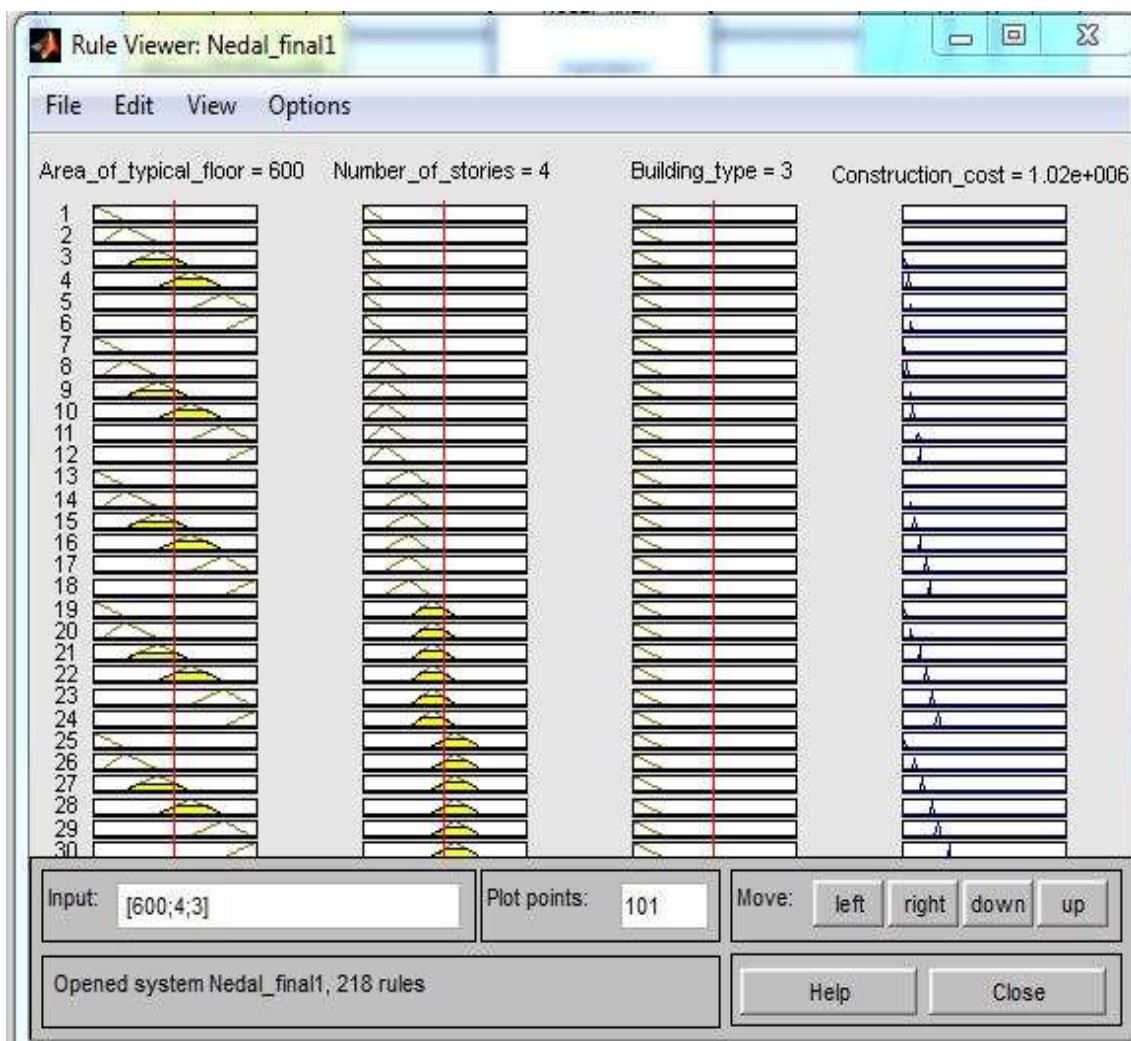


Figure 5.5: Rule viewer

The Surface Viewer has a special capability that is very helpful in cases with two (or more) inputs and one output, we can actually grab the axes and reposition them to get a different three-dimensional view on the data. The Ref. Input field is used in situations when there are more inputs required by the system than the surface is mapping. The surface viewer of our model is shown in Figure 5.6.

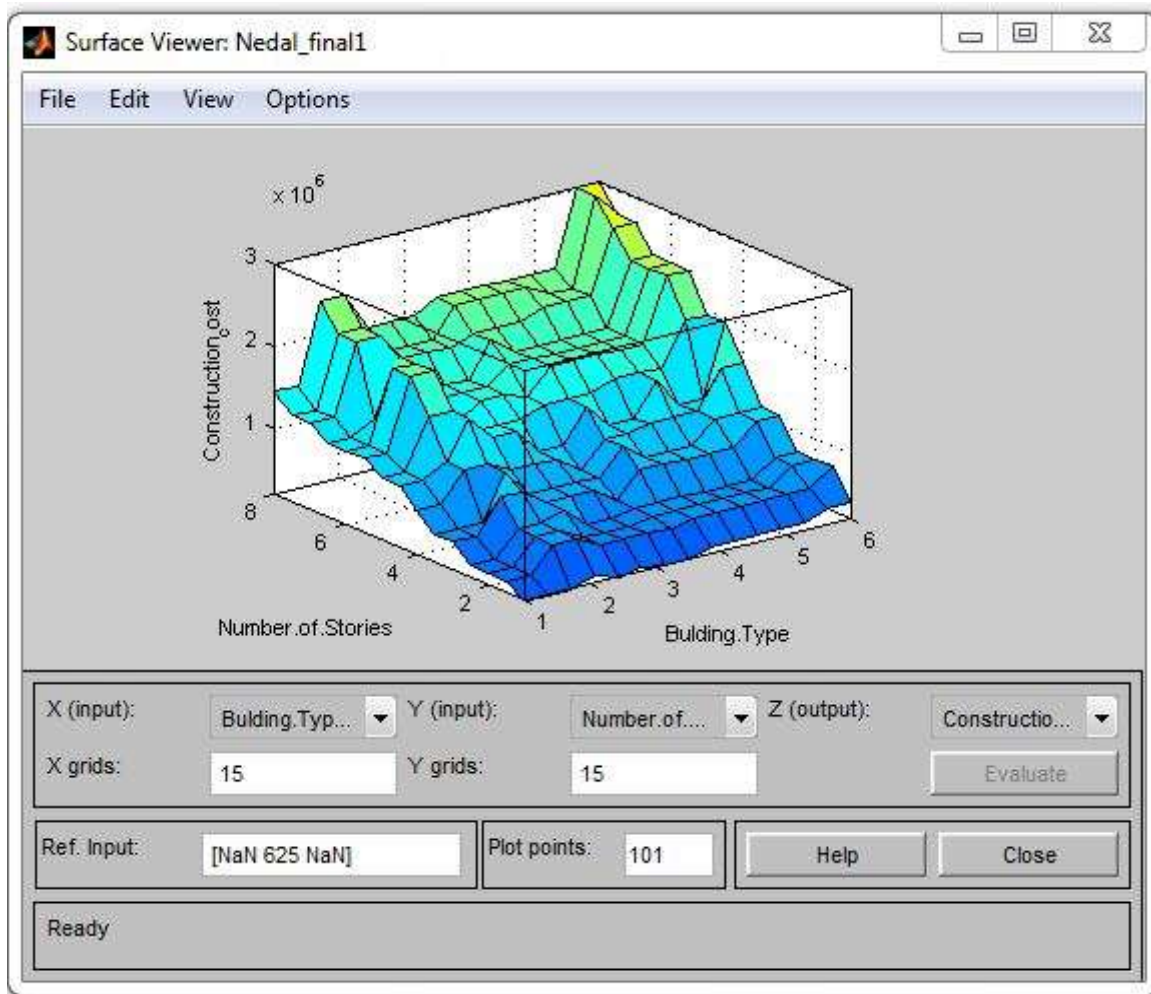


Figure 5.6: Surface viewer

### 5.2.4 Model User Interface

Model run is the core of this research. After getting the results from the rule viewer and surface viewer, the model can be run. The next step is to build the fig file and m-file. The fig file is user interface which contains the text edit buttons for the inputs and the push buttons (Cost Estimate) for the output (construction cost estimation) as shown in Figure 5.7. The m-file is built automatically after the built of the fig file, its need to



write the normalization equations for the inputs and defuzzification equation for the output ( see annex "5").

Figure 5.7: Model user interface

### 5.3 Model Reliability and Validity

Reliability is the extent to which a test or procedure produces similar results under constant conditions on all occasions (Bell, 2005). Validity refers to the degree to which an instrument measures what it is supposed to be measuring. When an instrument is valid, it truly reflects the concept it is supposed to measure (Bell, 2005).

#### 5.3.1 Validity Test

Structure validity concerns the degree to which the variables, as measured by the research, reflect the hypothesised construct (Fellows and Liu, 2008). After building the model and preparing all needed rules the model run and it give output for cost, many changed on input data done and the model give output, so the model is valid for cost estimating.

Validation is the task of demonstrating that the model is a reasonable representation of the actual system. A proven approach of model validation may be applied as appropriate to the different aspects of a particular model. This approach called expert intuition

(Eriksson, 2003). Here, however, the examination of the model should ideally be led by someone other than the modeler. This validation technique is applied on FL model by run the model by two of my colleagues for twenty projects chosen randomly from the 169 collected projects as shown in Table 5.4.

**Table 5.4: Validation set**

No.	Area	Floor no.	Build. type	Found. Type	Slab type	Elevat. no.	Extern. Finish	Tiles type	HVA C	Electro. Mecha.	Model Cost	Actual Cost
1	165	1	1	1	2	0	1	2	0	1	131882	114980
2	465	3	1	1	2	0	1	2	0	1	401847	433000
3	670	5	1	1	2	0	1	2	0	1	848335	813945
4	440	4	1	1	2	0	3	3	0	1	351275	340000
5	76	1	1	1	2	0	1	1	0	1	16047	21300
6	300	3	2	1	3	0	0	2	0	1	246366	228000
7	470	1	2	1	3	0	1	2	0	1	384190	438969
8	750	2	2	1	3	0	1	2	0	1	824177	847535
9	410	3	3	2	3	0	2	1	0	1	292918	320000
10	780	2	3	3	3	0	1	2	0	1	848335	860246
11	850	3	4	3	3	0	2	2	0	1	884344	901236
12	980	3	4	3	3	0	2	2	0	1	1013614	1051399
13	850	3	4	3	3	0	2	2	0	1	884344	977208
14	955	3	4	3	3	0	2	2	0	1	1013614	1032105
15	900	3	4	3	3	0	2	2	0	1	1013614	1012194
16	980	3	4	3	3	0	2	2	0	1	1013614	1066946
17	710	4	5	1	2	0	2	1	0	1	848335	835395
18	1200	5	5	4	2	2	2	1	1	1	2122216	2030400
19	430	6	2	1	3	0	1	2	0	1	384190	355238
20	1000	6	2	3	3	0	2	1	1	1	1013614	1152000

As shown in the Table 5.4 the results of model runs were the same at the two trial of my colleagues, the model's input and output relationships are reasonable and acceptable.

### 5.3.2 Reliability Test

Test of reliability of model according to the model run. The reliability of an instrument is the degree of consistency which measures the attribute; it is supposed to be measuring (Fellows and Liu, 2008).

Eriksson (2003), said that the simulation models reliability can be checked by continuity testing and degeneracy testing . Continuity testing consists of running the model several times for slightly different values of input parameters. For any one parameter, a

slight change in input should generally produce only a slight change in the output. Any sudden changes in the output are taken to be an indication of a possible error which should be investigated unless this is known behavior of the system. While degeneracy testing consists of checking that the model works for the extreme values of system and work input parameters.

