EXPERT SYSTEM ON MARK - UP SIZE DECISION IN COMPETITIVE BIDDING

BY

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THE THESIS SUBMITTED IN PARTIAL FULFILMENT OF THE REQUIREMENT FOR THE DEGREE OF MASTER OF SCIENCE (CONSTRUCTION PROJECT MANAGEMENT)

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Declaration

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To my Parents
for their endeavours.......

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Oct 2005 *G R S Pathirana*

Abstract

In line with the advancement of society, the construction industry with no exception, has been upgrading rapidly. As the contributors to the construction industry raises the complexity of the industry too raises demanding us to explore and analyze the industry with much needed attention. The bidders who can cope up with the competitive nature of the bidding only will survive. Therefore it is very much in importance to have a bidding strategy, which leads to win- win situation to both the client and the contractor.

The critical early analysis of factors affecting the mark- up size decision for any given project plays a vital role.

The contractors' behavior of bidding affects by a large number of factors which ranging from the construction company characteristics (internal to the company considered) to Macro Economic environment (society at large) including the project specific characteristics.

In this context the bidding decisions are of highly complex, unstructured where clear guidelines are difficult to set up. The decisions on bidding will be usually made based on the intuition and experience of the domain experts. The aim of this exercise is to develop a Knowledge Based System (KBS) to help the contractors to streamline their attention on to most critical factors identified, which are affecting bidding decision and to suggest a reasonable range of mark up size for a given project under specific context.

There were ten important factors selected through intensive literature review; Availability of Projects, Need for work, Owner Client relation, Past profits in similar projects, Rate of return in investment, Experience in similar projects, Cash flow (negative), Current work load, Competition, and the KBS was developed using the Fuzzy logic tool box on Matlab platform.

This KBS enables the decision makers to evaluate the impact of said factors on a specific bid situation. Given the subjective nature of the mark up size decision the Fuzzy set theory, which is a sub branch of Artificial Intelligence (AI), enables the assessments to be arrived in qualitative and approximate terms. Seven decision rules were constructed based on the expert comments. Seven sets of data analysis were carried out in this system.

The quality of information and awareness of the decision on mark up size of a particular tentative project that can be gained from this model may help the construction companies to obtain a competitive edge in bidding.

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1. INTRODUCTION

1.1 BACKGROUND

The contribution of the construction industry for the economy and social development of any country whether developed or not is vital. The improvements in the infrastructure for any society are never ending.

The combination of the effort made by the players involved in the construction industry it self give an idea about the complexity of the construction industry. The competitiveness of the industry has increased dramatically due to the technological advancements related to the industry and the dynamic nature of the customer demand. Even the simplest of construction projects involve many different participants assembled into a once only team. The generic organizational structure of the U.K. construction industry is shown in Fig. 1 (Brown et.al., 2001), and illustrates the range of contributors that are required for a construction project. The construction industries in other developed countries will have equally extensive and complex structures.

It is very much in importance to consider the selection of best possible project team in order to get the maximum economic benefit to the client and thereby to the society as a whole. The selection of contractors for this purpose has increasingly become a competitive game and plays a vital role in any given project for its success. Methods have been introduced to select the contractors by generating the competition among them.

The most commonly used method of selection of contractors is the open competitive bidding in which the bidding opportunity is open to all competent contractors. This method guarantees the all-competent contractors are given the equal opportunity to take part in a project. On the other hand the client can obtain the maximum advantage on QCD (i.e. quality, cost, timely delivery). Hence for any construction company, being able to deal with any bidding situations is of crucial importance, especially in today's highly competitive construction market.

As mentioned it is evident that the construction bidding is a serious scientific game and it is entrusted to the professionals who are perceived dependable. Much information is needed in pre-bid stage; prices of materials and those availability, labour climate, tender conditions, technology and resource requirement etc are to name a few of those. The performance of a construction contractor in the competitive environment is important and the availability of information and the proper use of those will ease the confidence in bidding decisions including mark-up size decision.

Researchers have argued that the bidding decision tend to be based on intuition and experience, and involve emotional responses to the pressures of the moment (Fayek, 1998). However, the thorough knowledge of the factors affecting in bidding and critical analysis of those are vital, in identifying the optimum bid mark-up. The contractors will set the mark up at a level perceived to be sufficient to win the tender at a margin that is in line with the strategy of the firm within the market.

A considerable number of researches in this context have been done by various academics in various part of the world for decades. Most of them have identified that the proper identification of factors affecting the construction bid decisions are of crucial importance. Ahmed and Minkarah (1988), Shash (1993) suggested that a thorough investigation of the underlying factors affecting the bid decisions is essential before attempting to develop a realistic bidding strategy. Lifson and Shaifer (1982) argued that knowing the importance of the factors affecting the decision making process would allow key and major decisions to be reviewed and discussed regularly. Dozzi et.al (1996) have stated that contractors need to take into consideration numerous factors when evaluating their bids.

Most of the researchers indicated that factors influencing the growth, security and reputation of a company should be taken into consideration during the bid mark-up decision. Drew and Skitmore (1997) identified several factors affecting competitiveness in bidding. However, their research was focused only on contract size and type. Ahmed and Minkarah (1988) identified 31 factors affecting bid mark-up decisions made by the top general contractors in USA. Shash and Abdul-Hadi (1992) further developed this research and presented 37 factors underlying the mark-up size decision, with the relative importance to contractors operating in Saudi Arabia. Shash (1993) revised the questionnaire by Ahmed and Minkarah (1988) and suggested 55 factors that they argued to be appropriate and applicable to the tendering decisions considered by top UK contractors.

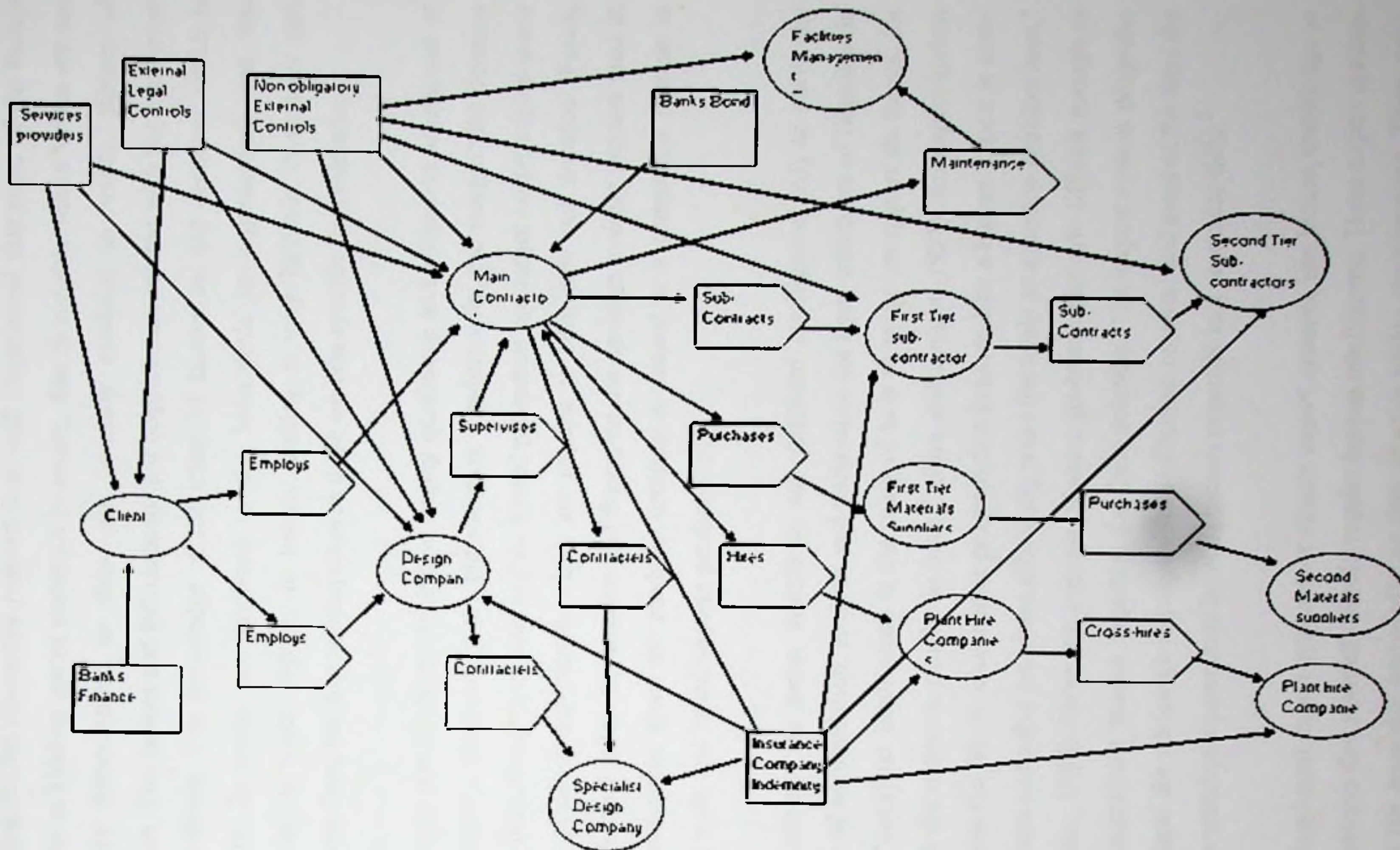


Fig 1. Contributors of the Construction Industry

Source: Brown et a (2001)

According to the researches referred it is well emphasized that most of the factors affecting in bidding are of uncertain in nature, that is variable whose values are not explicitly demonstrated as those are normally available in words, phrases of sentences. The factors and influence for bid decisions are related with the experience of individuals. The knowledge of the effect of factors on bid decisions which is uncertain, imprecise are confined to the individuals in organizations and this knowledge is quite abstract in nature, making it very difficult to transfer this experience from humans to computers as these are less specific than numeric.

The margin size decision involves a largely qualitative and subjective assessment of the conditions surrounding the bid situation. Traditionally, the margin size decision has not been based on a standard or formal procedure but rather on principles learnt through years of experience, which are applied to each new bid situation (Fayek, 1998). A need exists to structure and formalize the decision making process used in setting a margin, since the mark-up decision is critical to a company's success in winning work and its subsequent profitability.

In this context the paper intends to use Artificial Intelligence (AI) to solve the problem of accumulation, analysis and retrieval of the data, which are of linguistic in nature. "Artificial Intelligence is the study of how to make computers do things, for which at the moment, people do better" (Rick and Knight, 1991). An expert system which uses the AI is a computer program that behaves like a human expert in some useful ways and solve problems efficiently and effectively in a narrow problem area." (Waterman, 1986) Those are capable of solve problems that are difficult enough to require significant human expertise for their solution. The expert system programs could mimic the advice-giving capabilities of human experts" and most of the time the solutions matches a competent level of human expertise in a particular field."

Knowledge-based expert systems, or simply expert systems, use human knowledge to solve problems that normally would require human intelligence. These expert systems represent the expertise knowledge as data or rules within the computer. These rules and data can be called upon when needed to solve problems. Books and manuals have a tremendous amount of knowledge but a human has to read and interpret the knowledge for it to be used. Conventional computer programs perform tasks using conventional decision-making logic containing little knowledge other than the basic algorithm for solving that specific problem and the necessary boundary conditions. This program knowledge is often embedded as part of the programming code, so that as the knowledge changes, the program has to be changed and then rebuilt.

Knowledge-based systems collect the small fragments of human know-how into a knowledge base, which is used to reason through a problem, using the knowledge that is appropriate. A different problem, within the domain of the knowledge-base, can be solved using the same program without reprogramming. The ability of these systems to explain the reasoning process through back-traces and to handle levels of confidence and uncertainty provides an additional feature that conventional programming do not handle.

Here the techniques of Fuzzy logic will be used for the development of the model, which help a decision maker choose an appropriate margin to add to the estimated cost of the project. The techniques of Fuzzy logic will enable us to organize professional knowledge, which is uncertain and imprecise in nature. In retreating from precision in the face of overpowering complexity, it is natural to explore the use of these linguistic variables i.e. the variables with values are not presented in numeric but in languages with no crisp values. As these facts or user supplied information are imprecise and uncertain, the Fuzzy reasoning techniques can be used for the basis of representing imprecision inherent to the in an expert's knowledge. The uncertainty nature usually arises from system complexity and the input and out put we use in the system is not precise. By encoding the input and out put variables in fuzzy system with those inter-relationships in a form of well defined *if/then* rules allows us a far greater flexibility in formulating system descriptions at the approximate level of detail. Fuzziness has lot to do with the parsimony and hence accuracy and efficiency of a description considered (Tsoukalas and Uhrig 1997). This means that the complex process behaviour can be described in general terms without precisely defining the complex (usually non-linear) phenomena involved.

1.2 MAIN OBJECTIVES

Based on the above background the followings are the main objectives of the project.

1. To identify the key factors affecting the bid mark-up size decision in construction competitive bidding
2. To review the existing traditional bidding models and their applicability
3. To develop and test a Knowledge Based (KB) Artificial intelligence (AI) using Fuzzy logic for stochastic decision on mark-up size decision In Competitive Bidding.

Sub Objectives

- To review the factors affecting the mark-up size on competitive bidding
- To develop a knowledge base.
- To prototype the KBS.
- To test the model for feasibility and accuracy of the system.

1.3 METHODOLOGY

This research was started with extensive literature reviews on the various publications. A range of relevant publications/research papers were studied and this study consisted of critical reviewing of traditional bidding models for those validity and applicability with giving much attention on to the restrictions/limitations of those models.

Studied extensively about the factors affecting on bidding at pre bid situations with little emphasis of Estimating. The papers referred on this were ranging from developing countries to developed countries, where the construction industry shows distinct behaviors. However, most of the literatures referred were confined to the construction of buildings. Further, studied about the methodologies used to obtain the data required in each research and those were guided to model interview guideline data collection procedures and formation of Questionnaires.

Then conducted the semi structured interviews with professionals in the industry and collected the data through Questionnaire surveys. These data guided to draft the term of references, of the system for the proposed mathematical model. The data collected through Questionnaire surveys were analyzed statistically and results used for conceptual modeling of the system.

Then the conceptual model was used for the development of knowledge based system on Artificial Intelligence using Fuzzy logic tool box in MATLAB R11.

Finally, the system was tested for its applicability and accuracy with a real reference data from a Construction organization.

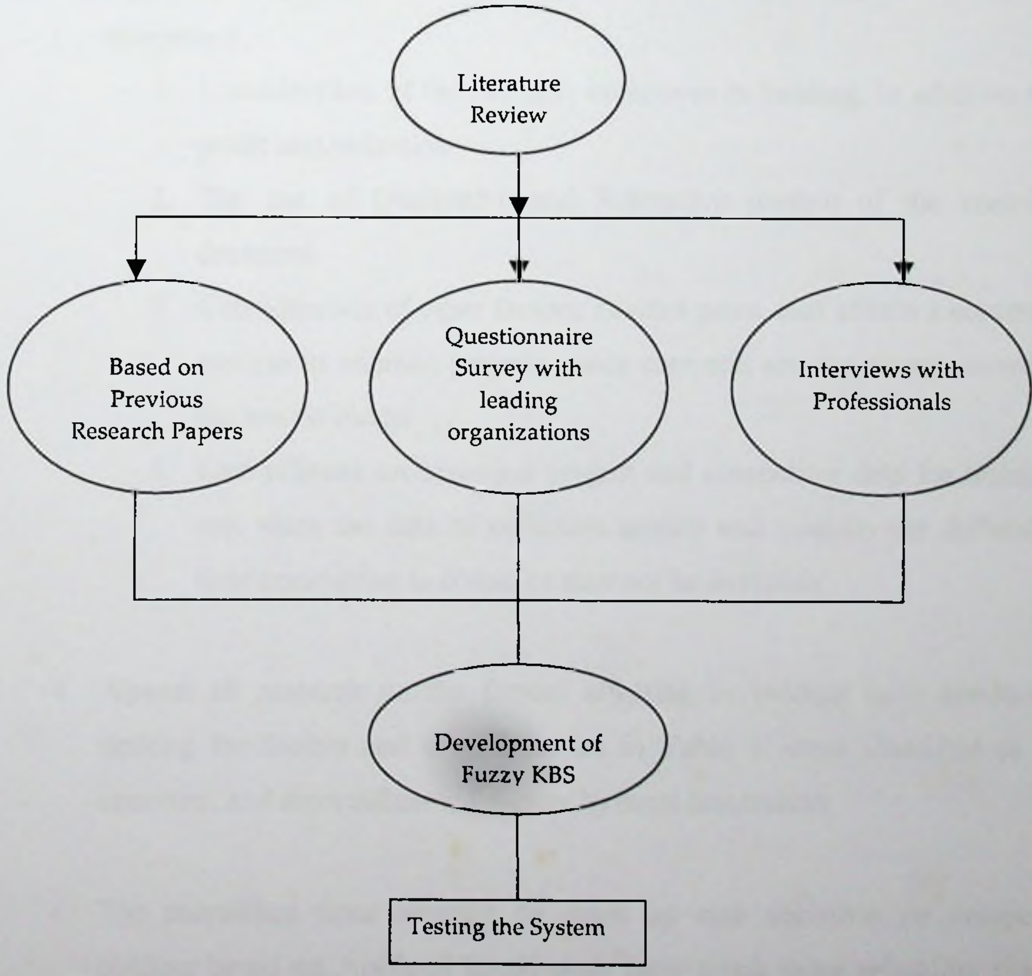


Fig 2. Research Methodology

for the development of KBS

1.4 MAIN FINDINGS

- The most of mathematical models done by researchers have not got the much acceptance in the industry due to the assumptions made by them. Some of the assumptions contributed to the non acceptance of the previous models are
    1. Competitors will bid as they have done in the past;
    2. Competitors bid to maximize total expected profit;
    3. The ratio of actual cost to estimated cost is unity.
    4. The models are incomplete and model only a tiny part of the situation

- The following factors to be addressed in a new bidding model for wider acceptance.
    1. Consideration of the multiple objectives in bidding, in addition to the profit maximization
    2. The use of Qualitative and Subjective portion of the contractors decisions
    3. Consideration of other factors, besides price, that affects a contractor's success in winning projects, since contracts are not always awarded to the lowest bidder
    4. Less reliance on historical project and competitor data for training or use, since the data of sufficient quality and quantity are difficult and time-consuming to obtain or may not be available

- Almost all research on the factors affecting in bidding have conducted a ranking for factors and the 10 factors in Table 1, were identified as most common, and most influential factors by most researchers.

- The researches done recently on mark up size decisions on competitive bidding based on Artificial Intelligence have much more reliability than the mathematical models done in the era of Fridmen and Gates. Hence, the development of fuzzy logic based model for competitive bidding will be relevant in the industry.

- The method of fuzzy logic is more reliable to model the uncertain – linguistic conditions, prediction into crisp values to obtain meaningful outputs.

- The model developed in the bid mark-up size on the competitive bidding based on fuzzy logic achieved reasonably reliable outputs; the deviations from the predictions by a domain expert and KBS developed (CombiD) are varied only about +/- 5 % to 20 % range, in building construction projects.

Table 1. Selected factors with Sources

Factor(s)	**Source (s)**
1.Availability of Projects *Bidding Situation*	• Ali A. Shash (1993) • Chua D.K H. and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)
2.Need for work *Related to the firm*	• Ali A. Shash (1993) • Chua D.K.H. and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)
3.Owner /Client identity *Related to the firm*	• Chua D.K.H. and Li D. (1999) • Ali A. Shash (1993) • Dulaimi M.F. and Guo Shan (2002)
4.Past profits in similar projects *Related to the firm*	• Ali A. Shash (1993) • Chua D.K.H. and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)
5.Rate of Return *Economic situation*	• Ali A. Shash (1993) • Chua D.K.H. and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)
6.Risk involvement *Economic situation*	• Ali A Shash (1993) • Chua D.K.H and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)

7. Experience in similar Projects *Related to the firm*	• Ali A. Shash (1993) • Chua D.K.H. and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)
8. Project Cash Flow (based on cash flow diagram) *Project characteristic*	• Ali A. Shash (1993) • Chua D.K.H. and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)
9. Current work load Volume of all current Projects the company has committed *Related to the firm*	• Ali A. Shash (1993) • Chua D.K.H. and Li D. (1999) • Dulaimi M.F. and Guo Shan (2002)
10.Competition *Bidding situation*	• Ali A. Shash (1993) • Dulaimi M.F. and Guo Shan (2002)

1.5 PLAN OF THE THESIS

The content of each chapter of this thesis is as follows.

Chapter 1

This chapter describes the background of the problem, the problem definition, and objective of the research, research methodology and the outline of the research.

Chapter 2

This chapter confined to the literature review relevant to the research and, describes and comments on the findings based on

Factors affecting in Bidding

Revisiting of bidding models, extensive review of the usage of Artificial Intelligence and Expert Systems in Competitive Bidding Models.

Chapter 3

This chapter describes the system development on Fuzzy KBS for mark-up size decision. The description consists of conceptual design of the system, physical development of the system, Fuzzification De-Fuzzification etc. of the system and system performance also evaluated in this chapter.

Chapter 4

The use of the developed CombiD system, conclusion about the research and recommendations on what directions this research could be extended is discussed, giving the much-needed emphasis on how the objectives of the research are achieved, in this chapter.

2 LITERATURE REVIEW

2.1 FACTORS AFFECTING IN BIDDING

2.1.1 Introduction

The tendering process involves two crucial decisions. The first decision is the Bid or No-bid decision for a given project. The importance of the tender decision emerges from its financial consequences. The decision implies the incurring of substantial costs, which may not be recovered immediately. The value of the decision outcome is not defined. That is, if the contractor decides not to bid, an opportunity loss might be incurred. On the other hand, if the contractor decided to bid, the direct and indirect costs that the project will consume have to be estimated. Tendering job involves the contractor in preparing an estimate, which requires the commitment of resources (for example financial deposits for bidding document and estimator's hours).

The second decision is associated with the determination of the price under the traditional cost plus markup pricing model, the contractor calculated the cost of direct and indirect labour, equipment, and materials that will be consumed in the project. Then, the contractor marks up the estimated cost by a certain percentage to cover his/her office overhead, contingencies, and profit. The contractor wants to decide on a markup size that chance of achieving a domination criterion of the competition. For example, if price dominates the competition, each contractor will attempt to offer a price that maximizes the differences between his/her bid and the bid price of a rival competitor. In the event of an unsuccessful bid, the contractor has to be prepared to write off the preparation costs involved. The importance of the markup size decision derives from its direct bearing on the contractor's business. A contractor must secure a designated business volume in a fiscal year to cover his/her operation costs and to realize a reasonable profit. Failure to do so will force the contractor into one of the following actions: to reduce his/her operating capacity, to liquidate the business, or to declare bankruptcy.

Both the above decisions are very important to every contractor as these decisions stems from the fact that the success or failure of a contractor's business lies in the outcomes, derived from those decisions. Both decisions are considered complex due to the two following elements:

- The consequences of each alternative are uncertain (this uncertainty rules out any guarantee that the best outcome is obtained), and
- The large number of factors having considerable effect on both decisions (Ahamad and Minkarah, 1988).

The complexity associated with these two decisions suggests the use of a modeling technique to develop representative models that will aid contractors in making a proper choice. The development of the model entails as a prerequisite the identification of the factors affecting such decisions.

2.1.2 Previous Researches

Through the literature review it was revealed that the researchers have not put a great interest on the bid/no bid decision, other than the Ahmed and Minkarah (1988) whose attempt had identified 31 factors influencing the bid / no bid decision of US contractors.

There are more papers on mark-up size decision, which are developed on the base of the pioneering work of Frideman (1956) and Gates (1967). But there is not much acceptance in these models among the practitioners and instead they tend to more rely on their experience and know how of the construction industry.

The situation is happening mainly due to the researchers have developed their mathematical models by over simplification of the situation, so that the yield outcomes that give no significant value for practitioners. Some of the parameters used in developing the mathematical models are as follows.

- Competitors will bid as they have done in the past
- Competitors bid to maximize total expected profit
- The ratio of actual cost to estimated cost is unity.
- The models are incomplete and model only a tiny part of the situation (Bell, 1969)

It is therefore emphasized that the looking beyond the original framework of the problem is essential rather than testing the validity of the work done by Friedman 1956 etc., whose work in the bidding model assumed to be the foundation in the field.

It is much important that to consider the key factors in bidding and as the bidding decision is a complex decision-making process that is affected by numerous factors. To study how bid decisions are made, it is important to identify the underlying key determining factors. Surveys by Ahmad and Minkarah (1988), Shash and Abdul-hadi (1992) and Shash (1993) have identified some of the important factors in the bid/no bid and markup decision-making

In addition Chua and Li (2000) has taken challenge of this and studied how these decisions are to be made. They found that in actuality, a contractor arrive at a bid decision only after a complex reasoning process.

Through the interviews conducted by them, they have identified four main bidding considerations.

- Potential level of competition
- Possible Risk Margin
- Company's position in bidding
- Company's keenness of getting the job and these were the sub goals in reaching their bid decision.

Moreover, the effect of different contract types has also been considered, unlike previous studies. Depending on the type of contract, the exposure to risk and contractual obligations will differ. Consequently, the contractors will evaluate the bid decision differently. Accordingly, the various determining factors will contribute differently to the sub goals in the decision process. Altogether, three contract types have examined namely unit rate, lump sum, and design/build, being the prevailing forms of contract in the industry.

The technique of the Analytic Hierarchy Process (AHP) is adopted to establish the key determining factors. Unlike the usual ranking surveys, this approach not only ranks the factors but also determiner their relative importance toward the sub-goals through pair wise comparison between the factors.

With this technique, the factors have classified into several subset groups and systematically organized into various levels of hierarchies. In this case, four hierarchies have constructed focusing respectively on the four reasoning sub-goals.

Despite the researches done by Ahmed (1990), who had adopted the technique called Utility Value Approach whereas Moselli (1993), who used Neural Network model with large numbers of determining factors Chua and Li (2000) claims that the previous researches were not adequately modeled.

To address the heart of the problem Chua and Li (2000) has developed a model for bid reasoning as per the following Fig 3.

The model incorporated four key considerations (or reasoning sub goals) of the contractors in the bid decision process, namely, competition, risk, need for work, and company's position in the bidding. The potential key determining factors comprising internal and external factors support the bid decision through the four reasoning sub-goals.

Competition

The assignment of an appropriate level of markup to the base estimate is the critical part of a contractor's business strategy. To bid with a higher markup increases the profit it the bid can be won, but decreases the probability of winning. The probability of winning a bid is closely associated with the potential level of competition, which is commonly reflected by the number and competitiveness of the competitors. For a given project and level of risk, the keener the competition, the lower is the markup of the winning bid. The level of competition can be assessed from external factors pertaining to the nature of the project, bidding requirement, and the social-economic environment.

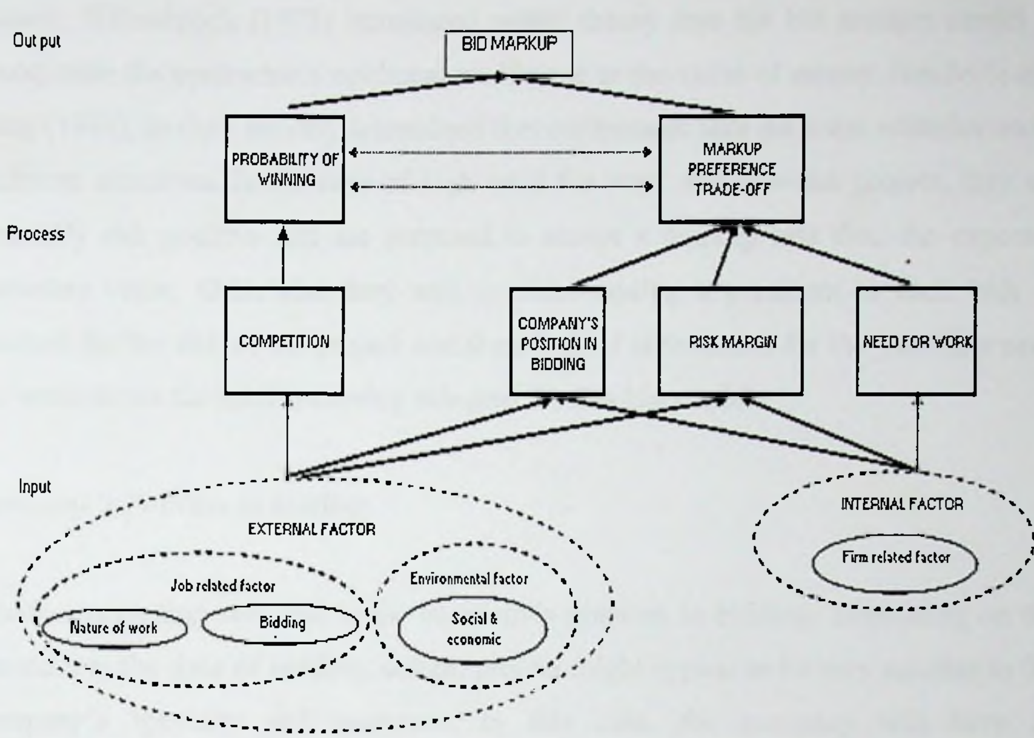


Fig 3. Multi-attribute Bid Reasoning Model Source: Chua &Li (2000)

Risk

The estimated cost forms the base for markup evaluation to arrive at the final bid. However, due to uncontrollable risk elements, the actual construction cost will never be exactly equal to the estimated construction costs. A contingency provision is usually included in the estimate for these elements. However, if it is inadequate, the cost overruns will cut into the markup and, in some cases, result in a pure loss at the end of the project for the contractor. In addition to external factors, the internal factors, which reflect the capabilities and resources of the company in relation to the project and environment, also determine the risk exposure.

Need for Work

For a given markup, the expected profit can be determined based on the level of competition and risk assessment. An optimal markup can then be ascertained to maximize expected profit. However, this assumes a linear preference to the value of money. Willenbrock (1973) introduced utility theory into his bid markup model to incorporate the contractor's nonlinear preference to the value of money. Neufville and King (1991), in their survey, determined that contractors take different attitudes under different situations. In the case of high need for work and low-risk project, they are generally risk positive and are prepared to accept a markup less than the expected monetary value. Otherwise they will consider adding a premium to their bids to account for the risk of the project and their lack of enthusiasm for the job. This need for work forms the third reasoning sub-goal for this bid model.

Company's Position in Bidding

Another reasoning sub goal is the company's position in bidding. Depending on the situation at the time of bidding, certain project might appear to be very suitable to the company's specialty and resources. In this case, the company will have an advantageous leverage in the competition over its competitors. A strong position in competition will make the company take a more risk-positive attitude.

By the literature, they have collected more than 50 factors that may be important from the perspective of the reasoning sub goals and those were categorized in two broad categories; internal factors and external factors as in the Table 2.

The internal factors are those inherently related to the company, including its experience, financial ability, resource possession, current workload, etc. these factors reflect the company's ability and present status. They evolve with time, but independent of job. The contractor can exert his control over most of these factors.

External factors are those that are job-related or uncontrollable by the contractor. These include factored related to the nature of the work, bidding requirement, and the social and economic environment. Factors pertaining to the nature of work, such as size of project, degree of technological difficulty, resource requirement, public exposure and prestige of the project, etc. reflect the pertinent features of the project.

Table 2. List of factors affecting in Bidding

Category	Reasoning sub goals and factors
External factors job related	*Nature of work* 1. Type of project 2. Size of project 3. Degree of technological difficulty 4. Cash flow requirement 5. Type and number of supervisory required 6. Type and number of labor required 7. Type and number *of* equipment required 8. Site accessibility 9. Project public exposure and prestige 10.Project timescale and penalty for non completion 11.Degree of subcontracting 12. Identity of owner/consultant 13.Safety hazards 14.Site space constraints 15.Consultants' interpretation of the specification Delay or shortage on payment 16.Bidding requirement 17. Required bond capacity 18. Pre qualification requirement 19. Bidding method (open/dose) 20. Time allowed for bid preparation 21. Completeness of drawing and specification
Environmental	*Social and economic condition* 22.Availability of Other projects 23.Availability of qualified labor 24.Availability of qualified staffs 25.Availability of equipment 26.Availability of qualified subcontractor 27.Government regulation 28.Degree of difficulty in obtaining bank loan 29.Resource price fluctuation
Internal factors	*Firm-related factors* 30. Expertise in management and coordination 31. Similar experience 32. Familiarity with site condition 33. Reliability of subcontractors 34. Current workload in bid preparation 35. Competence of estimators 36. Adequacy of resource market price information 37. Current workload of projects 38. Promotion of company reputation 39. Required rate of return in investment 40. General office's overhead recovery 41. Need for continuity in employment of key Personnel and work force

	Reasoning sub goals and factors
	42. Relationship with owner 43. Share of market 44. Financial ability 45. Strength of business partner/subsidiaries 46. Possession of qualified staffs 47. Possession of qualified labor 48. Possession of qualified subcontractor 49. Possession of required equipment 50. Company's ability *in* design involvement and innovation 51. Company's ability in required construction technique

Source Chua & Li (2000)

Most of the internal (firm-related) factors are not accessible to others and they vary from one company to another. Although they may affect the bid markup decision, there is no way to apply them to reason about the competition level the factors that can be employed to reason about the level. The factors that can be employed to reason about the level of competition are the external factors. On the other hand, the contractor's own internal factors would dictate directly his keenness to bid (i.e. need for work) for example, contractors with a current heavy workload will have no great interest for getting more new jobs. The interactions between the internal and external factors decide the level of risk and company's position in bidding

Based on the potential contributions of the four reasoning sub goals the factors in Table 2 are regrouped and organized in hierarchies as given in following figures.