The FL model degeneracy test was done by running the model many times with all inputs entries the result where responsible and satisfactory.

The FL model was exposed to continuity test, the area of typical floor factor entries were introduced with slight increase or decrease, the results obtained were reasonable and have the same value, an example is shown in Figures below 5-8 & 5-9, where the area is at case one in Figure 5.8 is 440m<sup>2</sup> and it was at the second case in Figure 5.9 is 580m<sup>2</sup>. The output at the two models is the same 351,275\$, where the input values have been slightly changed but they have the same membership MF3. The output responded to these changes in reasonable manner.

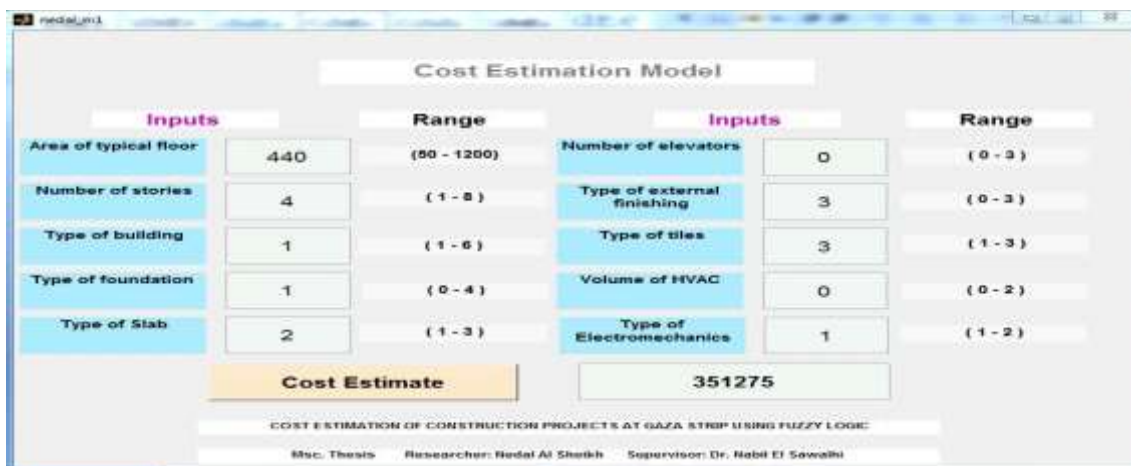


Figure 5.8: Model continuity testing case one

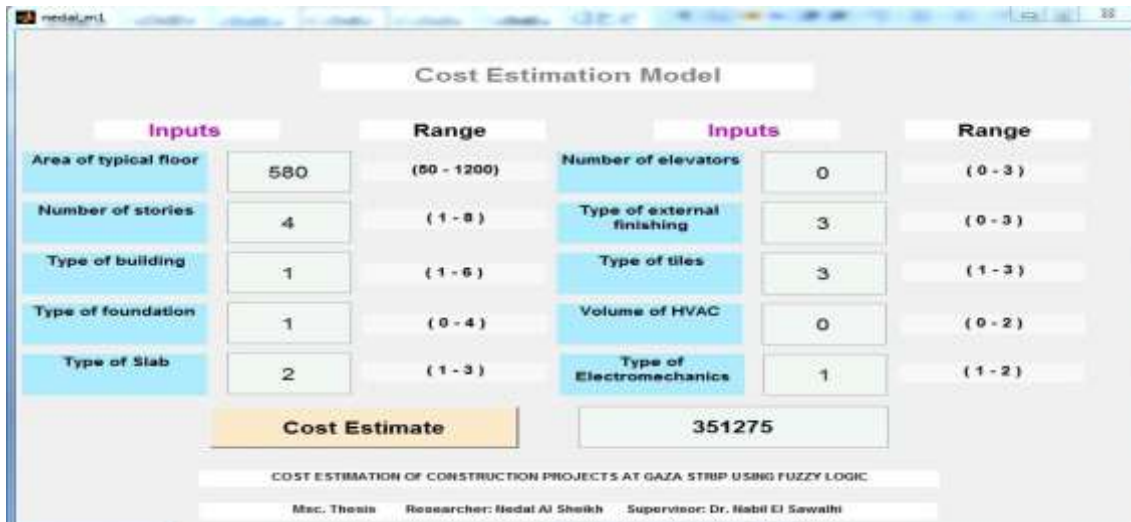


Figure 5.9: Model continuity testing case two

The results were compared with real projects cost as they were shown in Table 5.4, the outcome sometimes give a result more than the real project cost, other times the result was less than the real project cost but the model cost close to the real cost as shown in Figure 5.10.

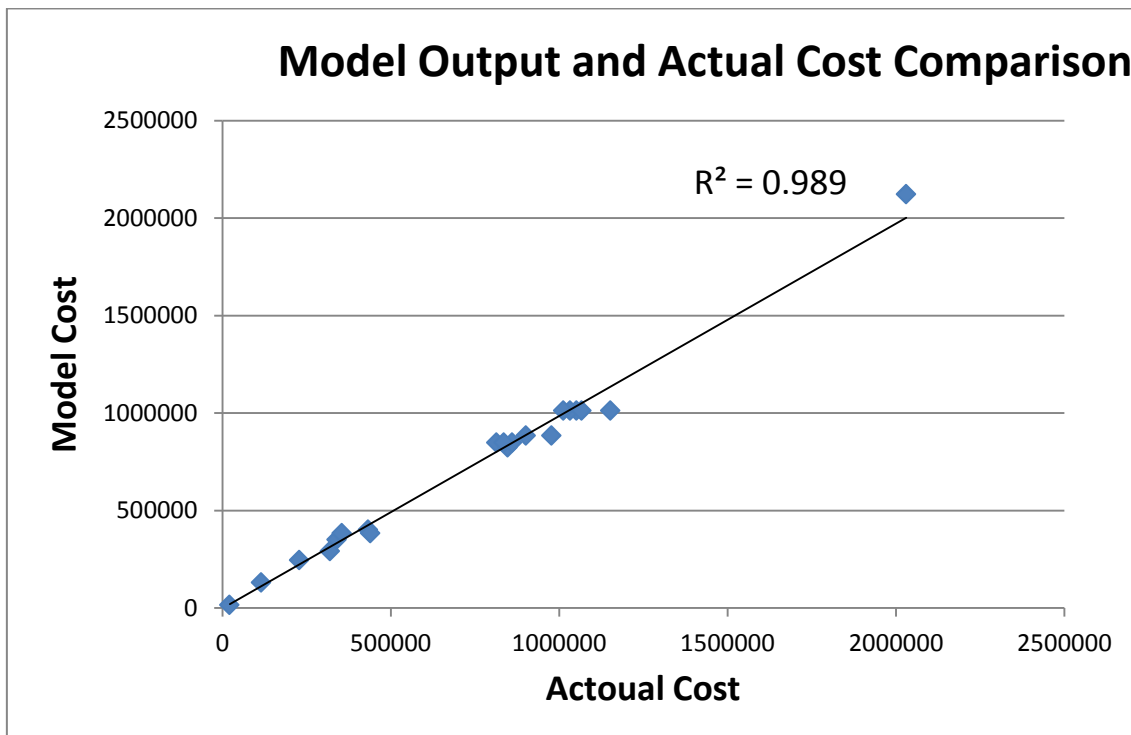


Figure 5.10: Model Cost and Actual Cost Comparison

So the model is reliable for all projects which have similar inputs to the model rules. In other words the model is working according to the rules which were developed according to the collected projects data. Therefore, if the model rules met with the

project inputs the outcome will be near the real project cost, otherwise the outcome will be far from the real project cost. For example we have a project with total cost ( **340,000** \$) the model cost (**351,275** \$). The project external finishing is normal stone. If we changed the external finishing to plastering, the cost must be decreased but in the model cost become (**2,500,000**\$). This cost is the average cost of the model. The model average cost appear when the inputs do not meet the model rules.

After making pilot study for the model, the problem where determined at the rules number. The needed rules for the model were **1,244,160** rules. The built model rules were **665** rules. Therefore, this model isn't reliable for all construction projects and there is a need to build a model that can be reliable for all construction projects.

#### **5.4 Modified Model**

The next step is to formulate a modified FL model to meet the research main goal which is to develop a computerized cost estimating system using fuzzy logic that hopefully may improve the local practice. This step is to build a model with all required rules which mean to reduce the inputs factors. According to Shehato (2013), the main factors affecting construction cost are the area of typical floor, numbers of stories and the building type. Therefore another model was built . However, the inputs were limited to three inputs with the same membership functions and also the same output. The average cost were calculated for every type of buildings. The area were divided every 200 m<sup>2</sup> and started from 100 m<sup>2</sup>. Accordingly, the construction cost was calculated for every type of building to find the output membership function and to write the model rules as shown in the Annex "B". The total number of rules were **288** rules which are the required numbers of rules as shown in Figure 5-11.

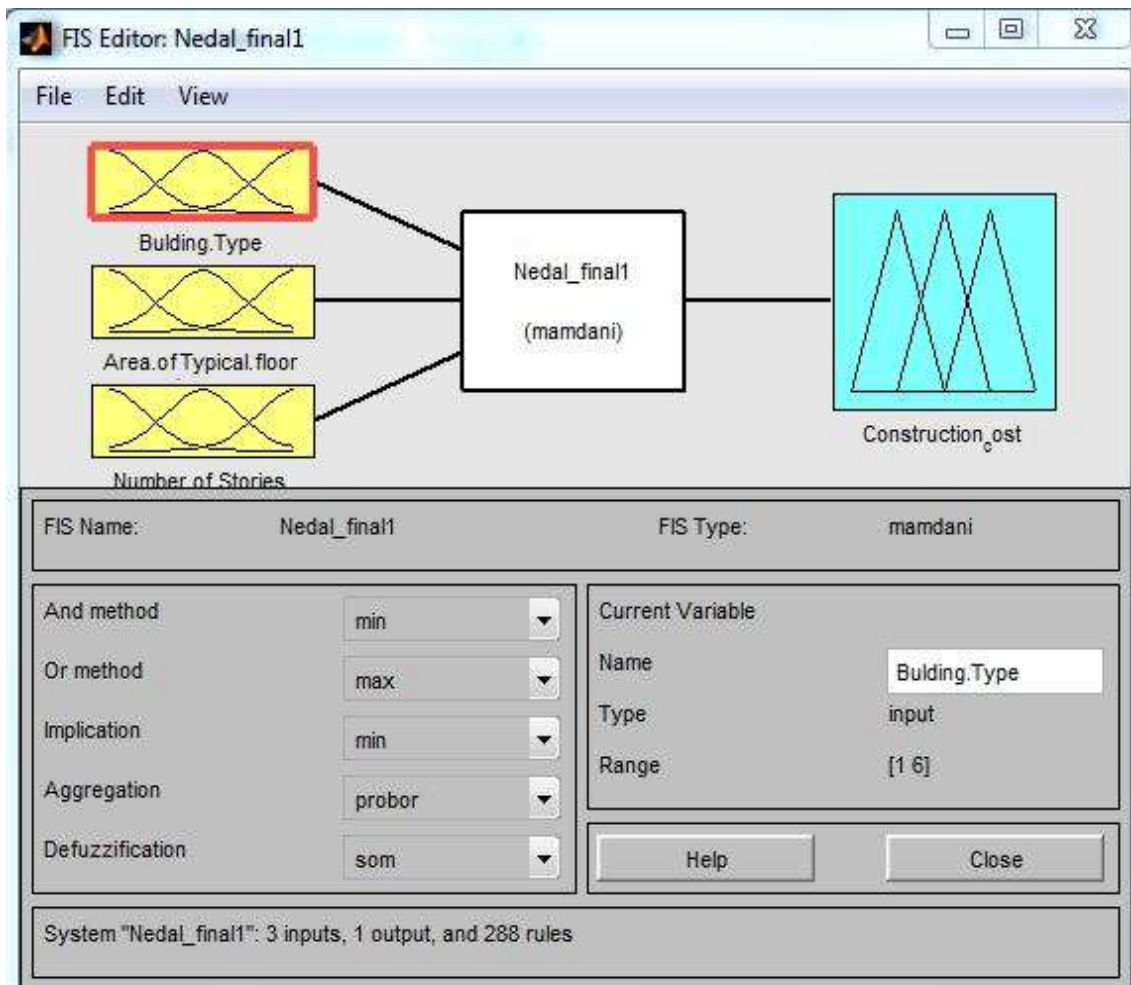


Figure 5-11: Modified model components

#### 5.4.1 Modified Model Reliability Test

This model was run and gives a very good results because the number of the rules were suitable and sufficient to give reliable results. 288 rules are required number for this model. Thirty projects were chosen for reliability test. The model output was responsible and satisfactory as shown in Figure 5.12. The result of the thirty projects are shown in Table 5.5.