- Fig. 4 Hierarchy of Competition Source ; (Chua & Li 2000)
- Fig. 5 Hierarchy of Risk Source ; (Chua & Li 2000)
- Fig. 6 Hierarchy of Need for Work Source ; (Chua & Li 2000)
- Fig. 7 Hierarchy of Company's position in Bidding Source ; (Chua & Li 2000)

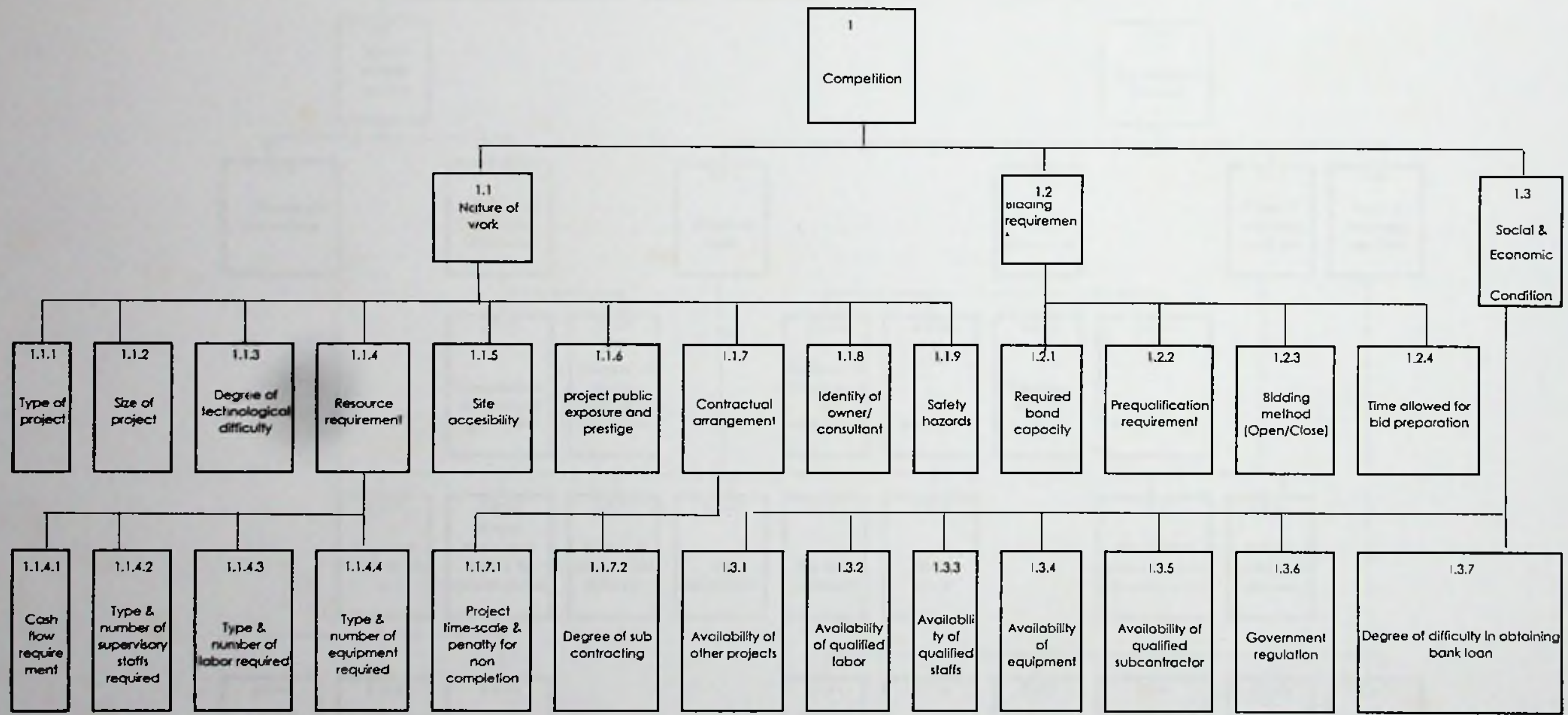


Fig. 4 Hierarchy of Competition

Source ,Chua &Li (2000)

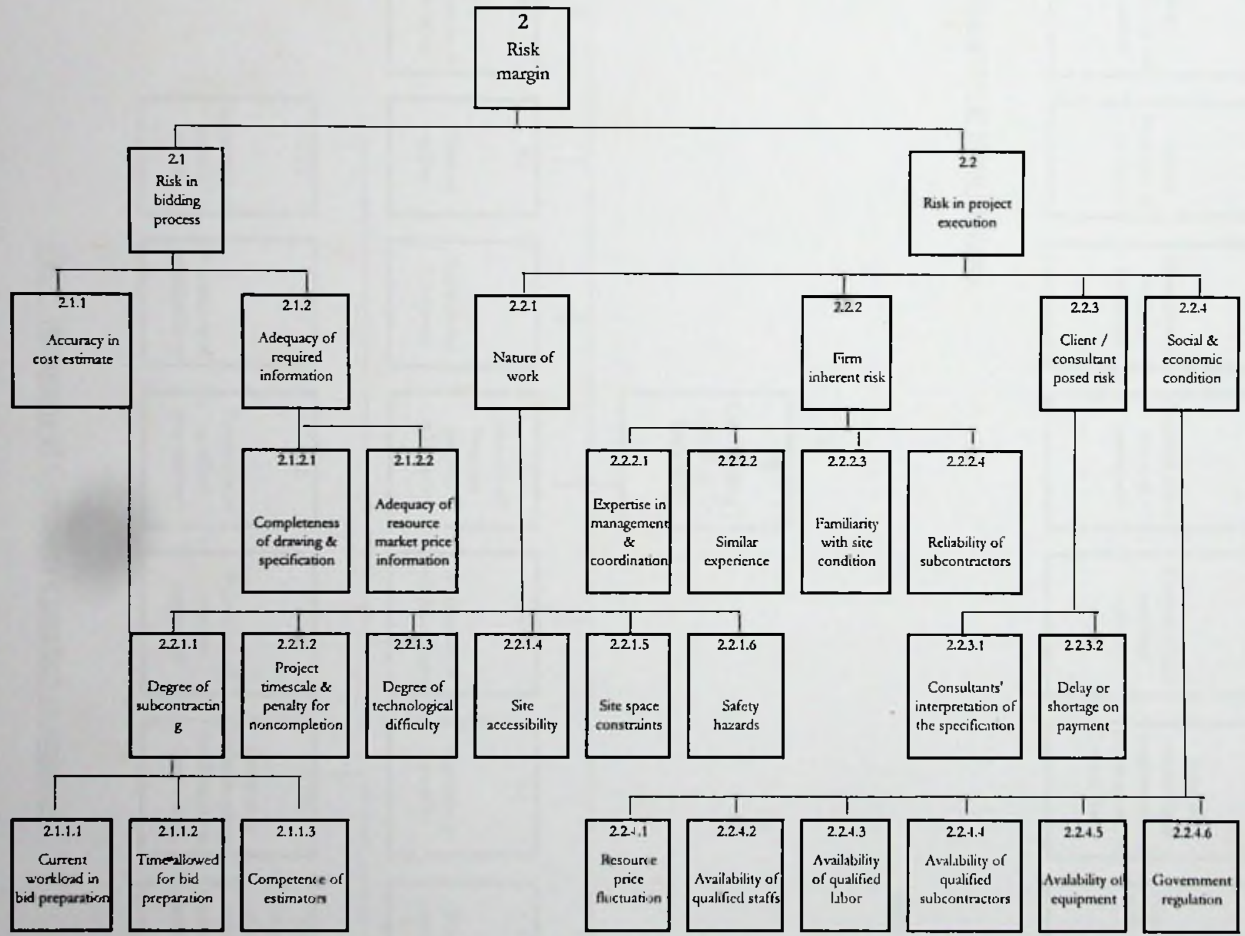


Fig.5 Hierarchy of Risk

Source ,Chua &Li (2000)

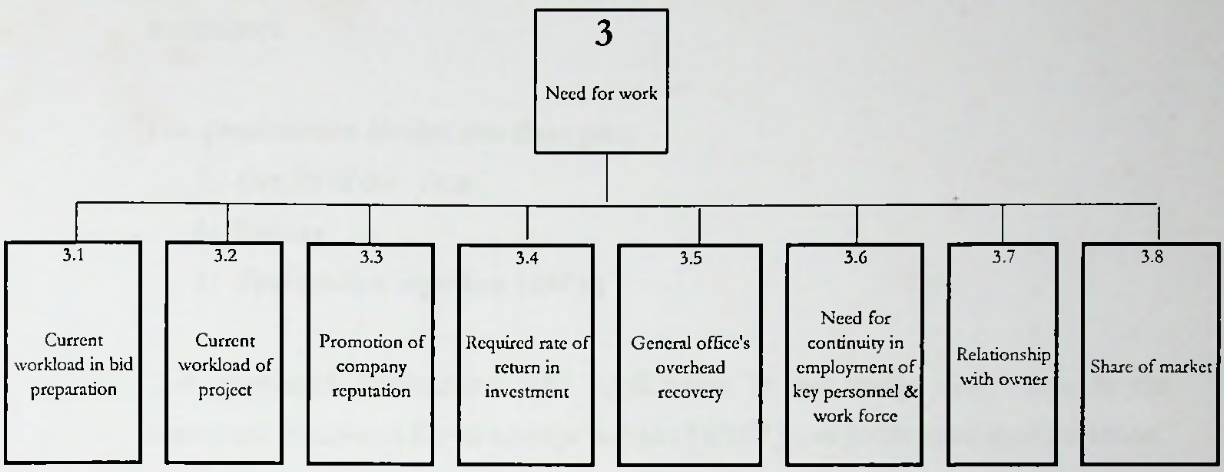


Fig. 6. Hierarchy of Need for Work

Source ;Chua &Li (2000)

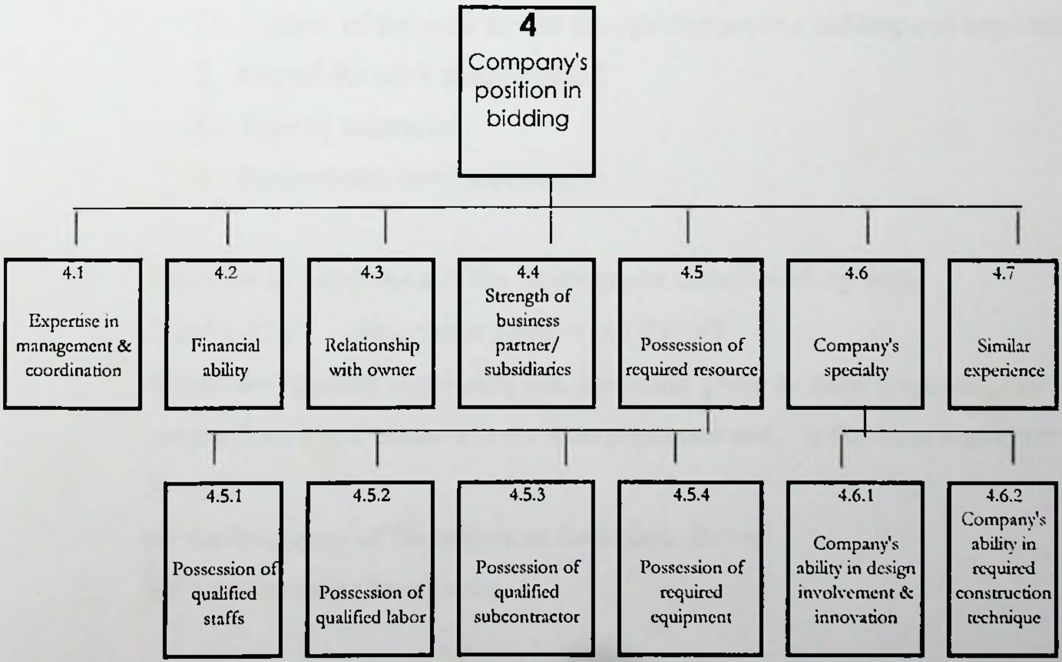


Fig.7. Hierarchy of Company's position in Bidding

Source ;Chua &Li (2000)

Similar study has conducted by Shash (1993) with the survey using 320 UK top contractors.

His questionnaire divided into three parts

1. Details of the firm.
2. Factors
3. Firms policy regarding bidding

The responded Contractors, who participated in the study, have been in the construction business for an average period of 60.87 years (with a standard deviation . of 54.76 years) and generating an annual average sales volume of 97.93 millions (with a S.D. of 163.12 million)

They have categorized the contractors by considering five types.

1. Average size of the job
2. Amount of the work obtain through competitive bidding and negotiation.
3. Size of the work subcontracted.
4. Type of contracts
5. Performance bond requirement

The level of importance of the factor s were determined by using

$\Sigma(ax) \times 100/7$ Importance Index = $(aX)*100/7$

Where a= constant expressing the weighting given to each response. The weighting ranges from 1 to 7 where 1 is the least important and 7 is the most important:

$X=n/N$;

n= the frequency of the responses for a given factor;

N= total number of responses.

In addition, the percentage of respondents scoring 3 or less,4 (the midpoint) , and 5 or higher on the developed scale was calculated each of factors . A score of 3 or lower represents the weak effect on decision. The factors are ranked according to their importance index.

The results obtained with the rank etc are given in Tables 3, 4 ,5 and 6.