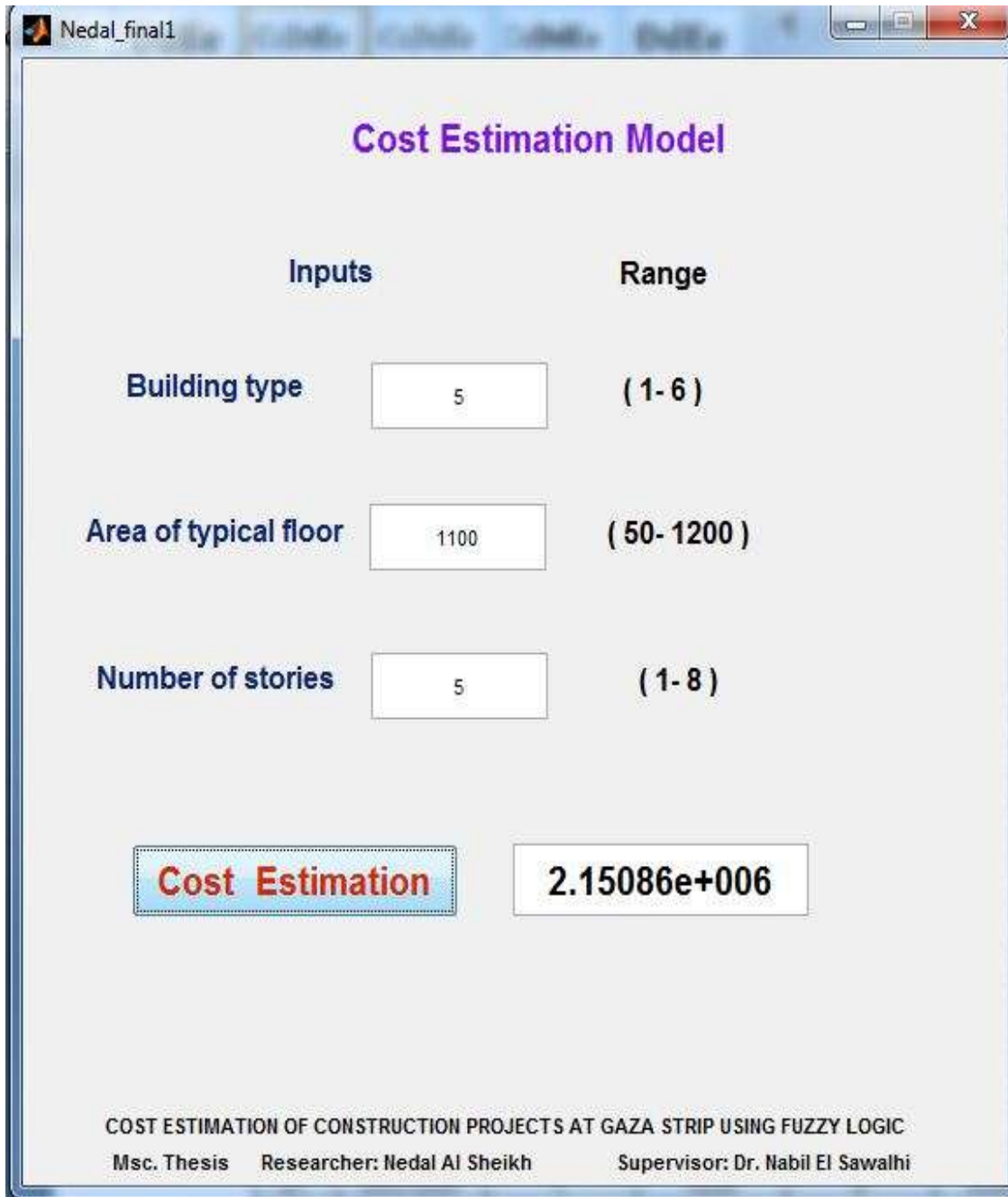


Figure 5-12: Modified model user interface

**Table 5.5: Modified model reliability test**

No.	Real Cost	Building Type	Floor Area	Stories number	Average cost	Model Cost
1	23200	1	84	1	21840	18950
2	34710	1	118	1	30680	32780
3	196898	1	255	4	265200	301410
4	441600	5	481	2	384800	401380
5	318450	3	410	3	430500	551335
6	297130	6	380	2	418000	351395
7	114980	1	165	4	171600	110865
8	700000	1	620	8	1289600	1451070
9	465900	1	500	7	910000	951215
10	1036080	1	960	2	499200	501350
11	320190	6	410	2	451000	551335
12	720000	6	630	2	693000	751275
13	170650	2	185	2	159100	118690
14	1388800	5	1100	5	2200000	2150860
15	835395	5	710	4	1136000	1101170
16	379000	2	460	1	197800	201440
17	901236	4	850	3	969000	1051190
18	1071278	4	980	3	1117200	1051190
19	1167559	4	1020	3	1162800	1251130
20	873600	4	810	3	923400	1051190
21	97370	3	148	2	103600	110865
22	860246	3	780	2	546000	501350
23	223542	1	280	5	364000	401380
24	520806	1	580	7	1055600	951215
25	2305000	5	1200	4	1920000	1750980
26	3287454	6	1200	4	2640000	2350800
27	2031200	1	1200	3	936000	851245
28	104608	5	150	3	180000	101470
29	1157901	5	1000	7	2800000	2950620
30	1152000	6	1000	2	1100000	1051190

## 5.5 Results Analysis

The model have been run and gives the required results as shown in Table 5.7. A comparison is required to see the degree of veracity for the model. A comparison was between the average project cost and the model output.

Figure 5-13 shows a comparison between the project real cost which received from the collected projects and the average cost which was calculated by the researcher from the collected projects. The figure shows disparity between the two costs, this because the collected project were constructed in a period where the construction industry was deteriorated as a result of Israel siege and border closure.



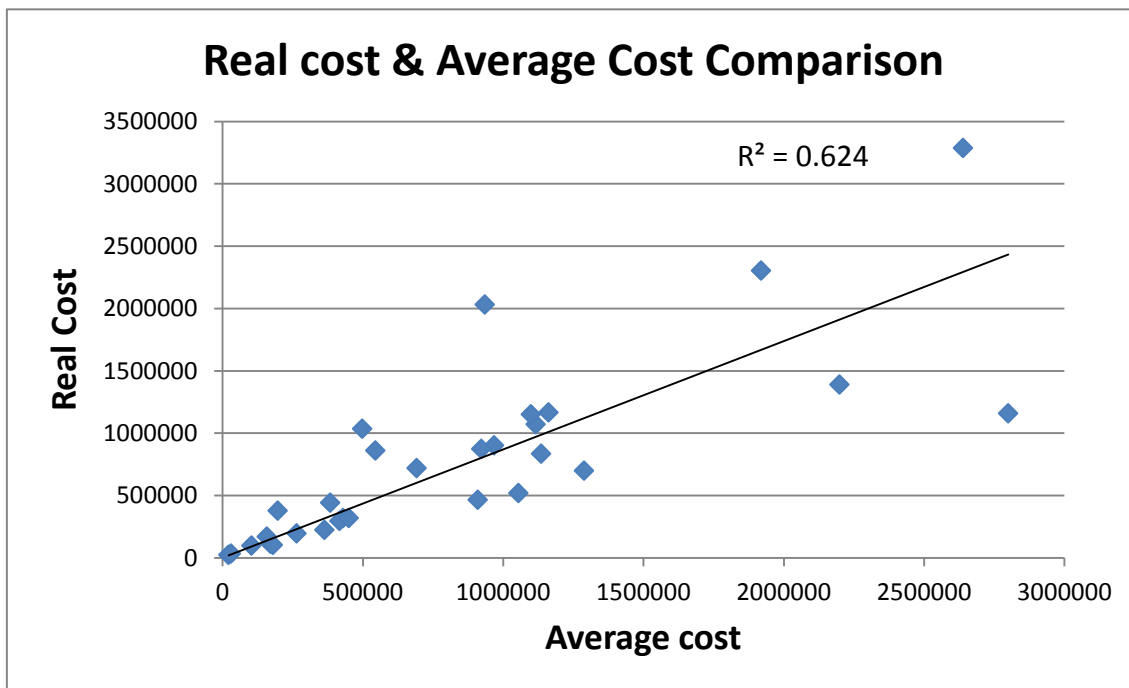


Figure 5-13: Average cost & real cost comparison

### Absolute Percentage Error & Mean Absolute Percentage Error

The absolute percentage error for the projects is calculated as :

$$\% \text{ Absolute} = [100 \times (\text{actual cost} - \text{predicted cost}) / \text{actual cost}]$$

as shown in Table5-7, the absolute percentage error is calculated for 30 projects. The mean absolute percentage error of the model is calculated which equals 12%. This result can be expressed in another way by accuracy performance (AP) according to Wilmot and Mei, (2005) which is found as:

$$AP = (100 - MAPE) \%$$

$$AP = 100\% - 12\% = 88\%$$

The accuracy of adopted model for building projects estimate in conceptual phase is 88%. This indicate that FL can be used as a tool for construction cost estimation. The most important step in FL cost estimation model is the rules which must be written completely to cover all inputs change.

### Correlation Coefficient (R)

Regression analysis was used to ascertain the relationship between the model estimated cost and the actual cost. The results of linearly regressing is illustrated graphically in

Figure 5-14. The correlation coefficient (R) is 0.991, indicating that, there is a good linear correlation between the actual value and the estimated FL model cost.