Table 3. Factors affecting Bid / No bid Decision

Factors	Percentage of respondents scoring			No of Resp-onses	Import-ance index	Rank
	>=5	4	=<3			
Need for work	91.70	7.10	1.20	84	86.39	1
Number of competitors tendering	82.10	11.90	6.00	84	83.50	2
Experience in such projects	85.70	10.70	3.60	84	83.16	3
Current work load	83.40	9.50	7.10	84	83.16	4*
Owner/promoter client identity	82.40	9.40	8.20	85	78.82	5
Contract conditions	75.00	17.90	7.10	84	78.57	6
Project type	77.40	11.90	10.70	84	78.57	7*
Past profit in similar projects	73.80	10.70	15.50	84	76.36	8
Project size	72.90	18.80	8.20	85	75.46	9
Tendering method (selective, open)	68.60	16.90	14.50	83	75.17	10
Risk involved owing to the nature of the work	69.10	13.10	17.90	84	74.83	11
Project location	71.80	18.80	9.40	85	74.12	12
Type of contract	64.70	20.70	14.60	82	71.60	13
Availability of qualified staff	60.80	20.20	19.00	84	71.60	14*
Rate of return	69.50	14.60	15.90	82	71.43	15
Project cash flow	60.20	16.90	22.90	83	69.19	16
Tendering duration	68.60	13.30	18.10	83	69.19	17*
Availability of other projects	57.20	21.40	21.40	84	68.88	18
Availability of labour	56.40	21.40	20.20	84	68.71	19
Completeness of the documents	61.40	19.30	19.30	83	68.67	20
Risk involved in the investment	54.20	21.70	24.10	83	68.33	21
Quality of available labour	56.00	23.80	20.20	84	68.20	22
Designer/architect/engineer	59.00	14.50	26.50	83	67.13	23
Anticipated value of liquidated damages	50.60	28.90	20.50	83	66.61	24
Type and number of supervisory persons available	52.90	22.40	24.70	85	65.21	25
Competitiveness of competitors	51.20	23.80	25.00	84	64.40	26
Contractor involvement in design Phase	47.10	20.00	32.90	85	63.53	27
Confidence in company work force	48.20	26.50	25.30	83	62.99	28
Degree of difficulty	45.20	25.00	29.80	84	61.73	29
Company strength in the industry	44.40	27.20	28.40	81	59.93	30

Factors	Percentage of respondents scoring			No of Resp-onses	Import ance index	Rank
	>=5	4	=<3			
Reliability of company cost estimate	51.30	16.30	35.00	80	59.79	31
Design quality	45.70	20.50	33.70	83	59.04	32
Risk in fluctuation in labour prices	41.70	25.00	33.30	84	58.84	33
Degree of hazard (safety)	36.60	28.00	35.40	82	58.54	34
Availability of required cash	41.70	14.30	44.00	84	58.50	35
Risk in fluctuation in material prices	48.10	29.80	32.10	84	57.65	36
Labour environment (union/ non-union)	39.50	25.00	34.50	84	57.65	37*
Identity of competitors	36.10	21.70	42.20	83	57.49	38
Owner's special requirements	36.10	25.30	38.60	83	56.63	39
General (office) overhead	29.90	28.80	41.30	80	54.01	40
Public exposure	29.30	28.00	42.70	82	54.01	41*
Project start time	28.20	24.70	47.10	85	52.77	42
Portion subcontracted to nominated subcontractors	29.70	27.40	42.90	84	51 .81	43
Project duration	31.80	24.70	43.50	85	51.43	44
Availability of equipment	32.20	21.10	46.40	84	51.19	45
Type and number of supervisory persons required	28.90	24.70	49.40	85	50.92	46
Job related contingency	23.90	31.60	44.70	76	50.38	47
Portion subcontracted to domestic Subcontractors	23.50	35.50	41.20	85	49.58	48
Qualification requirements	28.00	24.40	47.60	82	49.30	49
Policy in production cost savings	20.80	28.00	51.20	82	47.50	50
Policy in economic use of building resources	19.60	28.00	52.40	82	46.86	51
Bond requirements	20.20	22.60	57.10	84	43.88	52
Government regulations	8.40	44.00	47.60	84	43.71	53
Insurance premium	6.00	22.90	71.10	83	36.66	54
Tax liabilities	6.00	20.50	73.50	83	33.73	55

Source : Shash (1993)

**Equal importance Indices : Ranked in accordance with the Percentage of respondents scoring 5 or Higher*

Table 4. Factors affecting the mark-up size decision

Factors	Percentage of respondents scoring			No of respondents	Importance index	Rank
	>=5	4	=<3			
Degree of difficulty	83.10	13.30	3.60	83	81.76	1
Risk involved owing to the nature of the work	70.70	17.10	12.20	82	77.18	2
Current work load	70.40	16.00	13.60	81	76.37	3
Need for work	64.90	13.80	21.30	80	73.57	4
Contract conditions	68.70	17.50	13.80	80	73.37	5
Anticipated value of liquidated damages	62.50	25.00	12.50	80	71.07	6
Owner/promoter client identity	62.60	20.50	16.90	83	70.57	7
Past profit in similar projects	60.50	17.30	22.20	78	69.14	8
Completeness of the documents	55.00	25.00	20.00	80	68.75	9
Project size	55.40	26.50	18.10	83	68.33	10
Risk involved in the investment	55.60	22.20	22.20	81	68.07	11
Type of contract	55.60	24.10	20.30	79	67.81	12
Rate of return	52.50	22.50	25.00	81	76.37	13*
Contractor involvement in the design phase	53.60	24.40	22.00	82	66.55	14
Project type	52.50	26.80	20.70	82	66.55	15*
Experience in such projects	53.10	24.70	22.20	81	66.49	16
Project cash flow	54.90	18.80	26.30	80	66.07	17
Risk in fluctuation in labour prices	52.40	22.00	25.60	82	65.16	18*
Quality of available labour	48.80	30.50	20.70	82	65.16	19
Availability of labour	47.90	29.60	23.50	82	64.55	20
Risk in fluctuation in material prices	47.60	28.00	24.40	82	64.11	21
Project location	42.70	37.80	19.50	82	63.41	22
Reliability of company cost estimate -	46.20	26.90	26.90	80	63.37	23
Availability of other projects	45.20	26.80	28.00	82	63.07	24
Degree of hazard (safety)	47.40	21.80	30.80	78	61.90	25
Designer/architect/engineer	42.50	27.50	30.00	80	61.43	26
Design quality	46.20	23.80	30.00	80	60.89	27
Number' of competitors tendering	42.00	28.40	29.60	81	60.32	28
Competitiveness of competitors	43.20	25.90	30.90	81	59.61	29
Owner's special requirements	37.40	28.80	33.80	80	59.46	30
Tendering method (selective, open)	36.70	34.20	29.10	79	59.31	31

Factors	Percentage of respondents scoring			No of respon dents	Import-ance index	Rank
	>=5	4	=<3			
Confidence in company work force	37.40	28.80	33.80	81	59.11	32
Availability of qualified staff	38.70	25.90	35.80	78	58.20	33
Project duration	33.80	30.10	36.10	83	56.45	34
Availability of required cash	32.40	31.30	36.30	78	55.71	35
Type and number of supervisory persons available	34.60	25.90	39.50	80	67.68	36
Labour environment (union/non-union)	35.90	25.60	38.50	78	54.76	37
Portion subcontracted to nominated subcontractor	35.50	17.70	46.80	78	54.64	38
Portion subcontracted to domestic subcontractors	34.60	22.20	43.20	79	53.79	39
Company strength in the industry	25.90	31.20	32.90	81	53.43	40
Identity of competitors	31.70	27.80	40.50	79	53.16	41
General (office) overhead	26.90	32.10	41.00	77	53.11	42
Project start time	42.70	37.80	19.50	83	52.50	43
Type and number of supervisory persons required	32.50	18.10	49.40	83	52.32	44
Job related contingency	23.70	31.90	44.40	72	51.39	45
Public exposure	20.50	33.30	46.20	80	50.73	46
Tendering duration	30.40	26.60	43.00	79	50.09	47
Qualification requirements	21.80	33.30	44.90	78	49.45	48
Availability of equipment	20.80	26.80	52.40	82	47.21	49
Policy in production cost savings	16.70	33.30	50.00	81	55.38	50
Policy in economic use of building resources	12.80	32.10	55.10	78	45.05	51
Government regulations	8.70	38.80	52.50	80	44.11	52
Insurance premium	10.10	21.50	68.40	79	37.61	53
Bond Requirements	11.20	23.80	65.00	80	37.32	54
Tax Liabilities	7.50	22.50	70.00	80	35.00	55

Source : Shash (1993)

**Equal importance Indices : Ranked in accordance with the Percentage of respondents scoring 5 or Higher*

Table 5. Factors affecting the Chance of winning a Project

Factors	Percentage of Respondents
Owner	54.20
Competitors	66.30
Type of Job	91.60
Strength in the Industry	48.20
Experience	83.10
Overall Economy	16.90
Others	8.40

Source : Shash (1993)

Table 6. Factors that make contractors feel desperate to obtain a job

Factors	Percentage of Respondents
Need of Work	90.20
Strength in the Industry	18.30
Size of Job	34.10
Location of the Project	56.10
General office overhead required	42.70

Source : Shash (1993)

Sri Lanka being a developing country the bidding consideration in developing countries by international contractors is important. As the infrastructure development projects are increasingly introduced in developing countries the new opportunities are increasing in the global market for international contractors to obtain work in many parts of the world, especially in the developing countries where there is a need for almost all types of constructions; new electrical utilities, highways, hospitals, housing and maintenance of existing infrastructure. Major events in the world such as the formation of organizations (e.g. ADB, World Bank, UNO) with the primary aim of improving the life style of the people in the third world countries are creating the opportunities in new constructions and designs .Acting on these opportunities definitely bringing the additional work and increased profits if a firm can handle the situation carefully.

Developing countries share a common set of characteristics that represent their overall level of development. Some of the most important similarities are given below.

- Government / Political Instability
- Low Standard of living
- Low levels of productivity
- High levels of under employment and unemployment
- Project Financing Characteristics.

Even though the above factors are differ from country to country the effect of these are to be considered vital as the above may definitely affect the construction projects.

The information gathered highlighted several areas that had the potential to be very important in a firm's decision on working abroad. Informational requirements were identified from literature surveys and a list of key informational requirements gathered is given below. (Jasellkis and Talukhaba, 1998)

1. *Type of Laws and Regulatory requirements*. Legal requirements (e.g. Permit requirements, taxes, safety rules, environmental requirements) are considered very important because they include the types of rules that are not compatible with the practice of certain contractors. A company may risk being fined or a construction project may be shut down if a firm is not familiar with the rules and regulations in the host country.

2. *Type of import restrictions on materials, equipments and labour*. Knowledge of import restrictions of materials, equipment and labour has a higher rating among international contractors. Understanding the import

restrictions are important because factors such as pre-shipment inspections, warehousing arrangements, and different types of licensing that must be obtained need to be fully understood to develop a realistic project execution plan.

3. *Construction risks.* This factor is considered highly because knowing the risk (e.g. adverse weather conditions, potential labour and material shortages and numerous holidays) may determine whether a company will be a successful or not in the country of interest.

4. *Availability and cost of construction materials.* It is important to identify the availability and cost of construction materials in another country because the construction companies will most likely need to purchase many of the materials locally. Typical materials include cement, bricks, sand, steel, timber, fuel, asphalt and possibly electrical and mechanical equipments.

5. *Characteristics of Subcontractors.* The Characteristics of subcontractors in a foreign country is critical factor to the international contractor because most foreign countries require that a percentage of the construction work to be subcontracted to the resident's contractors of the host country. This will require the international company to plan, schedule and construct the project based on local sub contractors, which could impact several aspects of the work.(e.g. quality , productivity, and training requirements etc..

6. *Availability of construction materials, facilities.* Because many countries have strict importation requirements, it is important to understand the production capabilities found in the host country. This factor provides the information on production, facilities, such as ready-mix concrete plants, brick manufacturing companies etc.

7. *Pre qualification requirements.* This is a process where by contractors out side of the country of interest submit comprehensive capability reports, which include a firm's area of expertise, supervisory personnel experience,

available equipments and performance on past projects. Pre qualification requirements for out side firms may be important to international firms because these criteria will determine whether or not they are allowed to bid on a particular project.

8. *Client information.* This information includes the clients' reputation to pay for services and how well they work with previous contractors, designers or consulting firms. Background information on client is important because it is advantageous for international contractors to know if the client is capable of paying or has a history of financial default.

9. *Stability of foreign country.* This knowledge indicates whether or not the country of interest will provide the stable environment to operate in terms of its government, currency, and legislation. Knowing about the country stability is important because factors such as contracts are terminated during construction, government nationalizing property, or fluctuating exchange rates may occur if laws frequently change and the government is unstable.

10. *Quality of equipments and materials.* This describes whether or not materials and equipments in a host country meet certain specifications, regulations and building codes required to construct projects satisfactorily.

11. *Craft workers' wage rates.* This factor provides a construction company with necessary information to develop accurate labour cost estimates associated with performing the work in other countries. It provides base wage rates and benefit for craft workers and common laborers.

12. *Availability and cost of heavy construction equipments.* This is important information necessary to bid and execute a construction project. It includes economic information and data on equipment such as bulldozers and loaders, cranes etc. Knowing the availability and cost of heavy construction equipment is important for construction planning and cost

estimating and can help the contractors determine the most effective and less expensive way to perform construction activities of a project.

13. *Contacts.* This factor represents a list of individual firms' and organization that have relevant insights regarding the country of interest. Examples of contact information are international construction companies, material suppliers, design firms, law firms and lending agencies. Contact information may be important because current pertinent data is received directly from a knowledgeable person in a particular country

14. *Transportation logistics*. Movement of people, materials and equipment is vital for a smoothly running construction operation. This information provides and overall description of the conditions of roads, railways, marine ports and air port facilities including their efficiency and cost.

15. *Craft worker productivity rates*. This information provides the amount of time a worker can accomplish a particular task.. Productivity rates are very important because they help determine the duration and cost of construction activities.

In recent past a research was conducted by Dulaimi and Guo Shan (2002) for the factors influencing mark –up size decision. They considered the context of Singaporean construction industry and concentrated their study in two categories; large and medium size contractors where large size contractors can work up to S$50 million or more whereas medium size contractors can work up to S$ 10 million. Dulaimi and Guo Shan (2002) limited their research to a certain sector of the industry by focusing on contractors under the general building contractors for public sector projects. This register maintain by the Building and Construction Authority (BCA) in Singapore. They noted that the construction industry in Singapore is dominates by a competitive business environment driven by a lowest cost mentality that has significantly eroded the profit margins in the industry. Generally, the construction projects in Singapore are awarded on the basis of the lowest tender that meets the stated standards and specifications.

They had referred the researches done in last two decades for the context of Construction bid decisions and has revealed 40 common factors that the different researchers have argued influence local contractors' bid mark-up decisions. These factors have been grouped under five broad categories; Project Characteristics, Project Documentation, Company Characteristics, Bidding Situations, and the Economic Environment. The following table will give the details of the factors

Table 7. Factors affecting Bid Mark-up size Decision

Category	Factors
Project Characteristics	Size of Contract
	Duration of Project
	Project cash flow
	Location
	Type of owner
	Degree of difficulty
	Degree of safety
Company's Characteristics	Availability of required cash
	Uncertainty in cost estimate
	Need for work
	Past profit
	Current workload
	General overhead
Company's Characteristics	Portion Subcontracted to others
	Experience in similar project
	Need for public exposure
	Availability of qualified staff
	Establishing long relationship with client

Contd...

Category	Factors
Bidding Situation	Tendering method
	Tendering duration
	Pre- qualification requirement
	Bidding document price
	Availability of other project
	Number of competitors
	Identity of competitors
	Requirement of bond capacity
Economic Environment	Overall Economy
	Risk involved in investment
	Anticipated rate of return
	Availability of labour/ Equipment
	Government division requirement
	Tax liability
Project Documentation	Type of contract
	Type of procurement
	Completeness of document
	Owner's requirement
	Use of nominated sub-contractors
	Value of liquidated damages
	Risk of fluctuation in material price
	Insurance premium

Source; (Dulaimi & Guo Shan 2002)

The responses of how these factors affects the construction bid decisions was collected through a questionnaire and the respondents were asked to give a score for each of the 40 factors identified by the research. Respondents were also asked to indicate the extent to which their company would consider these factors to be important in their bid mark-up size decisions. The ranks were 1 (low importance) to 5 (high importance).

The data collected were processed using a sophisticated program called Statistical Package for the Social Sciences (SPSS). The techniques used in this research enabled to analyze and examine certain aspects of the bidding environment, the *Importance Index,* of the different factors that impacts the decision on mark-up size.

The factors are ranked according to their calculated importance index based on the data collected and literature reviewed.

This index helps in ranking the factors in accordance with their importance to the contractors, and also determines any similarities or differences between the medium and large contractors (Shash and Abdul-Hadi, 1993).

The attitude of the contractors towards the factors influencing the bid mark-up size decision has been assessed by evaluating the level of importance that contractors placed on the identified set of factors

Table 8. Importance indices and Rank order of the factors considered by Medium size and Large size contractors

No.	Factors	Medium		Large	
		Importance	Rank	Importance	Rank
	PROJECT CHARACTERISTICS	65.1%	4	63.3%	1
1	Size of Contract	67.7%	15	75.8%	5
2	Duration of project	67.7%	16	66.3%	12
3	Project cash flow	78.5%	9	60.0%	19
4	Location of Project	41.5%	38	42.1%	37
5	Owner (Private/ Public)	80.0%	7	47.4%	32
6	Degree of difficulty	64.6%	21	82.1%	1
7	Degree of Safety	55.4%	31	69.5%	9
	PROJECT DOCUMENTATION	59.4%	5	59.6%	3
8	Type of Contract	64.6%	22	64.2%	14
9	Type of Procurement method	56.9%	30	60.0%	20

Contd...