**Table 5.7: Modified Model Results Analysis**

<b>No.</b>	<b>Actual Cost (\$ )</b>	<b>Model Cost (\$ )</b>	<b>Absolute Error AE (\$ )</b>	<b>Absolute Percentage Error (%)</b>
1	21840	18950	2890	13
2	30680	32780	2100	7
3	265200	301410	36210	14
4	384800	401380	16580	4
5	430500	551335	120835	28
6	418000	351395	66605	16
7	171600	110865	60735	35
8	1289600	1451070	161470	13
9	910000	951215	41215	5
10	499200	501350	2150	0
11	451000	551335	100335	22
12	693000	751275	58275	8
13	159100	118690	40410	25
14	2200000	2150860	49140	2
15	1136000	1101170	34830	3
16	197800	201440	3640	2
17	969000	1051190	82190	8
18	1117200	1051190	66010	6
19	1162800	1251130	88330	8
20	923400	1051190	127790	14
21	103600	110865	7265	7
22	546000	501350	44650	8
23	364000	401380	37380	10
24	1055600	951215	104385	10
25	1920000	1750980	169020	9
26	2640000	2350800	289200	11
27	936000	851245	84755	9
28	180000	101470	78530	44
29	2800000	2950620	150620	5
30	1100000	1051190	48810	4

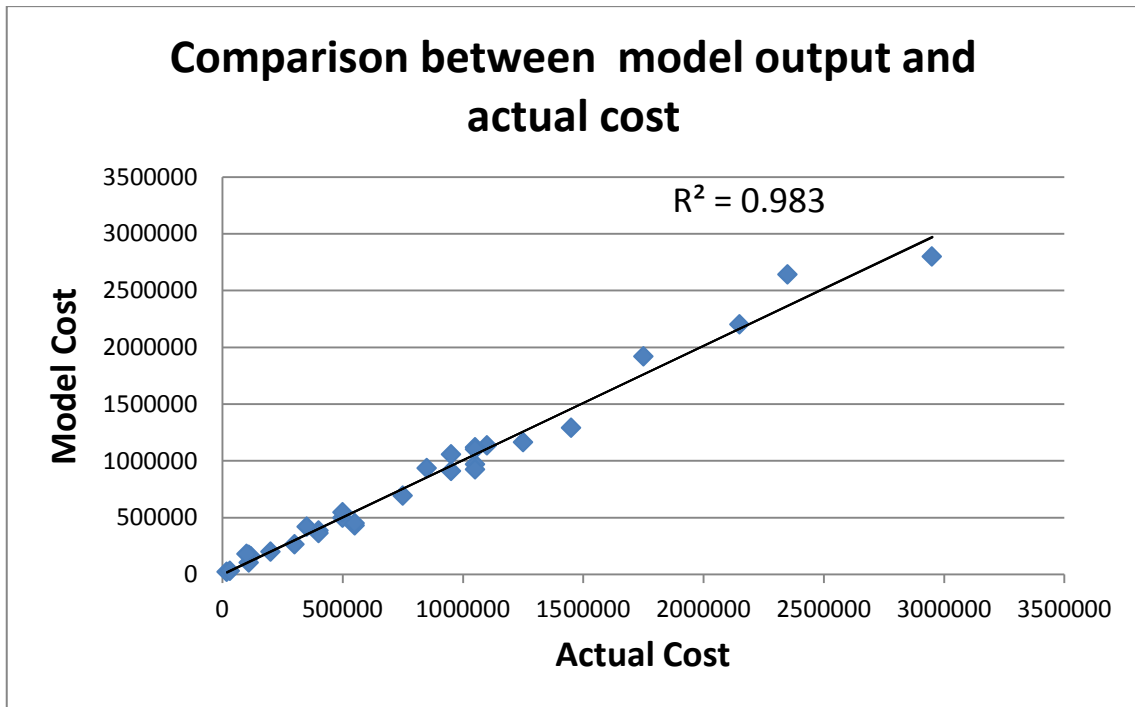


Figure 5-14: Actual cost and model estimated costs comparison

## CHAPTER 6

### CONCLUSION AND RECOMMENDATIONS

#### 6.1 Introduction

Cost estimation model using fuzzy logic has been developed to satisfy the needs of Gaza Strip contracting companies in cost estimating. After conducting a field survey and FL model development and evaluation, the researcher provides conclusion and recommendations which emerged from the results and observations of this study.

The conclusion and recommendations aim at improving the capability of contractors in better handling the cost estimation of construction projects. It also introduces recommendations for further studies.

#### 6.2 Conclusion

Based on the results obtained from this research, the following conclusion of the research are listed:

- An exploration of factors affecting construction cost estimate was conducted in order to find the degree of importance for each factor. The result of analysis of two main group factors concluded that the most important factors affecting construction cost estimate are the skeleton group factors :
  - 1- Area of typical floor.
  - 2- Number of stories in building.
  - 3- Type of Building.
  - 4- Type of foundation.
  - 5- Type of slab.
  - 6- Number of elevators.
  - 7- Number of columns.
  - 8- Number of rooms in the building.
  - 9- Location of the project.
- The target stakeholder see that the most important factors affecting construction cost estimate for finishing group are:
  - 1- Type of external finishing.
  - 2- Volume of HVAC works.
  - 3- Type of tiles.
  - 4- Type of electrical works.

#### 5- Type of mechanical works.

- The findings shows the skeleton group is more important than the finishing group. Contractors, clients and consultants have to be aware for these factors.
- The main factors affecting construction cost are the area of typical floor, numbers of stories and the building type.
- Most of contracting companies are still using manual cost estimate methods. Shortage of suitable estimating software is considered the main obstacle for computerized estimating. Another important factor is lack of availability of qualified persons in using computerized estimating packages.
- FL Model was developed in order to help local contractors, consultant and clients to estimate the construction cost.
- The first trial run for model composed of ten factors. After checking the model logic and the rules, it's found that the rules built were insufficient to meet the required accuracy. This is because the required rules for the model were **1244160** rules, while the input rules in the built model where **665** rules.
- The second modified model was built with three inputs: building type, area of typical floor and numbers of stories. The number of the rules were 288 rules. This number is sufficient number to built up the model.
- The accuracy performance of the adopted model recorded 88%. The acceptable error rate in early stage of building projects is ranging between (-25% to +50%). The average percentage error of this model is 12% ( $100-88=12\%$ ).
- FL model can help decision maker to take a fast decision and make many alternatives in few minutes at the early stage of the project when there is a lack of information and nebulous details.

### 6.3 Recommendations

The following recommendations are the most important ones that can be deduced by this research:

#### To Owners & Consultants :

- As this study revealed that the vast majority of construction cost exceed the estimation cost, clients and consultant are advised to ensure that the pricing team is fully supported with the necessary tools and techniques to deal with this matter.

- Clients and consultants should give more attention to cost estimating process in order to enhance productivity and accuracy. They should monitor the performance of their estimates in terms of accuracy and hire a qualified technical staff in order to obtain the accurate estimate.
- A clear identification of the construction project requirements is essential before the start of the estimate. Care by clients should be taken to keep changes in the scope of work as minimum as possible.
- Estimates based on updated price information should be considered in order to come up with accurate estimate and avoid any wrong estimation.
- After the completion of each project, clients and consultants have to compare actual costs with projected costs to evaluate their cost estimating proficiency and improve their skill.
- Clients and consultants are recommended to keep continuously records for all cost related data and built a historical database of finished project. This unique database should be the main source of information that will be used in estimating future projects.

#### **To Contractors :**

- It is recommended that each contracting company continuously keeps records for all cost related data and built a historical database for the company. This unique database should be the main source of information that will be used in estimating future projects.
- It is recommended that the estimators in contracting companies attend courses in using estimating software to improve their capabilities in this field.
- The local contracting companies are invited to have an estimating software package and use it in estimating the works in order to get more accurate estimate, save time, minimize error, and hopefully to have better chance to win bids.

### **TO Government, Contractors' Union and Association of Engineers**

- It is highly recommended to expand the fields of using FL technique to reach more fields of civil engineering.
- It is recommended to conduct training courses in computer applications in estimating. This training and seminars aim to improve the local practice in cost estimating and increases the capabilities of estimators in using estimating software packages.
- The construction projects information should be organized in a computerized system to improve the accuracy of cost estimation practice in Gaza Strip. Its recommended if there is center for construction data.

### **6.4 Recommendations for Further Studies**

- The survey was conducted in Gaza Strip in a period where the construction business was deteriorated or even paralyzed, which in turn was reflected on the results of the research. It is recommended to conduct another survey when the construction industry recovers and make a comparative analysis to the results.
- It is recommended to compare FL model with other cost estimation software in order to have a comprehensive system which enables the stakeholders to use the most effective software.
- It's recommended to make models for every type of building alone, to enable the researcher to write all rules to get general results that can be generalize to all projects.

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## Annexes

### Annex "1" Fuzzy Logic and Matlab

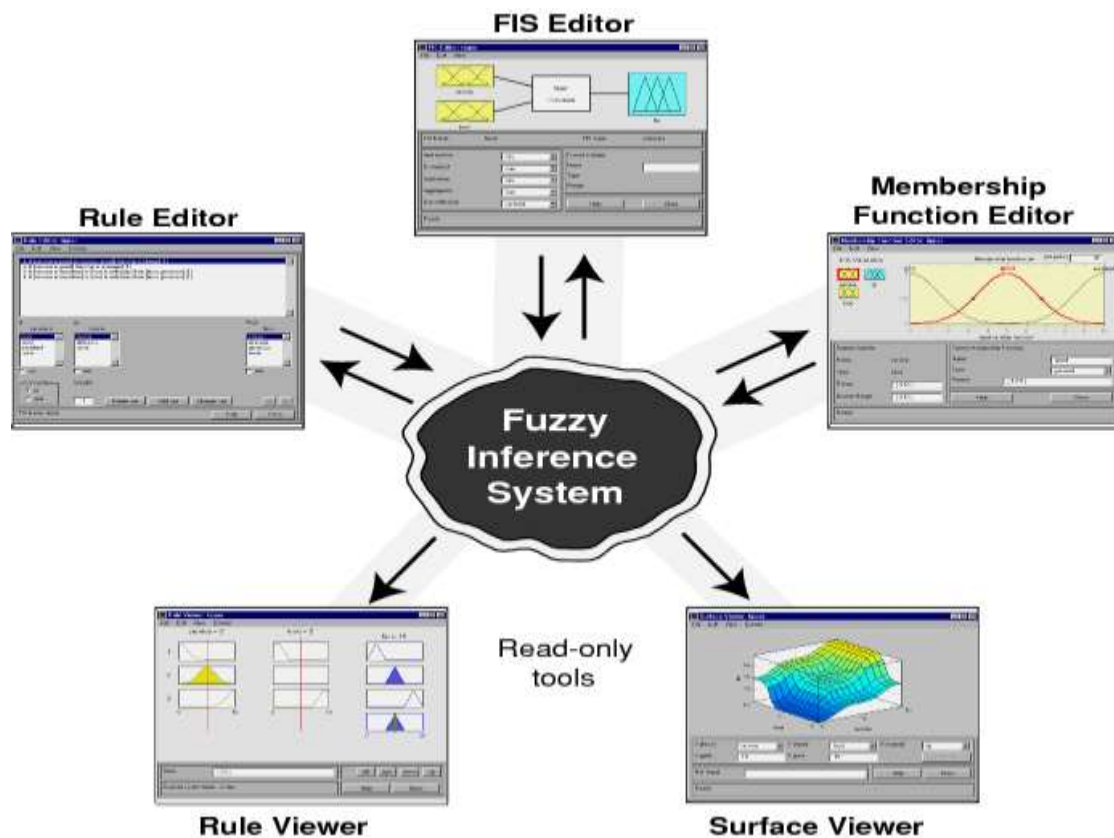
Matlab is a product of the Math works, Inc. and is an advanced interactive software package specially designed for scientific and engineering computation. Matlab is an interactive system whose basic elements are an array that does not require dimensioning. This allows solving many computing problems, especially those with matrix and vector formulations. Matlab is both an environment and programming language, and the major advantage of the Matlab language is that it allows building our own reusable tools. Our own functions and programs (known as M-files) can be created in Matlab code (Sivanandam et al., 2007).