	PROJECT DOCUMENTATION	59.4%	**5**	59.6%	3
10	Completeness of document	60.0%	28	70.5%	8
11	Owner's Special requirement	64.6%	23	60.0%	21
12	Use of nominated Subcontractor	61.5%	26	53.7%	28
13	Anticipated value of liquidated	69.2%	14	61.1%	17
14	Risk in Fluctuation in materials	58.5%	29	67.4%	10
15	Percentage of insurance premium	40.0%	40	40.0%	38
	COMPANY RELATED ISSUES	69.2%	**2**	56.0%	5
16	Availability of required cash	67.7%	17	56.8%	25
17	Uncertainty in cost estimate	67.7%	18	66.3%	13
18	Need for work	87.7%	2	62.1%	15
19	Past profit in similar job	86.2%	4	55.8%	27
20	Current work load	78.5%	10	60.0%	22
21	General Overhead	64.6%	24	67.4%	11
22	Portion Subcontracted to others	50.8%	34	45.3%	33
23	Experience in similar project	80.0%	8	62.1%	16
24	Need for public exposure	41.5%	39	36.8%	39
25	Availability of qualified staff	49.2%	35	44.2%	36
26	Establishing long relationship with	87.7%	3	58.9%	23
	BIDDING SITUATION	65.2%	**3**	59.5%	4
27	Tendering method	73.8%	11	56.8%	26
28	Tendering duration	67.7%	19	57.9%	24
29	Pre- Qualification requirement	52.3%	32	53.7%	29
30	Bidding document price	61.5%	27	51.6%	31
31	Availability of other projects	66.2%	20	61.1%	18
32	Number of competitors tendering	73.8%	12	72.6%	7
33	Identity/Competitiveness of	73.8%	13	76.8%	3
34	Requirement of bond capacity	52.3%	33	45.3%	34

Contd….

	ECONOMIC SITUATION	70.3%	1	62.1%	2
35	Overall economy (availability of	93.8%	1	80.0%	2
36	Risk involved in investment	84.6%	6	76.8%	4
37	Anticipated rate of return on project	86.2%	5	74.7%	6
38	Availability of labour /equipment	64.6%	25	53.7%	30
39	Governmental division requirement	49.2%	36	45.3%	35
40	Tax liability	43.1%	37	36.8%	40

Source; (Dulaimi & Guo Shan 2002)

The importance indices and the rank order of the factors affecting contractors' mark-up size decision presented in the above table and these has compounded from the average mean value of each factor generated from the Statistical Package for Social Sciences (SPSS) program.

The top ten factors identified by medium size contractors as the most influential in their bid mark-up size decision were;

- Availability of Projects
- Need for work
- Owner/client identity
- Anticipated rate of return
- Risk in investment
- Type of owner
- Experience in similar projects
- Project cash flow
- Current workload

The results in Table 8 show that the medium size contractors have assigned the highest level of importance for the Economic situation. Factors such as overall economy, risk involved in investment and anticipated rate of return on a project were given a higher importance level because they reflected the availability of works in the market and the feasibility and profitability of projects, which would be key to the survival of such contractors.

'Company related issues' was the second highest ranking category. Factors such as the need for work, current workload, past profit and experience in similar project were given a higher level of importance. It may be argued that due to the relatively limited capacity, low working capital and low turnover of the medium contractors the acceptable level of uncertainty in their profit margins tends to be lower. Medium size contractors also placed the higher emphasis on establishing long relationship with their clients would help them generate future contracts crucial to their long term business operations.

The top 10 factors identified by medium – size contractors are all listed under the above two categories with the exception of the factors ranked 7 and 9 (table 6). Medium – size contactors placed a high emphasis on the type of owner (ranked 7) when making a bid mark – up decision. It seems that medium – size contractors feel that for the owner to be private or public has a significant influence on their desired mark-up. The relatively limited financial capacity of the medium – size contractors may have influenced them to place a higher emphasis on the project cash flow (ranked 9) because this factor will determine the short term liquidity of such contractors and their economic leverage to function profitably

2.1.3 Comments

The study done by Chua & Li (2001) is a bid-reasoning model that goes deeper into the heart of the bid decision. In this way, the significance of the factors with respect to each reasoning sub goal of the bid decision can be ascertained. These reasoning sub-goals include competition, risk need for work, and company's position in biding. The AHP method has been adopted to identify the key determining factors for the bid decision. The hierarchical structure of the approach allows the participants to focus on each criterion one at a time. Despite some spreads in opinions that are linked to their organizational philosophy or background, the respondents exhibit a reasonable level of consensus in the ranking of these factors.

The effect of the type of contract has been addressed. The impact of contract type is the most significant in risk assessment, as the risk exposure and its allocation are very different for the type of contract considered.

Most of top contractors depend on subjective assessment in making bid/no bid decision and mark up size. They evaluate many influencing factors whenever they make either decision. Some factors are considered seriously in both decisions while some other is critically for only one decision.

The work of Shash (1993) has identified the need for work, number of competitors tendering and experience in similar projects as the major factors that affect a contractor's decision to bid a project. On the other hand the degree of difficulty, risk involved owing to the nature of the work, and current workload were the highest ranked factors that affect the mark up size decision. A contractors' confidence in winning a project is depend on his experience and strength in the industry but not on the economy. Need for work and project location are the driving factors that increase the contractors motivation to win a project.

The researches done by various researchers discuss the key informational factors to be considered in developing countries in addition to the other factors normally considered in developed countries.

It is evident that who ever tend to work in a third world countries as a contractor he should thoroughly reviewed these factors in the relevant context on the reasoning of bid/ no bid decision. The unawareness of the country in which the construction to be carried out may be disastrous.

The research done by Dulami and Guo Shan (2002) has a similarity of what Shash (1993) has done end up with factors affecting bid mark-up size decision with the ranks of importance.

As Dulaimi and Guo Shan (2002) separated the sample in to two categories of large scale contractors and medium scale contractors the results obtained from the research has a good representation of the sample analyzed. The top ten factors considered being the most important factors were different for large and medium scale contractors. That enables us to differentiate what are the key considerations of contractors in each of these two layers i.e. the large scale contractors has considered the issue related to Project Characteristics are critical fro their bid mark-up size decision and the Economic Situation Project Documentation at second and third considerations respectively. Whereas the medium size contractors are in the view that Economic Situation is the most critical while Company related issues keeping as the second critical issue.

For this research it is relevant to consider the factors affecting in bid mark –up size decision for the medium size contractors as the respondents in the considered context for the research could be more or less the same as the medium scale contractors in Singapore construction industry while there may not be any local company that falls in to the category of large scale contractors category based on the information in BCA of Singapore (2001) and ICTAD Sri Lanka.

Hence, it was decided to incorporate top ten critical factors for the medium scale contractors for the development of Fuzzy expert system for the determination of bid mark-up size in competitive bidding.

2.2. REVISITING OF BIDDING MODELS

2.2.1 Introduction

Estimating and bidding are two important functions performed by construction contractors. Many of the decisions required in arriving at the final bid price are based on experience and intuition. Deciding on an appropriate margin or mark up to add to the estimated cost of the project is one such decision. Margin is defined as the amount of money added to the estimated cost of the project (i.e., project direct costs and project overhead costs) to arrive at the contract (selling) price. A margin may cover both corporate overhead costs (i.e., head office and branch office running costs) and profit. Some companies may treat corporate overhead as a separate project cost item, since they should be allocated to each project and recovered just like other project costs. For some projects, particularly small ones, the margins may include the project risk and opportunity allowance too. The margin is usually expressed as a percentage of the contract price, or as a lump sum.

Research in the area of competitive bidding (tendering) strategy models has been in progress since the 1950s (e.g., Friedman (1956)). Numerous models have been developed some of which are designed specifically for the construction industry (Stark and Rothkopf, 1979). Despite the number of competitive bidding strategy models have been developed a few of these are used in practice, largely because they do not suit the actual practice of a construction contractor (Ahmed and Minkarah 1988; Hegazy and Moselhi 1995; Shash 1993; Ting and Mills,1996). A need remains for models that are designed to suit the actual practices of construction contractors so that they will be more readily accepted and used.
The following features need to be addressed in a competitive bidding strategy model to make it more suitable in practice:

- Consideration of a wide range of factors, besides profit maximization and the competition, that effects the margin-size decision, to more realistically capture the decision making process.
- Consideration of multiple objectives in bidding, in addition to profit maximization
- The use of qualitative and subjective contractor judgment statistical techniques
- Consideration of other factors, besides price, that affects a contractor's success in winning projects, since contracts are not always awarded to the lowest bidder (Odusote and Fellows, 1992: Ferguson et.al, 1995)
- Less reliance on historical project and competitor data for training or use, since the data of sufficient quality and quantity are difficult and time-consuming to obtain (Benjamin, 1972) or may not be available (Fayek, 1996a)
- A method not to be based on population-specific data, training examples, or rules, for wide applicability to other construction environments, beside the one for which the model is designed
- Quickness and ease of use, to suit the time-constrained nature of the competitive bidding process

2.2.2 Previous Models

The bidding strategy has been addressed since mid 1950 and the practitioners rarely use most of these, claiming, these probabilistic models are based on mathematics. The probabilistic models will predict the chances of winning according to the applied mark up size. Most researchers try to devices their results, which represent the "Optimum mark up"(McCaffer, 1976) that is the mark up, which in the long term will produce the maximum profit. But the optimum mark up theories so far devised have not been taken into account that the bidding pattern and the mark up size of a company do not remain consistent as the other considerations such as the current work load, the budgeted turnover etc. too has an impact.

In most of those researches the basic assumptions are

- Relationship exists between the tender sum and the probability that is chance of winning the contract.
- The contractor first estimates his costs and then adds the mark up to cover profit.

Friedman's Model

Friedman Model is the pioneer in the bidding strategy concept and his research is assumed to be the origin of the studies of bidding models.

He has analyzed the competitors by considering their past behaviors in the tenders in which the considered company too has competed and established a relationship which address to competitors mark up and probability of beating him.

Friedman (1956) tried to get a graphical representation of competitors' historical performances against us by dividing the competitors bid by said company's cost estimate in each tender. The obtained graph is given in Fig.8.

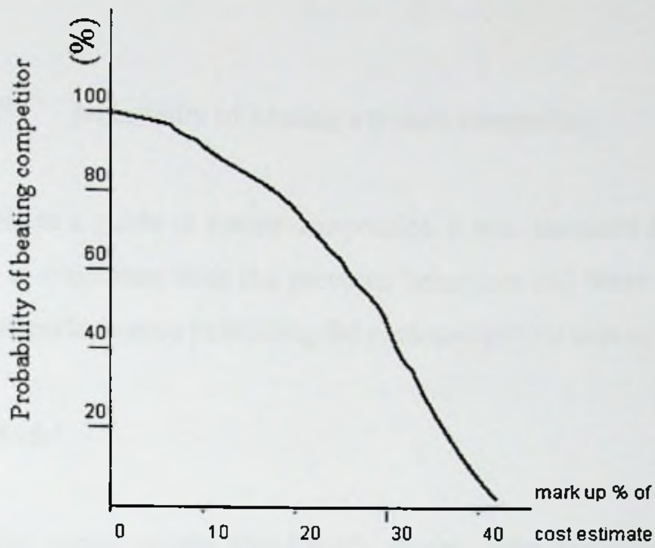


Fig 8. Probability of Beating the contractor Vs Mark-up

Source : (Mc Caffer 1976)

Friedman ultimately ends up with a graph similar Fig 8, which represent the probability of beating competitor with the mark up size that we have to apply on our cost estimates.

If such a record as in Fig 8 can be generated for a particular competitor then the same process can be carried out for all major competitors likely to be dealt with the considered company. Therefore a collection of behaviour of the major companies should be developed in order to get a probable value of beating a particular contractor.

Once developed the competitors behaviour on bidding the Friedman's model for the probability of wining a contract at a given mark-up competing against number of known competitors (P) may given as,

P = Pa X Pb X Pc...

Where,	Pa	-	probability of beating *A*
	Pb	-	probability of beating B
	Pc	-	probability of beating C

For the case of the known number (n) of contractors whose behaviour are unknown

$P_n = P^n$

Where $P^n =$ probability of beating a typical competitor

To use this as a guide in future competition it was assumed that the competitor mark up policy is consistent with the previous behaviors and there should be a graph based on his past performance in bidding for each competitor that is to be considered.

Gates' Model

One of the critics of the Friedman's model, who criticized the Friedman on the theoretical grounds; Gates (1967), and he did the similar analysis and ended up claiming that the relationship between applied mark up and the probability of winning (P for known competitors) a contract at a given mark-up can be given as follows.

$$P = \frac{1}{[(1-Pa)/Pa]+[(1-Pb)/Pb]+[(1-Pc)/Pc]+\ldots\ldots\ldots+1}$$

where, Pa - probability of beating *A*

Pb - probability of beating B

Pc - probability of beating C

And for the case of unknown competitors this model becomes

$$Pn = \frac{1}{[(1-Ptyp)/Ptyp]+1}$$

where, Pn - probability of beating n unknown competitors

Ptyp - probability of beating a typical competitor

Among those who attempted to resolve the differences of the findings of Friedman (1956) and Gates (1967), Rickwood (1972) concluded that Friedman model was more accurate when the cost estimates used by the competitors was the same and the variability is only due to the mark-up sizes incorporated in each bid. Whereas Gates model was more correct when the mark-up incorporated by the competitors were more or less the same but the difference was due to the variations in cost estimates.

Fines Model

Fine (19xx) has approached the bidding in a different way by considering only the lowest bidder, claiming that our eventual aim is to beat the lowest bidder and win the contract in any given situation.

The low competitor model is based on a collection of historical data of the lowest bidder in each competition entered. He has ends up with a similar histogram of Friedman but not for the particular selected contractor but for the lowest bidder in each tender that we participated.

Chua and Li Model

As the interest in the subject of competitive bidding is increasing more researchers find to build bidding models to cater the requirement of the industry, even though the previous traditional bidding models were not widely accepted. Subsequently Case – Based Reasoning (CBR) approach was selected by Chua and Li (2001) for the construction bid decision model, case – based reasoning.

CBR is a method of solving a current problem by analogizing the solutions to previous similar problems (Kolodner,1993). A CBR system draws its knowledge from a reasonably large set of cases contained in the case library of past problems rather than only from a set of rules. It solves new problems by adapting solutions that were used to solve old problems. Instead of relying solely on general knowledge of a problem domain, or making associations along generalized relationships between problem descriptors and conclusions, the CBR approach collect information about previous cases, and then retrieves this information for similar cases. By adopting this approach, it is able to utilize the specific knowledge of previously experienced, actual situations (cases) (Aamodt and Plaza, 1994). Subsequently, the previous solutions may be adapted so that they more closely match the current problem and situation. A typical Lay out of data flow in CBR is illustrated in Fig. 9.

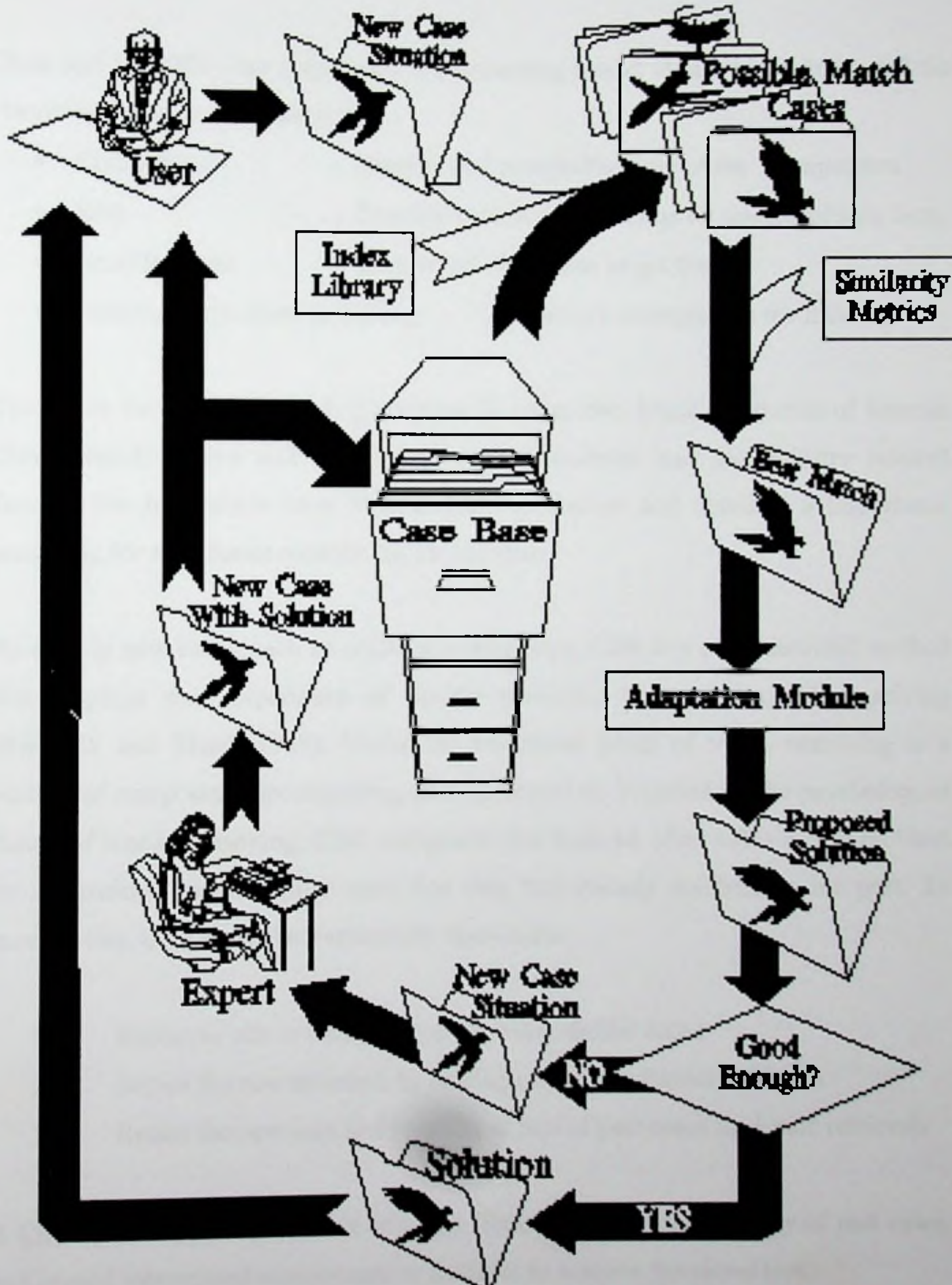


Fig 9. Data Flow of a CBR

Source Rick & Knight *URL*

Thus, Chua and Li (2001) argued such a reasoning method is very suitable for decision making in construction bidding a complex, dynamically changing, and highly unstructured problem domain.