Sivanandam et al., (2007) reported that the main features of Matlab are:

1. Advance algorithms for high-performance numerical computations, especially in the field of matrix algebra.
2. A large collection of predefined mathematical functions and the ability to define one's own functions.
3. Two- and three-dimensional graphics for plotting and displaying data.
4. A complete help system online.
5. Powerful matrix/vector-oriented high-level programming language for individual applications.
6. Ability to cooperate with programs written in other languages and for importing and exporting formatted data.
7. Toolboxes available for solving advanced problems in several application areas.

#### **Fuzzy Logic System Using Matlab**

Gandhinathan et al. (2004) said it's easy to built a fuzzy system using the graphical user interface (GUI), there are five primary GUI tools for building, editing, and observing fuzzy inference systems (FIS) as shown in Figure 1.



**Figure 1: The main components of a Fuzzy Inference System (Math works 2010).**

The FIS Editor handles the high-level issues for the system: How many input and output variables? What are their names?

The Membership Function Editor is used to define the shapes of all the membership functions associated with each variable.

The Rule Editor is for editing the list of rules that defines the behavior of the system.

The Rule Viewer and the Surface Viewer are used for looking at, as opposed to editing, the FIS. They are strictly read-only tools. The Rule Viewer is a MATLAB based display of the fuzzy inference. Used as a diagnostic, it can show (for example) which rules are active, or how individual membership function shapes are influencing the results.

The Surface Viewer is used to display the dependency of one of the outputs on any one or two of the inputs, it generates and plots an output surface map for the system.

## Annex "2" Structured Interviews ( Arabic version )



الجامعة الإسلامية - غزة

كلية الدراسات العليا

قسم الهندسة المدنية - برنامج إدارة المشروعات الهندسية

### دراسة ميدانية Structured Interviews

الأخوة المهنيين في مشاريع الإنشاءات ..... حفظكم الله  
تحية طيبة وبعد

بداية أتقدم لكم بجزيل الشكر والعرفان لمساهمتم بجزء من وقتكم الثمين لهذه المقابلة والتي تعتبر جزء مساهما لإتمام هذا العمل البحثي كمتطلب لنيل درجة الماجستير في إدارة المشاريع الهندسية بالجامعة الإسلامية بإشراف الدكتور نبيل الصوالحي. و العنوان الذي تم اختياره للبحث هو " تقدير تكلفة المشاريع الإنشائية في قطاع غزة باستخدام منطق الغموض". ولإتمام أهداف البحث توجب جمع البيانات اللازمة وذلك من خلال هذه المقابلة.

#### أهداف البحث

الهدف الرئيسي لهذا البحث هو تطوير برنامج حاسوب لتقدير تكلفة المشاريع الإنشائية في قطاع غزة باستخدام منطق الغموض من اجل تطوير صناعة الإنشاءات. وهذا الهدف يتحقق من خلال دراسة الممارسات الحالية لتقدير تكلفة المشاريع الإنشائية, والعوامل التي تؤثر على تكلفة المشاريع الإنشائية.

#### الفئة المستهدفة

يستهدف هذا البحث المهنيين في حرفة الإنشاء وبالتحديد الأشخاص المعنيين بتكلفة المشاريع ويقومون بأعمال التسعير للمشاريع الإنشائية. لتحقيق هذه الأهداف تم دعوة سيادتكم لتزويدنا بالبيانات والمعلومات المطلوبة مع العلم أنه سيتم الاحتفاظ بأية معلومات تم جمعها من هذه الدراسة بسرية تامة لأغراض أكاديمية بحتة. وأخيرا وليس أخرا نشكركم على مشاركتكم ووقتكم الثمين الذي منحتموه لي من خلال هذه المقابلة والمساهمة في إنجاح هذا العمل البحثي.

وتفضلوا بقبول فائق الاحترام

الباحث



الجزء الأول : معلومات عامة

1. اسم الشخص :
  2. اسم المؤسسة / الشركة
  3. الموقع الوظيفي:
- مدير مشروع     مهندس موقع     حاسب كميات     أخرى، حدد .....
- 
4. عدد سنوات الخبرة في مجال الإنشاءات:
- 1 - 3 سنوات     4 - 6 سنوات     7 - 10 سنوات     أكثر من 10 سنوات
- 
5. الطريقة المتبعة في تقدير تكلفة المشاريع الإنشائية :
- يدوي أو بواسطة الحاسوب وإذا كان بالحاسوب فهل هناك برنامج متخصص وما هو ؟
- 
6. هل تتوافق قيمة التقديرات لتكلفة المشاريع الإنشائية مع القيمة الفعلية للمشروع بعد التنفيذ ؟

الجزء الثاني : العوامل المؤثرة على عملية التسعير في إنشاء المباني في قطاع غزة.

مرفق لسيادتكم العوامل التي تؤثر على تكلفة المشاريع الإنشائية وقد تم تقسيمها إلى مجموعتين رئيسيتين مجموعة متعلقة بمرحلة العظم ومجموعة متعلقة بمرحلة التشطيب. وكل مجموعة تحتوي على عدد من العوامل نرجو من سيادتكم ترتيب هذه العوامل حسب الأهمية في التأثير على تكلفة المشاريع . ويمكن لسيادتكم البداية برقم 1 للعامل الأكثر أهمية ويمكنكم زيادة أي عوامل ترونها مهمة ولم تذكر.

1. العوامل المتعلقة بعملية الإنشاء الأساسية للمبنى (مرحلة العظم).

**(Factors related to structural skeleton works)**

الرقم	العامل	درجة الأهمية			
		غير مهم	قليل	متوسط	مهم
1	نوع المبنى				
2	نوع التربة				
3	نوع الأساسات المستخدمة				
4	مساحة الطابق الأرضي				
5	مساحة الطابق المتكرر				
6	نوع السقف المستخدم				

					عدد الطوابق في المبنى	7
					عدد الأعمدة في الطابق	8
					عدد الغرف في الطابق	9
					عدد المصاعد في المبنى	10
					موقع المشروع	11

## 2. العوامل المتعلقة في عملية تشطيب المبنى.

### (Factors related to finishes works)

درجة الأهمية					العامل	الرقم
مهم جداً	مهم	متوسط	قليل	غير مهم		
					نوع التشطيب الخارجي	1
					نوع البلاط	2
					نوع الدهان	3
					حجم أعمال التكييف	4
					نوع الأعمال الكهربائية	5
					نوع الأعمال الميكانيكية ( الصحية )	6
					مساحة أعمال السقف المستعار	7
					نوع وكمية أعمال الألمنيوم	8
					نوع وكمية أعمال الحدادة	9
					نوع وكمية أعمال النجارة	10

شكراً على تعاونكم معنا

### Annex "3" Table of Factors of collected real projects

Cost \$	Area m2	Building type	Floors No.	Footing type	Slab type	Elevator No.	External finish	HAVAC	Tilling type	Electrical	Mechanical
170650	185	Prayer	2	Piles	D.B.	0	N. S	no	Ter.	normal	normal
185130	215	Prayer	2	isolated	D.B.	0	N. S	no	Ter.	normal	normal
228000	300	Prayer	3	isolated	D.B.	0	no	no	Ter.	normal	normal
308000	400	Prayer	3	isolated	D.B.	0	T.P	no	Ter.	normal	normal
313750	400	Prayer	3	isolated	D.B.	0	T.P	no	Ter.	normal	excellent
363780	450	Prayer	1	isolated	D.B.	0	T.P	no	Ter.	normal	normal
379000	460	Prayer	1	isolated	D.B.	0	T.P	no	Ter.	normal	normal
415334	460	Prayer	1	isolated	D.B.	0	T.P	no	Ter.	normal	normal
438969	470	Prayer	1	isolated	D.B.	0	T.P	no	Ter.	normal	normal
847535	750	Prayer	2	isolated	D.B.	0	T.P	no	Ter.	normal	normal
850000	755	Prayer	2	isolated	D.B.	0	T.P	no	Ter.	normal	normal
7810	34	residential	1	isolated	S	0	T.P	no	Cer.	normal	normal
20250	65	residential	2	Mat	H	0	T.P	no	Ter.	normal	normal
20510	75	residential	1	Mat	H	0	T.P	no	Ter.	normal	normal
21300	76	residential	1	isolated	H	0	no	no	Ter.	normal	normal
21520	79	residential	1	Mat	H	0	T.P	no	Ter.	normal	normal
21760	80	residential	1	Mat	H	0	T.P	no	Ter.	normal	normal
22780	80	residential	1	isolated	H	0	no	no	Ter.	normal	normal
22954	82	residential	1	isolated	H	0	T.P	no	Cer.	normal	normal
23200	84	residential	1	isolated	H	0	T.P	no	Cer.	normal	normal
23700	85	residential	1	isolated	H	0	no	no	Ter.	normal	normal
24300	85	residential	1	isolated	H	0	no	no	Ter.	normal	normal
24971	86	residential	1	isolated	H	0	T.P	no	Cer.	normal	normal
25276	87	residential	1	isolated	H	0	T.P	no	Cer.	normal	normal
26740	89	residential	1	isolated	H	0	T.P	no	Cer.	normal	normal
28065	95	residential	2	Piles	S	0	Oi	no	Por.	normal	normal
29499	100	residential	1	isolated	H	0	T.P	no	Cer.	normal	normal
32075	111	residential	1	isolated	H	0	T.P	no	Ter.	normal	normal
33050	117	residential	1	isolated	H	0	T.P	no	Ter.	normal	normal
34710	118	residential	1	isolated	H	0	T.P	no	Ter.	normal	normal
35710	125	residential	1	isolated	H	0	T.P	no	Ter.	normal	normal
56550	130	residential	1	isolated	H	0	T.P	no	Ter.	normal	normal
77700	135	residential	1	isolated	H	0	T.P	no	Ter.	normal	normal
94464	140	residential	1	isolated	H	0	T.P	no	Ter.	normal	normal
111612	150	residential	4	Piles	H	1	N. S	no	Cer.	normal	normal
114980	165	residential	4	Piles	H	1	N. S	no	Cer.	normal	normal
157100	180	residential	4	Piles	H	1	N. S	no	Cer.	normal	normal
178000	195	residential	3	isolated	S	0	T.P	no	Ter.	normal	normal
189150	220	residential	4	isolated	H	0	T.P	no	Cer.	normal	normal
190205	250	residential	5	isolated	H	1	N. S	no	Por.	excellent	normal
196898	255	residential	4	isolated	H	0	Oi	no	Por.	normal	normal
213750	270	residential	3	isolated	H	0	Oi	no	Cer.	normal	normal
222350	279	residential	4	isolated	H	1	N. S	no	Por.	excellent	normal
223542	280	residential	5	isolated	H	1	N. S	no	Por.	excellent	normal
252000	340	residential	8	isolated	H	0	T.P	no	Cer.	normal	normal
257000	350	residential	8	Mat	H	0	Oi	no	Cer.	normal	normal
273200	360	residential	8	isolated	H	0	Oi	no	Cer.	normal	normal
273241	370	residential	6	Piles	H	0	Oi	no	Cer.	normal	normal
305000	390	residential	8	Piles	H	0	Oi	no	Cer.	normal	normal
320000	410	residential	8	isolated	H	0	Oi	no	Cer.	normal	normal
340000	425	residential	4	isolated	H	0	N. S	no	Por.	normal	normal
433000	465	residential	3	Piles	H	0	T.P	no	Cer.	normal	normal
465900	500	residential	7	isolated	H	0	Oi	no	Cer.	normal	normal

520806.3	580	residential	7	isolated	H	0	Oi	no	Cer.	normal	normal
579630	600	residential	8	isolated	H	0	Oi	no	Cer.	normal	normal
700000	620	residential	8	Mat	H	0	Oi	no	Cer.	normal	normal
813945	670	residential	5	isolated	H	1	N. S	no	Por.	normal	normal
820000	700	residential	4	isolated	H	0	Oi	no	Cer.	normal	normal
1036080	960	residential	2	isolated	S	1	T.P	no	Cer.	excellent	normal
1343000	1070	residential	3	Piles	S	0	Oi	no	Ter.	normal	normal
1578000	1150	residential	4	isolated	S	0	Oi	no	Cer.	normal	normal
1681290	1200	residential	3	Mat	S	1	N. S	no	Por.	normal	normal
2031200	1200	residential	3	Mat	S	1	N. S	no	Por.	normal	normal
97370.33	148	sch. ext.	2	Strap	D.B.	0	T.P	no	Ter.	normal	normal
112980	150	sch. ext.	3	Piles	D.B.	0	Oi	no	Ter.	normal	normal
163800	180	sch. ext.	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
173900	195	sch. ext.	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
181861	195	sch. ext.	3	Piles	D.B.	0	Oi	no	Ter.	normal	normal
203400	260	sch. ext.	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
208000	260	sch. ext.	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
231450	330	sch. ext.	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
243540	330	sch. ext.	2	Strap	D.B.	0	T.P	no	Ter.	normal	normal
251000	330	sch. ext.	3	Piles	D.B.	0	T.P	no	Ter.	normal	normal
286000	380	sch. ext.	1	no	D.B.	0	T.P	no	Ter.	normal	normal
320000	410	sch. ext.	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
444540	480	sch. ext.	2	Strap	D.B.	0	T.P	no	Ter.	normal	normal
562608.3	590	sch. ext.	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
680000	617	sch. ext.	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
860246	780	sch. ext.	2	Piles	D.B.	0	T.P	no	Ter.	normal	normal
873600	810	school	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
875000	830	school	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
897142.9	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
901236.1	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
901236.1	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
902025	850	school	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
902025	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
907228.8	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
936660	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
977208.2	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
993000	850	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1012194	900	school	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
1015000	900	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1020426	920	school	3	Strap	D.B.	0	T.P	no	Ter.	normal	normal
1020696	930	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1032105	955	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1038000	970	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1050000	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1051400	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1053495	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1066946	980	school	3	Piles	D.B.	0	Oi	no	Ter.	normal	normal
1070000	980	school	3	Piles	D.B.	0	Oi	no	Ter.	normal	normal
1071278	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1106640	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1110000	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1110000	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1147000	980	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1149000	995	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1167559	1020	school	3	Strap	D.B.	0	Oi	no	Ter.	normal	normal
1241000	1050	school	3	Strap	H	0	T.P	no	Ter.	normal	normal
29963	105	institution	3	isolated	H	0	T.P	no	Cer.	normal	normal
38350	130	institution	2	isolated	H	0	Oi	no	Ter.	normal	normal

104608	150	institution	3	isolated	H	0	N. S	no	Cer.	normal	normal
155420	175	institution	3	isolated	H	0	N. S	no	Cer.	normal	normal
173100	190	institution	4	Piles	H	0	Oi	central	3	excellent	normal
190000	225	institution	3	isolated	H	0	N. S	no	Cer.	normal	normal
211200	269	institution	2	no	H	0	Oi	no	Ter.	normal	normal
221756	270	institution	2	isolated	H	0	Oi	no	Ter.	normal	normal
224788	295	institution	2	isolated	D.B.	0	Oi	no	Por.	normal	normal
228137.3	320	institution	3	isolated	D.B.	0	Oi	no	Por.	normal	normal
267100	360	institution	3	isolated	D.B.	0	T.P	no	Cer.	normal	normal
275520	370	institution	2	no	H	0	T.P	no	Ter.	normal	normal
279000	370	institution	2	isolated	D.B.	0	T.P	no	Cer.	normal	normal
329993.6	420	institution	2	Strap	H	0	Oi	no	Por.	normal	normal
335881	420	institution	2	Strap	H	0	Oi	no	Por.	normal	normal
336700	420	institution	2	Strap	H	0	Oi	no	Por.	normal	normal
358000	450	institution	1	isolated	D.B.	0	Oi	no	Ter.	excellent	normal
441600	480	institution	2	isolated	H	0	Oi	no	Por.	normal	normal
491250	540	institution	3	isolated	D.B.	0	N. S	no	Cer.	normal	excellent
554050	580	institution	4	isolated	D.B.	0	N. S	no	Cer.	normal	excellent
565685	590	institution	3	isolated	H	0	T.P	no	Ter.	excellent	normal
621600	600	institution	1	isolated	D.B.	0	T.P	no	Ter.	normal	excellent
644000	600	institution	1	Piles	D.B.	0	T.P	no	Ter.	normal	normal
782460	630	institution	1	no	D.B.	0	T.P	no	Ter.	normal	normal
785700	630	institution	4	isolated	H	0	T.P	no	Por.	normal	normal
802235	670	institution	3	isolated	H	0	Oi	no	Cer.	excellent	normal
833490	700	institution	4	isolated	H	0	Oi	no	Cer.	excellent	normal
835395	710	institution	4	isolated	H	0	Oi	no	Cer.	excellent	normal
997000	870	institution	6	isolated	D.B.	0	Oi	central	Por.	excellent	excellent
1157901	1000	institution	7	Mat	H	0	T.P	no	Ter.	excellent	excellent
1388800	1100	institution	5	Mat	H	0	Oi	isolated	Cer.	excellent	excellent
1610000	1180	institution	3	isolated	D.B.	0	N. S	isolated	Por.	excellent	excellent
2030400	1200	institution	4	Mat	H	0	Oi	isolated	Cer.	excellent	excellent
2305000	1200	institution	4	Mat	H	0	Oi	isolated	Cer.	excellent	excellent
112980	160	Mosque	3	isolated	D.B.	0	T.P	no	Ter.	normal	normal
119511	170	Mosque	3	isolated	D.B.	0	T.P	no	Ter.	normal	normal
225000	300	Mosque	2	isolated	D.B.	0	no	no	Ter.	normal	normal
250000	330	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	excellent	normal
259200	350	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	excellent	normal
266100	350	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	normal	excellent
297130	380	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	normal	normal
318450	400	Mosque	2	isolated	D.B.	0	T.P	no	Cer.	excellent	excellent
320190	410	Mosque	2	isolated	D.B.	0	T.P	no	Cer.	excellent	excellent
327230.6	420	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	normal	normal
349623.6	430	Mosque	2	Mat	D.B.	0	T.P	no	Ter.	normal	excellent
355238	430	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	normal	normal
356304	450	Mosque	5	isolated	D.B.	0	Oi	no	Cer.	excellent	normal
375000	450	Mosque	2	Mat	D.B.	0	T.P	no	Ter.	normal	excellent
452000	490	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	normal	normal
485985	500	Mosque	2	isolated	D.B.	0	T.P	no	Ter.	normal	normal
510000	550	Mosque	2	Mat	D.B.	0	T.P	no	Cer.	excellent	normal
616150	600	Mosque	2	Piles	D.B.	0	T.P	no	Ter.	normal	excellent
720000	630	Mosque	2	no	S	0	N. S	no	Cer.	normal	normal
840971.4	750	Mosque	5	isolated	D.B.	0	T.P	no	Ter.	excellent	excellent
863192.6	780	Mosque	3	isolated	D.B.	0	N. S	no	Cer.	normal	normal
880486	835	Mosque	3	isolated	D.B.	0	no	no	Ter.	normal	normal
1152000	1000	Mosque	2	Piles	D.B.	0	Oi	isolated	Ter.	normal	excellent
1363000	1100	Mosque	3	Mat	D.B.	0	N. S	isolated	Ter.	excellent	excellent
1586561	1170	Mosque	3	Mat	D.B.	0	N. S	isolated	Ter.	excellent	excellent
3287454	1200	Mosque	3	Mat	D.B.	0	N. S	isolated	Ter.	normal	excellent

<b>668000</b>	200	hospital	3	isolated	H	0	T.P	central	Por.	excellent	excellent
<b>327000</b>	400	hospital	2	isolated	D.B.	0	T.P	central	Cer.	excellent	excellent
<b>1491500</b>	540	hospital	3	isolated	D.B.	0	T.P	central	Por.	excellent	excellent
<b>1650000</b>	800	hospital	7	isolated	D.B.	0	N. S	isolated	Por.	excellent	excellent
<b>378000</b>	1000	hospital	1	no	D.B.	0	N. S	central	Por.	excellent	excellent
<b>7131867</b>	2000	hospital	4	no	D.B.	0	T.P	central	Por.	excellent	excellent
<b>1193934</b>	2500	hospital	3	Strap	D.B.	0	no	no	Ter.	excellent	excellent
<b>2669978</b>	2800	hospital	3	Mat	D.B.	0	T.P	no	Por.	excellent	excellent
<b>2427360</b>	2900	hospital	2	isolated	D.B.	0	T.P	central	Por.	excellent	excellent

(sch. ext.= school extension; D.B. = Hollow slab with drop beam; H = Hollow slab; S= Solid slab; N. S = normal stone; T.P= Tryloon plastering; Oi = oixus plastering; Cer. = ceramic tiles; Ter. = terrazzo tiles; Por. = porcelain tiles).

## Annex "4" Modified Model Rules

Input Output	type of the building	Area of typical floor	Number of stories
Mf2	MF1	MF1	MF1
Mf4	MF1	MF2	MF1
Mf5	MF1	MF3	MF1
Mf7	MF1	MF4	MF1
Mf8	MF1	MF5	MF1
Mf9	MF1	MF6	MF1
Mf3	MF1	MF1	MF2
Mf6	MF1	MF2	MF2
Mf8	MF1	MF3	MF2
Mf10	MF1	MF4	MF2
Mf12	MF1	MF5	MF2
Mf13	MF1	MF6	MF2
Mf4	MF1	MF1	MF3
Mf8	MF1	MF2	MF3
Mf11	MF1	MF3	MF3
Mf13	MF1	MF4	MF3
Mf15	MF1	MF5	MF3
Mf16	MF1	MF6	MF3
Mf5	MF1	MF1	MF4
Mf9	MF1	MF2	MF4
Mf13	MF1	MF3	MF4
Mf15	MF1	MF4	MF4
Mf17	MF1	MF5	MF4
Mf19	MF1	MF6	MF4
Mf5	MF1	MF1	MF5
Mf11	MF1	MF2	MF5
Mf14	MF1	MF3	MF5
Mf17	MF1	MF4	MF5
Mf19	MF1	MF5	MF5
Mf22	MF1	MF6	MF5
Mf6	MF1	MF1	MF6
Mf12	MF1	MF2	MF6
Mf15	MF1	MF3	MF6
Mf19	MF1	MF4	MF6
Mf22	MF1	MF5	MF6
Mf25	MF1	MF6	MF6
Mf7	MF1	MF1	MF7
Mf13	MF1	MF2	MF7
Mf17	MF1	MF3	MF7
Mf20	MF1	MF4	MF7
Mf24	MF1	MF5	MF7
Mf28	MF1	MF6	MF7
Mf8	MF1	MF1	MF8