Chua and Li (2001) has proposed a bid reasoning model along this context and the reasoning based on four sub goals;

- Competition - Number and competitiveness of the competitors
- Risk - Possible variation of cost due to uncontrollable facts
- Need for work - Contractor's keenness to get the job
- Company's position in bidding - Contractor's strengths in the industry

The above four reasoning sub goals were to cover two broad categories of Internal (firm related) factors and External (project considered and the industry related) factors. The researchers have identified eleven factors and obtained a importance weighting for each factor considering the scenario.

As a fairly new sub branch of artificial intelligence, CBR is a computational method that employs past experience of similar problems in current problem solving (Riesbeck and Shank 1989). Under the traditional point of view, reasoning is a process of composing, decomposing, and recomposing. Founded on the psychological theory of human reasoning, CBR recognizes that humans often solve a new problem by comparing it with similar once that they had already resolved in the past. To emulate this, CBR comprises essentially three tasks:

1. Retrieves one or a small set of the most similar cases
2. Solves the new situation by reusing or revising former solutions
3. Retain the new case and solution as part of past cases for future retrievals

A CBR system typically consists of a case library, which is a repository of past cases, and several interrelated components or modules to achieve the above tasks.

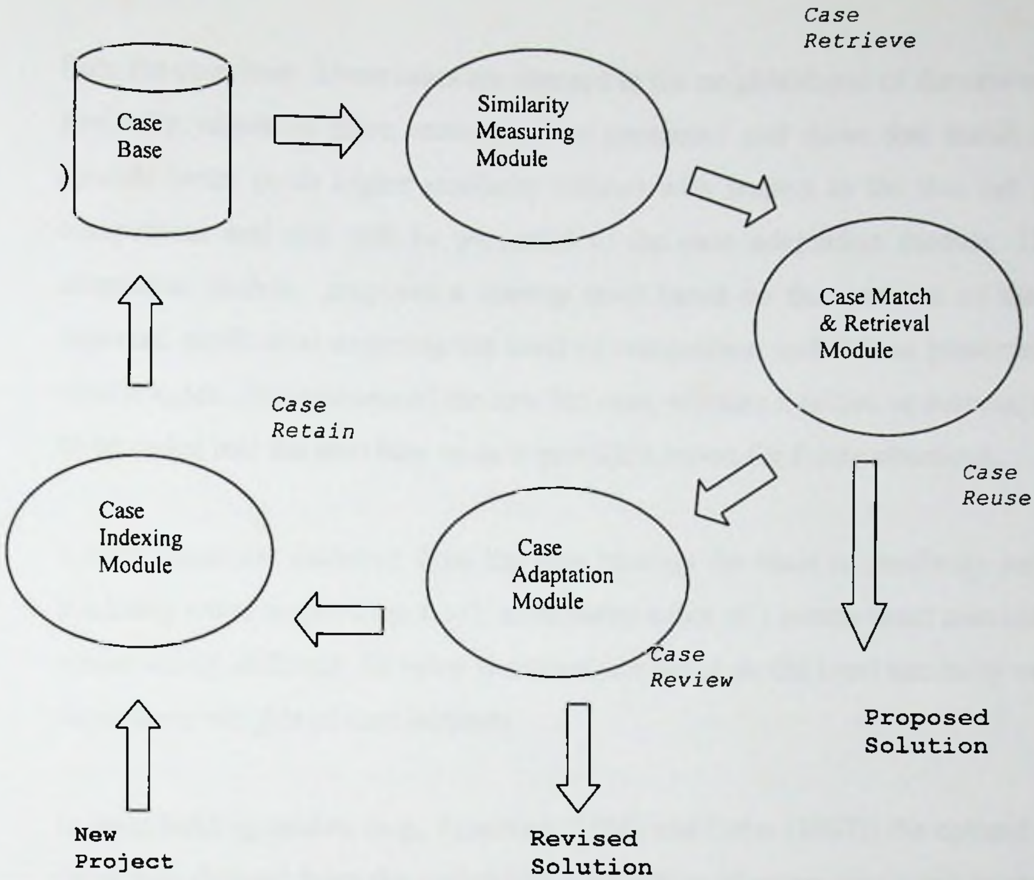


Fig. 10. Process of CBR Source : Chua et.al (2001)

Based on the above mentioned explanations the framework for the proposed bid decision support system, CASEBID, has developed is depicted in the above Fig. 9. A CBR development shell, ReCall (Isoft, 1996), has been used to develop the system. The TCL (tool command language) scripting language (Ousterhout, 1994) has been used to automate the procedures.

The objective of the system is to propose a bid markup level to the decision maker on the basis of past experience. Past bid cases are stored in the case base or case library. Factors that the decision maker considers to be significant determinants of the bid markup are built into the system as the domain knowledge. Weights 1 and 2 are the sets of relative importance weightings of the determining factors with respect to competition and risk, respectively. The case base coupled with the domain knowledge constitutes the knowledge base of the system.

The decision process begins when the user present a new case to the system. A set of cases relevant to the new episode according to an index tree structure will be extracted from the case base. These cases are deemed in the neighborhood of the new case. The similarity values of these cases are then computed and those that match the new episode better (with higher similarity values) with respect to the two sub goals of competition and risk will be presented to the case adaptation module. This case adaptation module proposes a markup level based on the criterion of maximized expected profit after assessing the level of competition and risk as presented by the similar cases. The outcome of the new bid case, whether a failure or success, needs to be recorded into the case base so as to provide a lesson for future situations.

Similar cases are retrieved from the case base on the basis of similarity value. The similarity value ranges from 0 to1; a similarity value of 1 means exact matching and 0 means totally different. Its value is determined based on the local similarity value and importance weights of each attribute.

In most bidding models (e.g., Friedman (1956) and Gates (1967)) the optimal markup value was derived from the probability distribution of competitor's bid markups. On the other hand, CASEBID adopts a method to evaluate the probability of winning and optimizes the markup value based on the probability distribution of the low bid markup, with which method adopted by researchers such as Ackoff and Sasieni (1968), and Broemeser (1968),. It is not difficult to determine the accumulative probability distribution of the winning chance (P_{wi}) for any given markup value (M_i)

$$P_{wi} = E1/E$$

Where, E = total number of cases retrieved; and E1 = number of cases with the winning bid markup higher than M_i

Assuming no bidding cost, the expected profit for any given markup value M_i can then be computed as

$$EP_i = P_{wi}(M_i - m_c)$$

Where, EP_i = expected profit at markup level M_i; and m_c = mean value of "Actual Cost/Estimated Cost" from the retrieved cases for risk. The expression can be easily adjusted to account for bidding cost. The markup level corresponding to the maximum expected profit is the optimal markup value M_{opt}. A Monte-carlo simulation also had performed to evaluate the efficiency of the system.

A research done by Fayek (1998) present a competitive bidding strategy model that uses techniques of fuzzy set theory to help a decision – maker to choose an appropriate margin to add to the estimated cost of a project. This model provides a systematic and standard methodology for setting a margin on Civil engineering and building project bids, which can be tailored to suit the individual practices of each company. The model has been implemented in the from of a prototype software system named PRESTTO, which makes the model quick and easy to use (Fayek 1996a,b, Fayek et.al., 1995).

In his research the need for an additional competitive bidding strategy model, despite the number of models already developed and how a fuzzy set theory suitable for modeling the margin – size decision are provided. Each component of the competitive bidding strategy model, and the method of analysis based on fuzzy set theory is presented.

The competitive bidding strategy model developed by Fayek (1998) is intended for use by Civil engineering and building construction contractors in setting a margin on competitively bid tenders (or bids). The goal of the model is to help a company to achieve its objectives in bidding. The model is based on the single – bid situation. It is used after the decision to bid on the project has been made, and after the detailed estimate has been completed. The basis of the margin – size recommendations of the model is not necessarily the margin that will maximize the company's chances of winning the bid, unless winning is the sole objective of the company in bidding. Rather, the margin size recommended by the model will help a company to achieve its objective(s) in bidding as specified by the user, while simultaneously accounting for the effects of factors internal and external to the company. The model does not assume that the lowest bidder will necessarily be awarded the contract; rather, it considers the effect of other, qualitative criteria that may influence the client's choice of the winning bidder and consequently the most suitable margin size.

Fayek (1998) has considered three objectives in bidding.

1. To win a project(O_1)
    - To meet the budgeted turn over requirements and to deploy idle resources.
    - To be seen as competitive and / or build a reputation with the client and/or with consultants.
    - To break in to a new market and / or to win the project for its strategic value.
2. To test a new geographical area, and to give the estimating team experience in the new area (O_2)
    - Will bid to test the new market or new Geographical area
    - Will bid with a medium size mark-up

3. To maximize the project's contribution to profit (O_3)
    - Will bid to maintain its feel for the mark-up
    - Will bid to remain competitive
    - Will bid even at a time in which the company already obtained its expected profits and work load in a relevant year

Then he considered 93 Nos. of factors both external and internal to the company that may affect the margin size. These factors have complied from previous research on the context; Ahmed and Minkarah 1998, Sanders and Cooper 1990, Shash 1993 etc. and categorized those in to 11 groups. Addressing the features, identified previously, that would make a competitive bidding strategy model more suitable in practice. Fuzzy set theory was therefore chosen to develop the competitive bidding strategy model presented in this paper. The basis of the model is given in Fig. 11.

The following notations had used in developing he model

Oj - Objectives

Fx - Factors under analysis

Mi - Mark up sizes.

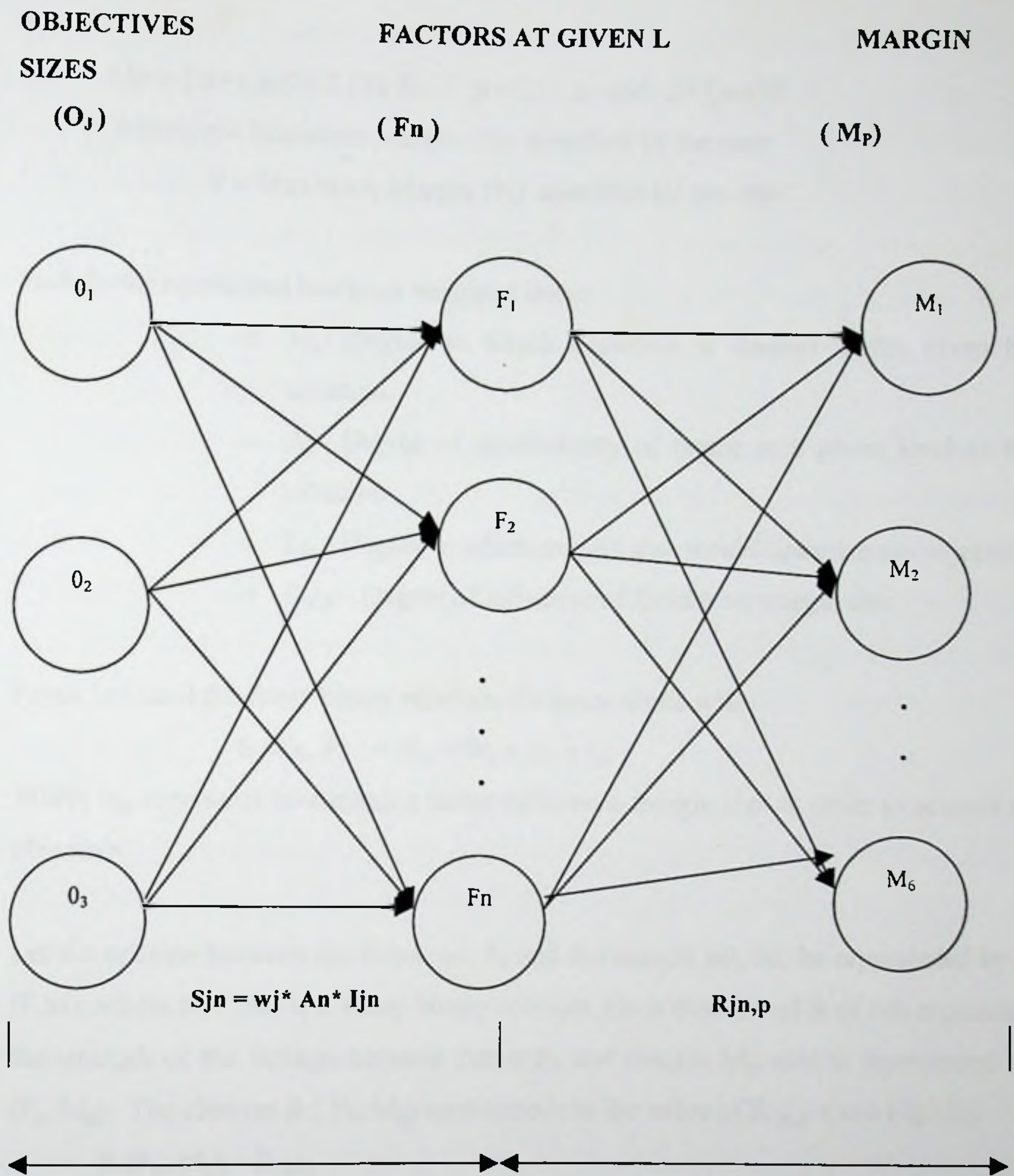


Fig 11. Components of Competitive Bidding Strategy Model and their Relationship Source(Fayek 1998)

The user selects factors that are relevant to the bid under analysis from pre – defined list provided by the model. The user may use additional factors other than the said 93 factors, to tailor the extent and complexity of the analysis to suit his requirements.

S_{jn} margin sizes had chosen by the author for the model as it is generally difficult for a person to distinguish subjectively between more than seven alternatives (Saaty, 1977). The six margin sizes were calculated as follows.

$Mp = [\, x + (p-1)\, Z \,]\ \%$ for $p = 1 \ldots 6$ and $Z = (y-x)/5$

Where, x – Minimum Margin (%) specified by the user

Y – Maximum Margin (%) specified by the user

Each factor considered had been weighted under

- W_j- Degree to which objective is desired in the given bid situation.
- A_n- Degree of applicability of factor at a given level to bid situation.
- I_{jn} - Degree to which margin size would optimize the objective.
- $R_{jn.p}$ – Degree of influence of factors on margin size

Fayek has used the fuzzy binary relations for the analysis with,

$$S\,(O_j, Fx) = S_{jn} = W_j \times A_n \times I_{jn}$$

Where S_{jn} represents how much a factor influences margin size in order to achieve an objective.

Let the relation between the factor set, F, and the margin set, M, be represented by R (F,M), where R(F,M) is a fuzzy binary relation. Each element of R (F,M) represents the strength of the linkage between factor F_n and margin M_p, and is represented by (F_n, M_p). The element R (F_n, M_p) corresponds to the value of $R_{jn.p}$ (see Fig. 10)

$$R\,(F_n, M_p) = R_{jn.p}$$

$R_{jn.p}$ is calculated by the model based on the user's choice of the most suitable margin for each factor and objective pair.