Mf14	MF1	MF2	MF8
Mf18	MF1	MF3	MF8
Mf22	MF1	MF4	MF8
Mf27	MF1	MF5	MF8
Mf29	MF1	MF6	MF8
Mf3	MF2	MF1	MF1
Mf5	MF2	MF2	MF1
Mf7	MF2	MF3	MF1
Mf9	MF2	MF4	MF1
Mf11	MF2	MF5	MF1
Mf12	MF2	MF6	MF1
Mf4	MF2	MF1	MF2
Mf9	MF2	MF2	MF2
Mf11	MF2	MF3	MF2
Mf14	MF2	MF4	MF2
Mf15	MF2	MF5	MF2
Mf17	MF2	MF6	MF2
Mf5	MF2	MF1	MF3
Mf11	MF2	MF2	MF3
Mf14	MF2	MF3	MF3
Mf17	MF2	MF4	MF3
Mf19	MF2	MF5	MF3
Mf22	MF2	MF6	MF3
Mf7	MF2	MF1	MF4
Mf13	MF2	MF2	MF4
Mf16	MF2	MF3	MF4
Mf19	MF2	MF4	MF4
Mf23	MF2	MF5	MF4
Mf27	MF2	MF6	MF4
Mf8	MF2	MF1	MF5
Mf14	MF2	MF2	MF5
Mf18	MF2	MF3	MF5
Mf23	MF2	MF4	MF5
Mf27	MF2	MF5	MF5
Mf29	MF2	MF6	MF5
Mf9	MF2	MF1	MF6
Mf15	MF2	MF2	MF6
Mf20	MF2	MF3	MF6
Mf27	MF2	MF4	MF6
Mf29	MF2	MF5	MF6
Mf30	MF2	MF6	MF6
Mf9	MF2	MF1	MF7
Mf17	MF2	MF2	MF7
Mf23	MF2	MF3	MF7
Mf28	MF2	MF4	MF7
Mf30	MF2	MF5	MF7
Mf31	MF2	MF6	MF7



Mf10	MF2	MF1	MF8
Mf21	MF2	MF2	MF8
Mf25	MF2	MF3	MF8
Mf29	MF2	MF4	MF8
Mf31	MF2	MF5	MF8
Mf33	MF2	MF6	MF8
Mf2	MF3	MF1	MF1
Mf5	MF3	MF2	MF1
Mf7	MF3	MF3	MF1
Mf8	MF3	MF4	MF1
Mf10	MF3	MF5	MF1
Mf11	MF3	MF6	MF1
Mf4	MF3	MF1	MF2
Mf8	MF3	MF2	MF2
Mf10	MF3	MF3	MF2
Mf12	MF3	MF4	MF2
Mf14	MF3	MF5	MF2
Mf15	MF3	MF6	MF2
Mf5	MF3	MF1	MF3
Mf9	MF3	MF2	MF3
Mf13	MF3	MF3	MF3
Mf15	MF3	MF4	MF3
Mf17	MF3	MF5	MF3
Mf19	MF3	MF6	MF3
Mf6	MF3	MF1	MF4
Mf11	MF3	MF2	MF4
Mf15	MF3	MF3	MF4
Mf17	MF3	MF4	MF4
Mf20	MF3	MF5	MF4
Mf23	MF3	MF6	MF4
Mf6	MF3	MF1	MF5
Mf13	MF3	MF2	MF5
Mf16	MF3	MF3	MF5
Mf20	MF3	MF4	MF5
Mf23	MF3	MF5	MF5
Mf27	MF3	MF6	MF5
Mf7	MF3	MF1	MF6
Mf14	MF3	MF2	MF6
Mf18	MF3	MF3	MF6
Mf22	MF3	MF4	MF6
Mf26	MF3	MF5	MF6
Mf29	MF3	MF6	MF6
Mf8	MF3	MF1	MF7
Mf15	MF3	MF2	MF7
Mf20	MF3	MF3	MF7
Mf25	MF3	MF4	MF7
Mf28	MF3	MF5	MF7

Mf30	MF3	MF6	MF7
Mf9	MF3	MF1	MF8
Mf16	MF3	MF2	MF8
Mf22	MF3	MF3	MF8
Mf27	MF3	MF4	MF8
Mf29	MF3	MF5	MF8
Mf31	MF3	MF6	MF8
Mf3	MF4	MF1	MF1
Mf5	MF4	MF2	MF1
Mf7	MF4	MF3	MF1
Mf9	MF4	MF4	MF1
Mf10	MF4	MF5	MF1
Mf11	MF4	MF6	MF1
Mf4	MF4	MF1	MF2
Mf8	MF4	MF2	MF2
Mf11	MF4	MF3	MF2
Mf13	MF4	MF4	MF2
Mf14	MF4	MF5	MF2
Mf16	MF4	MF6	MF2
Mf5	MF4	MF1	MF3
Mf10	MF4	MF2	MF3
Mf13	MF4	MF3	MF3
Mf16	MF4	MF4	MF3
Mf18	MF4	MF5	MF3
Mf20	MF4	MF6	MF3
Mf6	MF4	MF1	MF4
Mf12	MF4	MF2	MF4
Mf15	MF4	MF3	MF4
Mf18	MF4	MF4	MF4
Mf21	MF4	MF5	MF4
Mf24	MF4	MF6	MF4
Mf7	MF4	MF1	MF5
Mf13	MF4	MF2	MF5
Mf17	MF4	MF3	MF5
Mf21	MF4	MF4	MF5
Mf25	MF4	MF5	MF5
Mf28	MF4	MF6	MF5
Mf8	MF4	MF1	MF6
Mf14	MF4	MF2	MF6
Mf19	MF4	MF3	MF6
Mf24	MF4	MF4	MF6
Mf28	MF4	MF5	MF6
Mf29	MF4	MF6	MF6
Mf9	MF4	MF1	MF7
Mf15	MF4	MF2	MF7
Mf21	MF4	MF3	MF7
Mf26	MF4	MF4	MF7

Mf29	MF4	MF5	MF7
Mf31	MF4	MF6	MF7
Mf9	MF4	MF1	MF8
Mf17	MF4	MF2	MF8
Mf23	MF4	MF3	MF8
Mf28	MF4	MF4	MF8
Mf30	MF4	MF5	MF8
Mf32	MF4	MF6	MF8
Mf3	MF5	MF1	MF1
Mf5	MF5	MF2	MF1
Mf7	MF5	MF3	MF1
Mf9	MF5	MF4	MF1
Mf10	MF5	MF5	MF1
Mf11	MF5	MF6	MF1
Mf4	MF5	MF1	MF2
Mf8	MF5	MF2	MF2
Mf11	MF5	MF3	MF2
Mf13	MF5	MF4	MF2
Mf15	MF5	MF5	MF2
Mf17	MF5	MF6	MF2
Mf5	MF5	MF1	MF3
Mf10	MF5	MF2	MF3
Mf14	MF5	MF3	MF3
Mf16	MF5	MF4	MF3
Mf18	MF5	MF5	MF3
Mf21	MF5	MF6	MF3
Mf6	MF5	MF1	MF4
Mf12	MF5	MF2	MF4
Mf16	MF5	MF3	MF4
Mf19	MF5	MF4	MF4
Mf22	MF5	MF5	MF4
Mf25	MF5	MF6	MF4
Mf7	MF5	MF1	MF5
Mf14	MF5	MF2	MF5
Mf18	MF5	MF3	MF5
Mf22	MF5	MF4	MF5
Mf26	MF5	MF5	MF5
Mf28	MF5	MF6	MF5
Mf8	MF5	MF1	MF6
Mf15	MF5	MF2	MF6
Mf20	MF5	MF3	MF6
Mf24	MF5	MF4	MF6
Mf28	MF5	MF5	MF6
Mf30	MF5	MF6	MF6
Mf9	MF5	MF1	MF7
Mf16	MF5	MF2	MF7
Mf22	MF5	MF3	MF7

Mf27	MF5	MF4	MF7
Mf29	MF5	MF5	MF7
Mf31	MF5	MF6	MF7
Mf10	MF5	MF1	MF8
Mf17	MF5	MF2	MF8
Mf24	MF5	MF3	MF8
Mf28	MF5	MF4	MF8
Mf31	MF5	MF5	MF8
Mf32	MF5	MF6	MF8
Mf3	MF6	MF1	MF1
Mf6	MF6	MF2	MF1
Mf9	MF6	MF3	MF1
Mf11	MF6	MF4	MF1
Mf12	MF6	MF5	MF1
Mf14	MF6	MF6	MF1
Mf5	MF6	MF1	MF2
Mf10	MF6	MF2	MF2
Mf13	MF6	MF3	MF2
Mf15	MF6	MF4	MF2
Mf18	MF6	MF5	MF2
Mf20	MF6	MF6	MF2
Mf6	MF6	MF1	MF3
Mf12	MF6	MF2	MF3
Mf16	MF6	MF3	MF3
Mf19	MF6	MF4	MF3
Mf22	MF6	MF5	MF3
Mf26	MF6	MF6	MF3
Mf8	MF6	MF1	MF4
Mf14	MF6	MF2	MF4
Mf19	MF6	MF3	MF4
Mf23	MF6	MF4	MF4
Mf27	MF6	MF5	MF4
Mf29	MF6	MF6	MF4
Mf9	MF6	MF1	MF5
Mf16	MF6	MF2	MF5
Mf21	MF6	MF3	MF5
Mf27	MF6	MF4	MF5
Mf29	MF6	MF5	MF5
Mf31	MF6	MF6	MF5
Mf10	MF6	MF1	MF6
Mf17	MF6	MF2	MF6
Mf24	MF6	MF3	MF6
Mf29	MF6	MF4	MF6
Mf31	MF6	MF5	MF6
Mf32	MF6	MF6	MF6
Mf11	MF6	MF1	MF7
Mf19	MF6	MF2	MF7

Mf27	MF6	MF3	MF7
Mf30	MF6	MF4	MF7
Mf32	MF6	MF5	MF7
Mf33	MF6	MF6	MF7
Mf11	MF6	MF1	MF8
Mf21	MF6	MF2	MF8
Mf28	MF6	MF3	MF8
Mf31	MF6	MF4	MF8
Mf33	MF6	MF5	MF8
Mf33	MF6	MF6	MF8

## Annex "5" Model M-File

```
function varargout = nedal_m1(varargin)

% NEDAL_M1 MATLAB code for nedal_m1.fig
%     NEDAL_M1, by itself, creates a new NEDAL_M1 or
%     raises the existing
%     singleton*.
%
%     H = NEDAL_M1 returns the handle to a new NEDAL_M1 or
%     the handle to
%     the existing singleton*.
%
%     NEDAL_M1('CALLBACK',hObject,eventData,handles,...)
%     calls the local
%     function named CALLBACK in NEDAL_M1.M with the given
%     input arguments.
%
%     NEDAL_M1('Property','Value',...) creates a new
%     NEDAL_M1 or raises the
%     existing singleton*. Starting from the left,
%     property value pairs are
%     applied to the GUI before nedal_m1_OpeningFcn gets
%     called. An
%     unrecognized property name or invalid value makes
%     property application
%     stop. All inputs are passed to nedal_m1_OpeningFcn
%     via varargin.
%
%     *See GUI Options on GUIDE's Tools menu. Choose "GUI
%     allows only one
%     instance to run (singleton)".
%
% See also: GUIDE, GUIDATA, GUIHANDLES

% Edit the above text to modify the response to help
% nedal_m1

% Last Modified by GUIDE v2.5 26-Agu-2013 18:26:39

% Begin initialization code - DO NOT EDIT
gui_Singleton = 1;
gui_State = struct('gui_Name',       mfilename, ...
                  'gui_Singleton',   gui_Singleton, ...
                  'gui_OpeningFcn',   @nedal_m1_OpeningFcn,
                  ...
                  'gui_OutputFcn',    @nedal_m1_OutputFcn,
                  ...
                  'gui_LayoutFcn',    [] , ...
                  'gui_Callback',     []);
```

```

if nargin && ischar(varargin{1})
    gui_State.gui_Callback = str2func(varargin{1});
end

if nargout
    [varargout{1:nargout}] = gui_mainfcn(gui_State,
varargin{:});
else
    gui_mainfcn(gui_State, varargin{:});
end
% End initialization code - DO NOT EDIT

% uiwait(handles.figure1);

% --- Outputs from this function% --- Executes just before
nedal_m1 is made visible.
function nedal_m1_OpeningFcn(hObject, eventdata, handles,
varargin)
% This function has no output args, see OutputFcn.
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)
% varargin   command line arguments to nedal_m1 (see
VARARGIN)

% Choose default command line output for nedal_m1
handles.output = hObject;

% Update handles structure
guidata(hObject, handles);

% UIWAIT makes nedal_m1 wait for user response (see
UIRESUME)
are returned to the command line.
function varargout = nedal_m1_OutputFcn(hObject, eventdata,
handles)
% varargout  cell array for returning output args (see
VARARGOUT);
% hObject    handle to figure
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)

% Get default command line output from handles structure
varargout{1} = handles.output;