2.2.3 Comments

The first model developed for bidding is the publication of Friedman's research paper '*A competitive-bidding strategy*'. Friedman (1956) had a simple and clear message: to maximize the expected profit from a tender where each competitor simultaneously submits one closed bid, the bidder should select the markup on cost that maximizes expected value of the profit, i.e. the product of the mark-up and the probability of winning the contract. The real importance of the paper, however, was not so much in what it said, but in the way it generated interest and research, to the extent that tendering is now one of the most frequently researched areas of building economics, although the development of a consistent theoretical framework has been slower, and very little of the work has been devoted to testing, verifying or analyzing the theory itself.

The problem in Friedman's strategy lies in determining the probability of winning as a function of the mark-up. His solution was to establish the competitors' 'bidding patterns' by calculating the ratios between their tenders and the cost estimate. Provided there have been a sufficient number of previous encounters, it is then possible to establish the probabilities of winning with different mark-up against each competitor and, through aggregation, against each possible combination of competitors.

The next major paper on the topic was Gates (1967) '*Bidding strategies and probabilities'*, which reinterpreted Friedman's strategy for a single bid into a general, profit maximizing pricing model for tendering. While Gates does not acknowledge Friedman's paper in the development of his own model, there are many similarities between the two papers. There is one oblique reference to the book in which the 1957 version of Friedman's paper appeared, where Gates remarks that 'other investigators consider the problem of winning over several competitors as one of independent events' Like Friedman, Gates asserted that probability of winning a bid could be estimated from previous encounters and that the appropriate strategy was to maximize the expected value of the appropriate strategy for a single bid, Gates turns into a general strategy, with general applicability. In effect, Gates has taken a simple decision support model and reformulated it into an economic theory for pricing construction projects.

One of the crucial difference between Friedman's concept of a strategy for a single tender and Gates' general theory of tendering as well as extension of Friedman's model (e.g. Park and Chapin, 1992) is his ceteris paribus condition. According to Friedman's we assume 'that each competitor is likely to bid as he has done in the past', a condition that may not necessarily be an actual representation of reality, but may be sufficiently close to benefit the user.

On the other hand Gates, did not stated his assumptions explicitly, but uses empirical data derived over a period of several years to establish the probability of success, and a technique not much emphasis on the possibilities of systematic changes in the mark-up as a method for calculating the probabilities of success at different mark-ups. After having calculated the optimum mark-up for competition with firms A, B and C, Gates states that this optimum mark-up is constant over time, because this is 'the best mark-up to include whenever your competitors are only A, B and C. There is no need to re-estimate the probability density functions at any stage of for any reason. This statement specifically excludes the possibility of systematic variations in the mark-up.

In fact, the proposition that probabilities can be assigned to the bids at all assumes that bids occur in a manner amenable to statistical analysis. This implies that bids are fundamentally random in nature, drawn from an underlying probability density function with fixed parameters. To estimate the value of these parameters empirically for tendering inevitably involves making assumptions about the stability of these parameters over time as, by the nature of tendering, a sufficient number of observations would not be available at a single point in time (Curtis and Maines, 1973).

As the parameter estimation involves the practical assumption that the probability density function of bids is constant (or that if it changes, the magnitude of the change is trivial and can be ignored without any loss of accuracy), it follows logically that the same assumption is implied theoretically. Hence, the tendering theory proposed by Gates holds not only that the probability density functions do not change over time, but also that the variations in tenders originate in unsystematic or random variations in the competitors' and/or own cost estimates and/or mark-ups. In particular this means that market conditions or the competitors' capacity utilizations do not influence the behaviour of any of the competitors or their probability density functions.

It follows, therefore, that if systematic changes in bidding behaviour do occur in reality, as for instance in different markets or in response to changes in demand, the theory is not valid, as the bid distributions can be longer be regarded as random. A further difficulty, common in many areas in social systems, is that the mere application of prescriptions derived from a theory would be sufficient to undermine the behaviour from which the theory has been derived. In this case, the assumption that the competitors do not modify their behaviour at any time in response to the use of the strategy as developed by Gates is unlikely to be valid if Gates strategy is of value. This is a crucial difference between tendering theory and game theory.

In terms of using the calculated probability density functions, Gates starts with the situation where the competitors, and their probability density functions, are known, but extends the analysis to situations where the competitors are not known but are assumed to be 'typical bidders'; an average of bidders encountered in the past. Under these conditions, the optimum mark-up would remain constant for the typical case with n typical competitors. The probability density function would change only in response to changes in the number of competitors or to the other hand, any of these conditions is violated, the probability distribution for each tender process would be unique: hence the optimum mark-up also would be unique for each tender process.

For each tender, the tender price is set by the cost estimate plus a constant percentage mark-up. For obvious reasons, the bidder will not always be successful. After all, the bidder is aiming at winning only a predetermined fraction of the contracts, and the accuracy (or rather lack of accuracy) of the bidder's own and the cost plus a mark-up from a given probability density function. The bids will very somewhat between different bidders because of the uncertainties in assessing the cost in advance but, within narrow limits, the probabilities of winning will be the case across the market, and differences in the prices offered between different bidders and projects will reflect random differences alone. If all bidders behave rationally, tendering theory implies that they all a apply a constant mark-up consistent with the number of competing bidders, and any differences in bids are the result of differences in the original cost estimate.

Tendering theory as proposed by Gates assumes constant mark-ups unaffected by variations in demand. The price is calculated as costs plus a constant mark-up, and there are no counter-strategies by other competitors. Any differences between different competitors arise from the necessity to estimate the cost prior to the execution of the contract and the process of submitting a single, unchangeable bid rather than the more conventional method of pricing the product when the cost is known causes aberration.

As far as highly unstructured bidding problems are concerned, the proposed CBR bidding system, CASEBID, which was developed by Chua et.al. (2001) has certain obvious advantages over the other bidding systems. It has been admitted that, in practice, humans resolve such unstructured problems primarily based on their experience with similar previous cases. CBR systems augment the memory of humans by recalling similar situations. The decision is then resolved by adapting the past solutions found in the recalled situations to suit the new situation.

Comparing with traditional expert systems, CASEBID by Chua et.al. (2001) draws its knowledge from both the general domain knowledge and the lessons that concrete cases provided. Essentially, CASEBID approaches the bidding problem by assessing level of competition and risk from past similar cases to arrive at the optimal markup. It does not have to rely on well-for mutilated rules that are nonexistent or intractable in the bidding problem. On the other hand, case bid avoids the "black box" nature that is characteristic of neural networks systems. The user reviews the suggested markup level, makes comparisons with other similar cases, and makes heuristic adjustments over the markup level, if necessary. He can also draw on likely competitor's bidding profiles to make further adaptation.

It must be pointed out, however, that the main problem with this system might be the collection of cases. The system must ensure enough numbers of cases in the case library for the statistical processing. Since the jobs for one company will usually fall into only a few categories, the problem should be resolved with the passage of time.

A competitive bidding strategy model that uses techniques of fuzzy set theory to help in setting margins on civil engineering and bidding construction project has been developed and implemented in the from of a prototype software system named PRESTTO. Fuzzy set theory can be successfully applied to develop a model that suits the actual practices of construction contractors and that provides a realistic tool for setting margins. The use of fuzzy set theory allows assessments to be made in qualitative and approximate terms that suit the subjective nature of the margin- size decision. The resultant model is quick and easy to use, does not rely on historical project or competitor data, is not population- or context- specific, and captures many of the issues and factors that affect a contractor's margin-size decision. The competitive bidding strategy model presented in this paper improves on previously developed models by addressing many of their disadvantages that hinder their use in the construction industry.

The competitive bidding strategy model can help a company to assess its objectives in bidding and to account for the effect of numerous corporate, commercial, project, client, and competitive factors on the margin- size decision. By helping the company to logically consider all of its objectives in bidding and factors influencing margin size, the model can reduce some of the uncertainty associated with setting margin and help a company achieve its objectives in bidding.

The model provides a standard methodology for setting margins on civil engineering and building projects that is independent of any company or organization. Experienced personal can perform the analysis and obtain a reliable result each time. The model enables expert to express their experience in a formalized manner and provides a basis for discussion of the most appropriate margin size with other discussion –markers. The model can be used to validate the user's intuitive choice of margin size, to clarify the goals of the decision-maker, and to document the factors considered. The model is therefore useful as a quality and efficiency of the decision-marking process used in setting a margin, resulting in a more competitive bid.

The model can also be used as a training tool to help in experienced personnel to understand the corporate decision-making process used in setting margin. Because it has the built- in flexibility to allow the user to specify the relevant factors influencing margin choice, the model can be tailored to suit any project and any company's individual practices.

Because the competitive bidding strategy model is quick and easy to use, particularly in its implemented from in the PRESTTO software system, it is suitable to the time-constrained competitive bidding environment. Numerous risk and opportunity scenarios and commercial and competitive scenarios can be modeled, and their impact on the most suitable margin size quickly assessed. The model can therefore increase the efficient use of the limited time available for setting margin.

Future development of the model includes the addition of explanation facilities regarding how the output was obtained; a set of expert rules to recommend modifications to the input data in cases where the output is not definitive; the addition of other objectives in bidding; the ability to allow the user to specify the number of increments in witch to divide the range of margin under consideration; and a set of expert rules guiding the user to the most suitable margin size for different levels of each factor influencing margin, derived from a database of company experience in bidding.

The degree to which the competitive bidding strategy model mirrors actual industry practices is demonstrated through its validation with data from actual project bids, collected from a survey of the Australian construction industry.

2.3. ARTIFICIAL INTELLIGENCE

2.3.1 Introduction

Artificial Intelligence (AI) is a branch of science, which deals with helping machines, find solutions to complex problems in a more human-like fashion. This generally involves borrowing characteristic from human intelligence, and applying them as algorithms in a computer friendly way. A more or less flexible or efficient approach can be taken depending on the requirements established, which influences how artificial the intelligent behavior appears. AI is generally associated with computer science, but it has many important links with other fields such as *Mathematics,* *Psychology, Cognition, Biology* and *Philosophy*, among many others. Our ability to combine knowledge from all these fields will ultimately benefit our progress in the quest of creating an intelligent artificial being. There are so many definitions for AI and those are more or less based on the function or on structure or both. However, it is common that AI involve in solve problems that are difficult enough to require significant human expertise for their solutions (Feigenbaum et.al.,1985). The knowledge of an expert system consists of facts and heuristics. The facts contribute a body of information that is widely shared, publicly available and generally agreed upon by experts in the field. These facts are heuristic in nature in most instances. However, AI systems may match a competent level of a human expertise in a particular field, and typically pertains to problem that can symbolically represent.

The AI encompasses a number of technologies; Expert Systems, Neural Networks, Fuzzy Logic Systems, Cellular Automata etc.. It can be noted that most of these have a behavioural phenomena related to humans or Animals systems. The primary objective of an Expert system, which is the first field of AI, is to mimic human expertise and judgment using a computer program by applying knowledge of specific areas of expertise to solve finite, well-defined problems. These computer programs contain human expertise (called heuristic knowledge) obtained either directly from human experts or indirectly from books, publications, codes, standards, or databases, as well as general and specialized knowledge that pertain to specific situations. Expert systems have the ability to reason using formal logic, to seek information from a variety of sources including databases and the user, and to interact with conventional programs to carry out a variety of tasks including sophisticated computation.

An Expert System is a system, which employs human expertise captured in a Computer Based Information to solve problems which usually require human expertise. An expert system either supports or automates decision making in an area of which experts perform better than non-experts. It is also known as "Expert Computing Systems", or "Knowledge Based Systems". Expert Systems also work as a style of database, very much like a tree structure given in Fig. 12

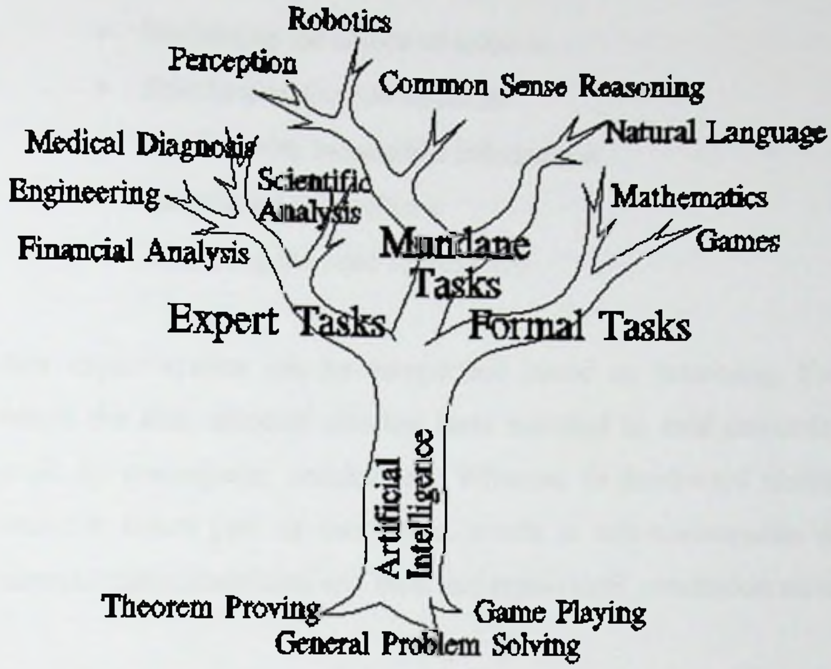


Fig 12 Task Domains of Artificial Intelligence Source : Rick & Knight 1991

Expert systems are used in two different ways:

Decision support : Reminding information or options to an experienced decision maker commonly used in medicine.

Decision making : Allowing an unqualified person to make a decision beyond his or her level or training or expertise commonly used in industrial systems.

A carefully crafted expert system, with a properly developed model will assist the users to,

- Recording and distributing scarce expert knowledge
- Applying the expert knowledge to remote locations
- Ensuring the quality of problem solving
- Training experts out of ordinary people

The ability of expert systems to adapt to and deal with unforeseen situations is very important when the outputs may not be precise or the model may be based on less-than- perfect data. The most of these systems are with the following abilities.

- Recognizing problems

- Recognizing solutions
- Explaining the choice of solution
- Selecting applicable solutions
- Dealing with incomplete information
- Restructuring problems
- Reducing the need for research

Any expert system can be categorized based on reasoning; Forward Chaining in which the data oriented existing facts matched to rule antecedents matching rules result in consequent: conclusions. Whereas, in Backward chaining, which is goal oriented, select goal or conclusion match to rule-consequents checking for match between rule-antecedents and facts and repeat until conclusion matches fact.

There are so many researches on the field of Artificial Intelligence have completed during the past few decades and most of these have identified some characteristics of expert systems, which are unique and generally advantageous. (Van Horn 1986, Feigenbaum et.al. 1998),

1. Experts need not be present for a consultation: expert systems may be delivered to remote locations where expertise may not be otherwise available.
2. Expert systems do not suffer from some of the shortcomings of human beings (e.g., they do not get tired or careless as the work load increases) but, when properly used, continue to provide dependable and consistent results.
3. The techniques inherent in the technology of expert systems minimize the recollection of information by requesting only relevant data from the user or appropriate databases. (i.e., data encountered in the reasoning path)
4. Expert knowledge is saved and readily available because the expert system can become a repository for undocumented knowledge that might otherwise be lost (e.g., through retirement).
5. The development of expert systems forces documentation of consistent decision-making policies. The clear definition of these policies makes the overall decision-making process transparent and the implementation of policy changes instant and simultaneous at all sites.

Whereas, expert systems have few disadvantages that affects the use of the system

1. They usually deal only with static situations.
2. They must be kept up to date as conditions change.
3. They often cannot be used in novel or unique situations.
4. Results are very dependent on the adequacy of the knowledge incorporated into the expert system.
5. Perhaps most important, they do not benefit from experience except through updating of the knowledge base (based on human experience).
6. Expert systems are unable to solve problems outside their domain of expertise. In many cases they are unable to detect the limitations of their domain (Swartout and Smoliar, 1987; Ricker, 1986).

The domain of expert systems refers to the scope of the knowledge contained within the knowledge base. If the expert system operates out side its domain, it may generate incorrect result by utilizing no applicable, irrelevant knowledge while searching for a solution. The inability of expert systems to recognize the limitation of their knowledge has been identified as a very serious shortcoming.