```

```

function edit1_Callback(hObject, eventdata, handles)
% hObject      handle to edit1 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% Hints: get(hObject,'String') returns contents of edit1 as
text
%           str2double(get(hObject,'String')) returns contents
of edit1 as a double

% --- Executes during object creation, after setting all
properties.
function edit1_CreateFcn(hObject, eventdata, handles)
% hObject      handle to edit1 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      empty - handles not created until after all
CreateFcns called

% Hint: edit controls usually have a white background on
Windows.
%           See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit2_Callback(hObject, eventdata, handles)
% hObject      handle to edit2 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% Hints: get(hObject,'String') returns contents of edit2 as
text
%           str2double(get(hObject,'String')) returns contents
of edit2 as a double

% --- Executes during object creation, after setting all
properties.
function edit2_CreateFcn(hObject, eventdata, handles)
% hObject      handle to edit2 (see GCBO)

```



```

% eventdata reserved - to be defined in a future version
of MATLAB
% handles empty - handles not created until after all
CreateFcns called

```

```

% Hint: edit controls usually have a white background on
Windows.

```

```

% See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

```

function edit3_Callback(hObject, eventdata, handles)
% hObject handle to edit3 (see GCBO)
% eventdata reserved - to be defined in a future version
of MATLAB
% handles structure with handles and user data (see
GUIDATA)

```

```

% Hints: get(hObject,'String') returns contents of edit3 as
text

```

```

% str2double(get(hObject,'String')) returns contents
of edit3 as a double

```

```

% --- Executes during object creation, after setting all
properties.

```

```

function edit3_CreateFcn(hObject, eventdata, handles)
% hObject handle to edit3 (see GCBO)
% eventdata reserved - to be defined in a future version
of MATLAB
% handles empty - handles not created until after all
CreateFcns called

```

```

% Hint: edit controls usually have a white background on
Windows.

```

```

% See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

```

```

function edit4_Callback(hObject, eventdata, handles)
% hObject handle to edit4 (see GCBO)
% eventdata reserved - to be defined in a future version
of MATLAB

```

```

% handles      structure with handles and user data (see
GUIDATA)

% Hints: get(hObject,'String') returns contents of edit4 as
text
%      str2double(get(hObject,'String')) returns contents
of edit4 as a double

% --- Executes during object creation, after setting all
properties.
function edit4_CreateFcn(hObject, eventdata, handles)
% hObject      handle to edit4 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      empty - handles not created until after all
CreateFcns called

% Hint: edit controls usually have a white background on
Windows.
%      See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit5_Callback(hObject, eventdata, handles)
% hObject      handle to edit5 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% Hints: get(hObject,'String') returns contents of edit5 as
text
%      str2double(get(hObject,'String')) returns contents
of edit5 as a double

% --- Executes during object creation, after setting all
properties.
function edit5_CreateFcn(hObject, eventdata, handles)
% hObject      handle to edit5 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      empty - handles not created until after all
CreateFcns called

```

```
% Hint: edit controls usually have a white background on Windows.
```

```
% See ISPC and COMPUTER.  
if ispc && isequal(get(hObject,'BackgroundColor'),  
get(0,'defaultUicontrolBackgroundColor'))  
    set(hObject,'BackgroundColor','white');  
end
```

```
function edit6_Callback(hObject, eventdata, handles)  
% hObject handle to edit6 (see GCBO)  
% eventdata reserved - to be defined in a future version  
of MATLAB  
% handles structure with handles and user data (see  
GUIDATA)
```

```
% Hints: get(hObject,'String') returns contents of edit6 as  
text
```

```
% str2double(get(hObject,'String')) returns contents  
of edit6 as a double
```

```
% --- Executes during object creation, after setting all  
properties.
```

```
function edit6_CreateFcn(hObject, eventdata, handles)  
% hObject handle to edit6 (see GCBO)  
% eventdata reserved - to be defined in a future version  
of MATLAB  
% handles empty - handles not created until after all  
CreateFcns called
```

```
% Hint: edit controls usually have a white background on  
Windows.
```

```
% See ISPC and COMPUTER.  
if ispc && isequal(get(hObject,'BackgroundColor'),  
get(0,'defaultUicontrolBackgroundColor'))  
    set(hObject,'BackgroundColor','white');  
end
```

```
function edit7_Callback(hObject, eventdata, handles)  
% hObject handle to edit7 (see GCBO)  
% eventdata reserved - to be defined in a future version  
of MATLAB  
% handles structure with handles and user data (see  
GUIDATA)
```

```
% Hints: get(hObject,'String') returns contents of edit7 as  
text
```

```
%          str2double(get(hObject,'String')) returns contents
of edit7 as a double
```

```
% --- Executes during object creation, after setting all
properties.
```

```
function edit7_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit7 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    empty - handles not created until after all
CreateFcns called
```

```
% Hint: edit controls usually have a white background on
Windows.
```

```
%          See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```
function edit8_Callback(hObject, eventdata, handles)
% hObject    handle to edit8 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)
```

```
% Hints: get(hObject,'String') returns contents of edit8 as
text
```

```
%          str2double(get(hObject,'String')) returns contents
of edit8 as a double
```

```
% --- Executes during object creation, after setting all
properties.
```

```
function edit8_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit8 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    empty - handles not created until after all
CreateFcns called
```

```
% Hint: edit controls usually have a white background on
Windows.
```

```
%          See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
```

end

```
function edit9_Callback(hObject, eventdata, handles)
% hObject      handle to edit9 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% Hints: get(hObject,'String') returns contents of edit9 as
text
%           str2double(get(hObject,'String')) returns contents
of edit9 as a double
```

```
% --- Executes during object creation, after setting all
properties.
```

```
function edit9_CreateFcn(hObject, eventdata, handles)
% hObject      handle to edit9 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      empty - handles not created until after all
CreateFcns called
```

```
% Hint: edit controls usually have a white background on
Windows.
```

```
%           See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end
```

```
function edit10_Callback(hObject, eventdata, handles)
% hObject      handle to edit10 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)
```

```
% Hints: get(hObject,'String') returns contents of edit10
as text
%           str2double(get(hObject,'String')) returns contents
of edit10 as a double
```

```
% --- Executes during object creation, after setting all
properties.
```

```

function edit10_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit10 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    empty - handles not created until after all
CreateFcns called

% Hint: edit controls usually have a white background on
Windows.
%         See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

function edit11_Callback(hObject, eventdata, handles)
% hObject    handle to edit11 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)

% Hints: get(hObject,'String') returns contents of edit11
as text
%         str2double(get(hObject,'String')) returns contents
of edit11 as a double

% --- Executes during object creation, after setting all
properties.
function edit11_CreateFcn(hObject, eventdata, handles)
% hObject    handle to edit11 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    empty - handles not created until after all
CreateFcns called

% Hint: edit controls usually have a white background on
Windows.
%         See ISPC and COMPUTER.
if ispc && isequal(get(hObject,'BackgroundColor'),
get(0,'defaultUicontrolBackgroundColor'))
    set(hObject,'BackgroundColor','white');
end

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.

```

```

% --- Otherwise, executes on mouse press in 5 pixel border
or over edit1.
function edit1_ButtonDownFcn(hObject, eventdata, handles)
% hObject    handle to edit1 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit2.
function edit2_ButtonDownFcn(hObject, eventdata, handles)
% hObject    handle to edit2 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit3.
function edit3_ButtonDownFcn(hObject, eventdata, handles)
% hObject    handle to edit3 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit4.
function edit4_ButtonDownFcn(hObject, eventdata, handles)
% hObject    handle to edit4 (see GCBO)
% eventdata  reserved - to be defined in a future version
of MATLAB
% handles    structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit5.
function edit5_ButtonDownFcn(hObject, eventdata, handles)

```

```

% hObject      handle to edit5 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit6.
function edit6_ButtonDownFcn(hObject, eventdata, handles)
% hObject      handle to edit6 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit7.
function edit7_ButtonDownFcn(hObject, eventdata, handles)
% hObject      handle to edit7 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit8.
function edit8_ButtonDownFcn(hObject, eventdata, handles)
% hObject      handle to edit8 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit9.
function edit9_ButtonDownFcn(hObject, eventdata, handles)
% hObject      handle to edit9 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB

```



```

% handles      structure with handles and user data (see
GUIDATA)

% --- If Enable == 'on', executes on mouse press in 5 pixel
border.
% --- Otherwise, executes on mouse press in 5 pixel border
or over edit10.
function edit10_ButtonDownFcn(hObject, eventdata, handles)
% hObject      handle to edit10 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% --- Executes on button press in pushbutton1.
function pushbutton1_Callback(hObject, eventdata, handles)
clc

inp1=get(handles.edit1,'string');
inp1=eval(inp1)
inp1=(inp1-1)/5
inp2=get(handles.edit2,'string');
inp2=eval(inp2)
inp2=(inp2-1)/7
inp3=get(handles.edit3,'string');
inp3=eval(inp3)
inp3=(inp3-1)/5
inp4=get(handles.edit4,'string');
inp4=eval(inp4)
% inp4=(inp4-1)/4
inp5=get(handles.edit5,'string');
inp5=eval(inp5)
% inp5=(inp5-1)/2
inp6=get(handles.edit6,'string');
inp6=eval(inp6)
% inp6=(inp6)/3;
inp7=get(handles.edit7,'string');
inp7=eval(inp7)
% inp7=(inp7)/3
inp8=get(handles.edit8,'string');
inp8=eval(inp8)
% inp8=(inp8-1)/2
inp9=get(handles.edit9,'string');
inp9=eval(inp9)
% inp9=(inp9)/2
inp10=get(handles.edit10,'string');
inp10=eval(inp10)
% inp10=(inp10-1)/1

```

```

% message='please note that input 1 ,input 2 and input 3
must be between ( 0 - 100)';
% if ((inp1 > 100)|| (inp2 > 100)|| (inp3 > 100))
%     set(handles.textout,'string',message);
% else

a=readfis('nedal_m1')

output=evalfis ([inp1 inp2 inp3 inp4 inp5 inp6 inp7 inp8
inp9 inp10],a)
set(handles.edit11,'string',output);

% hObject      handle to pushbutton1 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      structure with handles and user data (see
GUIDATA)

% --- Executes during object creation, after setting all
properties.
function text10_CreateFcn(hObject, eventdata, handles)
% hObject      handle to text10 (see GCBO)
% eventdata    reserved - to be defined in a future version
of MATLAB
% handles      empty - handles not created until after all
CreateFcns called

```