As described an Expert system can, under certain circumstances, deal with imprecise or" fuzzy" information, missing information, and even a certain amount of conflicting information though the use of "certainty factors" or Bayesian probabilities (Kaplan et. al., 1987) Certainty factors represent a measure of belief of the user that a piece of evidence is true. These are not probabilities but rather simply subjective judgment on the degree of truth or validity of an assertion. Some of the information used in development and application of an expert system may not be absolutely certain, and the use of certainty factors allows this subjective evaluation to be incorporated in to the expert system. The final results in these cases may be the "most probable" solution or the "best" solution, but there is no absolute guarantee that the solution is the "correct" solution. Recent work incorporating "fuzzy logic" and "reasoning under uncertainty" into expert systems has greatly improved the performance of expert systems when dealing with complex systems.

A comparison of human and artificial expertise will help convey the strength and weaknesses of expert systems. Human expertise is perishable and difficult to transfer, whereas artificial expertise is permanent and easy to transfer. Human expertise is not always consistent, whereas artificial expertise is consistent. (If you give an expert system the same problem on two occasions you will get the same answer unless stochastic processes are involved; this is not necessarily true of a human expert). On the other hand, human expertise is creative and has a broad focus, whereas artificial expertise is uninspired and usually has a very narrow focus. Above all, human expertise is adaptive and demonstrates common sense. Characteristics usually lacking in expert systems as the knowledge is entirely technical or subjective in nature. For instance, Artificial Expertise does not know that the objects cannot occupy the same space unless it is told. (Tsoukalas and Uhrig, 1997)

2.3.1.1 Components of an Expert System

The principal components of an expert system are the inference engine, the knowledge base, and the interface between the expert system and humans (user knowledge engineers, and expert). The inference engine is a computer program that gathers the information needed from the knowledge base, associated data base, or the user, guides the search process in accordance with a reselected strategy, user rules of logic to draw inferences or conclusions (where warranted) with explanations or bases.

The knowledge base consists of information stored in retrievable from in the computer, usually in the form of rules or frames. The correctness and completeness' of the information within the knowledge base is the key to obtaining correct results or solutions using expert systems. Knowledge bases may contain models of systems, which produce real-time results, or certain learning systems (such as neural net works) that provide new knowledge. (Tsoukalas and Uhrig,1997)

2.3.1.2 Common uses of an Expert system

The impact of expert system technology has been felt in many areas of science, education, and industry. In the past decade a great many applications have been initiated, and many are now in operation or in the prototype stage. The acceptance of the expert systems has highly enhanced the usefulness with the invent of Fuzzy rules.

Generally, but not always, problems that are amenable to a numerical solution should be solved using conventional computer programs. However, there are many situation in which expert systems offer unique advantages over conventional programs. Most applications of expert systems today can be classified into the following six categories;

(1) Monitoring systems,
(2) Control systems,
(3) Configuring systems,
(4) Planning systems,
(5) Scheduling systems, and
(6) Diagnostic systems.

Monitoring Systems; Monitoring systems are dedicated to data collection and analysis over a period of time. The collected values are compared against expected performance, and if discrepancies are identified the expect system generates recommendations and/ or notifies the operator.

Control Systems; Control systems are monitoring systems in which action (e.g., opening a valve, adjusting a bias, turning on a heater, etc.) is taken as a result of the discrepancy identified by the monitoring system.

Configuring Systems; Configuring Systems address problems in which a finite set of components is to be arranged on one of many possible patterns. The classical example in this category is XCON, an expert system used by a large computer manufacturer to configure its equipment in accordance with its own rules and the user specifications.

Scheduling and Planning Systems; Scheduling and planning expert system coordinate the capabilities or components within an organization to optimize production and/ or increase efficiency. The difference between planning and scheduling systems is that the components for a task are not always known in planning systems.

Diagnostic Systems; Diagnostic systems observe and analyze data and map the analysis results to a set of problems. Once the problems have been identified, the expert system usually recommends a solution based on facts in its knowledge base and on the other information it can acquire. Expert systems have been used to solve many different problems in a variety of field. Some of these areas are listed in Table 9, which is intended to give a brief overview of the breadth of applications that has developed. One area in which there has been extensive efforts to utilize expert systems is the nuclear power field, many of which could affect safety and safety-related systems. The scope of these applications has been documented by Bernard and Washio (1989).

Table 9. Applications of Expert Systems

FIELD	*USE*
Design and Engineering	Collecting and storing knowledge of best designers speeding the design process
Computer applications	Configuring equipment to user specifications Diagnosing problems with computer equipment
Manufacturing	Managing human and machine resources Facilitating factory automation
Finance	Decision support tools Providing tax and other business advice Processing loan and mortgage applications Analyzing financial risk
Science and Medicine	Providing medical advice in hospitals Providing diagnostic assistance to medical personnel Patient monitoring
Geological applications	Advising regarding mineral deposit and oil locations Advising drillers regarding stuck bits

Source ; Tsoukalas & Uhrig (1997)

2.3.2 Models on Expert System platform

Most of the mathematical models are developed with the prime objective to gain an understanding of the phenomena involved and to evaluate relevant parameters quantitatively by processing the available data and/or information. This is usually accomplished through "modeling" of the system, either experimentally or analytically (using mathematics and physical principles). Most hybrid system relates experimental data to systems or models. By having a developed expert system the user can perform distinct processes such as sensitivity analysis, statistical regression, etc. to gain a better understanding of the system. Such experimentally derived models give insight into the nature of the system behavior that can be used to enhance mathematical and physical models. There are, however, many situations in which the phenomena involved are very complex and often not well understood and for which first principles models are not possible. Even more often, physical measurements of the pertinent quantities are very difficult and expensive. These difficulties lead us to explore the use of neural networks and fuzzy logic system as a way of obtaining models based on experimental measurements. (Tsoukalas and Uhrig, 1997)

Neural network and fuzzy theory have been underground technologies for many years. They have had far more critics than supporters for most of their brief histories. Until recently most neural and fuzzy researchers published and presented papers in non-neural and non-fuzzy journals and conferences. This has prevented standardization and suggested that the two fields represent pantheons of ad hoc models and techniques.

Neural networks and fuzzy systems estimate functions from sample data. Statistical and artificial intelligence (AI) approaches also estimate functions. For each problem, statistical approaches require that we guess how outputs functionally depend on inputs. Neural and fuzzy systems do not require that we articulate such a mathematical model. Neural and fuzzy systems are numerical model–free estimators, and dynamical systems. Numerical algorithms convert numerical inputs to numerical outputs. Neural theory embeds in the mathematical fields of dynamical systems, adaptive control, and statistics. Fuzzy theory overlaps with these fields and with probability, mathematical logic, and measure theory. Researchers and commercial firms have developed numerous neural and fuzzy integrated– circuit chips. High-speed modems, long – distance telephone calls, and some airport bomb detectors depend on adaptive neural algorithms. Fuzzy systems run subways, tune televisions and computer disc heads, focus and stabilize camcorders, adjust air conditioners and washing machines and vacuum sweepers, defrost refrigerators, schedule elevators and traffic lights, and control automobile motors, suspensions, and emergency braking systems. In these cases, and in general, we use neural networks and fuzzy systems to increase *machine* IQ. (Kosko,1992)

2.3.2.1 Neural Networks

Neural networks, neurocomputing, or ‘ brainlike’ computation is based on the wistful hope that we can reproduce at least some of the flexibility and power of the human brain by artificial means. Neural networks consist of many simple computing elements–generally simple nonlinear summing junctions–connected together by connections of varying strength, a gross abstraction of the brain, which consists of very large numbers of far more complex neurons connected together with far more complex and far more structured couplings.

Neural networks help solve these problems with neural mechanisms of generalization. To oversimplify, suppose we represent an object in a network as a pattern of activation of several units. If a unit or two responds incorrectly, the overall pattern stays pretty mush the same, and the network still responds correctly to stimuli. Or, if an object, once seen, reappears, but with slight differences, then the pattern of activation representing the object closely resembles its previous appearance, and the network still tends to respond almost as it did before. When neural networks operate, similar inputs naturally produce similar outputs. Most real –world perceptual problems have this structure of input–output continuity.

2.3.2.2 *Fuzzy logic*

Many decision-making and problem-solving tasks are too complex to be understood quantitatively, however, people succeed by using knowledge that is imprecise rather than precise. Fuzzy set theory, originally introduced by Lotfi Zadeh in the 1960's, resembles human reasoning in its use of approximate information and uncertainty to generate decisions. It was specifically designed to mathematically represent uncertainty and vagueness and provide formalized tools for dealing with the imprecision intrinsic to many problems. By contrast, traditional computing demands precision down to each bit. Since knowledge can be expressed in a more natural by using fuzzy sets, many engineering and decision problems can be greatly simplified.

Fuzzy set theory implements classes or groupings of data with boundaries that are not sharply defined (i.e., fuzzy). Any methodology or theory implementing "crisp" definitions such as classical set theory, arithmetic, and programming, may be "fuzzified" by generalizing the concept of a crisp set to a fuzzy set with blurred boundaries. The benefit of extending crisp theory and analysis methods to fuzzy techniques is the strength in solving real-world problems, which inevitably entail some degree of imprecision and noise in the variables and parameters measured and processed for the application. Accordingly, linguistic variables are a critical aspect of some fuzzy logic applications, where general terms such a "large," "medium," and "small" are each used to capture a range of numerical values. While similar to conventional quantization, fuzzy logic allows these stratified sets to overlap (e.g., a 85 kilogram man may be classified in both the "large" and "medium" categories, with varying degrees of belonging or membership to each group). Fuzzy set theory encompasses fuzzy logic, fuzzy arithmetic, fuzzy mathematical programming, fuzzy topology, fuzzy graph theory, and fuzzy data analysis, though the term fuzzy logic is often used to describe all of these.

Fuzzy logic emerged into the mainstream of information technology in the late 1980's and early 1990's. Fuzzy logic is a departure from classical Boolean logic in that it implements soft linguistic variables on a continuous range of truth values, which allows intermediate values to be defined between conventional binary. It can often be considered a superset of Boolean or "crisp logic" in the way fuzzy set theory is a superset of conventional set theory. Since fuzzy logic can handle approximate information in a systematic way, it is ideal for controlling nonlinear systems and for modeling complex systems where an inexact model exists or systems where ambiguity or vagueness is common. A typical fuzzy system consists of a rule base, membership functions, and an inference procedure. Today, fuzzy logic is found in a variety of control applications including chemical process control, manufacturing, and in such consumer products as washing machines, video cameras, and automobiles.

2.3.3 Comments

Neural networks and fuzzy systems represent two distinct methodologies that deal with uncertainty. Uncertainties that are important include both those in the model or description of the systems involved as well as those in the variables. These uncertainties usually arise from system complexity (often including nonlinearities; we think of complexity as a property of system description-that is, related to the means of computation or language and not merely a system's complicated nature). Neural networks approach the modeling representation by using precise inputs and outputs, which are used to "train" a generic model which has sufficient degrees of freedom to formulate a good approximation of the complex relationship between the inputs and the outputs. In fuzzy systems, the reverse situation prevails. The input and output variables are encoded in "fuzzy" representations, while their interrelationships take the form of well-defined if/then rules. Zadeh ingenious observation that the uncritical pursuit of precision may be not only unnecessary but actually a source of error led him to the notion of a fuzzy set. Each of these approaches has its own advantages and disadvantages. (Tsoukalas and Uhrig, 1997)

Neural networks can represent (i.e., model) complex nonlinear relationships and they are very good at classification of phenomena into reselected categories used in the training process. On the other hand, the precision of the outputs is sometimes limited because the variables are effectively treated as analog variables (even when implemented on a digital computer), and "minimization of least squares errors" does not mean "zero error." (Kosko, 1992) Further more, the time required for proper training can be substantial (sometimes hours or days). Perhaps the "Achilles heel" of neural networks is the need for substantial data that are representative and cover the entire range over which the different variables are expected to change.

Fuzzy logic systems address the imprecision of the input and output variables directly by defining them with fuzzy numbers (and fuzzy sets) that can be expressed in linguistic terms (e.g.,cold, warm, and hot). Furthermore they allow far greater flexibility in formulating system descriptions at the appropriate level of detail. Fuzziness has a lot to do with the parsimony and hence the accuracy and efficiency of a description. This means that complex process behavior can be described in general terms without precisely defining the complex (usually nonlinear) phenomena involved. The philosophical principle holding that more parsimonious descriptions are more representative of nature, we may say that fuzzy description are more parsimonious and hence easier to formulate and modify and perhaps more tolerant of change and even failure.

Neural and fuzzy systems differ in how they estimate sampled functions. They differ in the kind of sample used, how they represent and store those samples, and how they associatively "inference" or map inputs to outputs.

These differences appear during system construction. The neural approach requires the specification of a nonlinear dynamical system, usually feedforward, the acquisition of a sufficiently representative set of numerical training samples, and the encoding of those training samples in the dynamical system by repeated learning cycles. The fuzzy system requires only that we partially fill in a linguistic "rule matrix". This task is markedly simpler than designing and training a neural network. Once we construct the systems, we can present the same numerical inputs to either system. The outputs will reside in the same numerical space of alternatives

Which system, neural or fuzzy, is more appropriate for a particular problem depends on the nature of the problem and the availability of numerical and structured data. To date engineers have applied fuzzy techniques largely to control problems. These problems often permit comparison with standard control- theoretic and expert system approaches. Neural network so far seem best applied to ill-defined two-class pattern-recognition problems (defective or non-defective, bomb or not, etc.)

Fuzzy system estimate functions with fuzzy-set samples (A_i,B_i) Neural systems use numerical-point samples (x_i , y_i). Both kinds of samples reside in the input-output product space X x Y.

We shall refer to the antecedent term Ai in the fuzzy association (A_i,B_i) as the input associant and the consequent term Bi as the output associant.
The fuzzy-set sample (A_i,B_i) encodes structure. It represents a mapping, a minimal fuzzy association of part of the output space with part of the input space.

The fuzzy association (A_i,B_i) represents system structure, as an adaptive clustering algorithm might infer or as an expert might articulate. In practice there are usually fewer different output associants or "rule" consequents B_i than input associants or antecedents A_i .

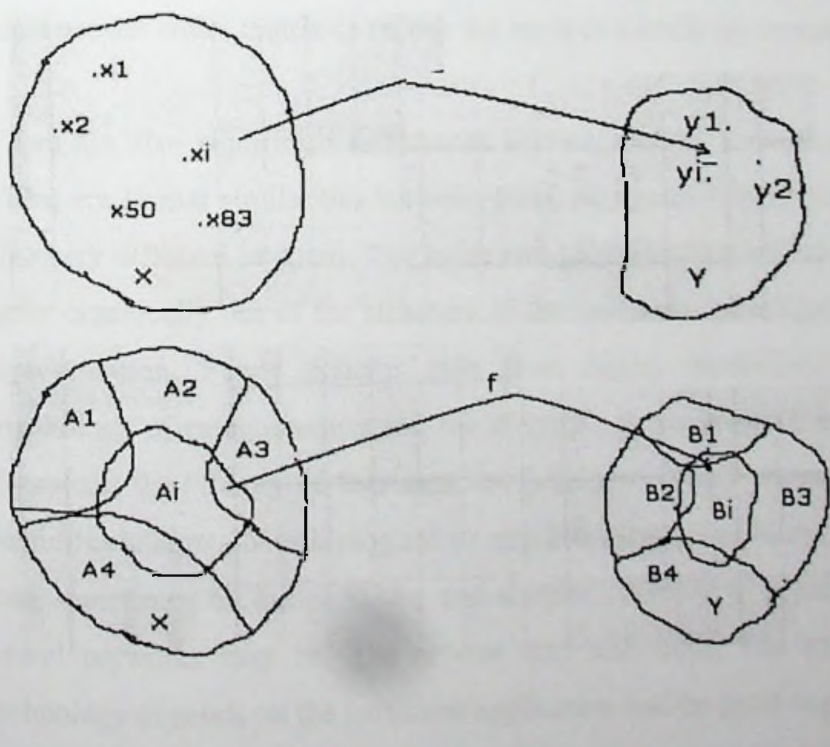


Fig. 13. Fuzzy and Neural Function Estimators Source : Kosko (1992)

Function f maps domain X to range Y. In the first illustration we use several numerical - point samples (Xi, Yi) to estimate f: X⟶ Y. In the second case we use only a few fuzzy subsets A_i of X and B_i of Y.

Fig. 13 illustrates the geometry of fuzzy -set and numerical-point samples taken from the function f: (XxY)

The neural approach suffers a deeper problem than just the computational burden of training. What does it encode? How do we know the network encodes the original structure? What does it recall? There is no natural inferential audit trail. System nonlinearities wash it away. Unlike an expert system, we do not know which inferential paths the network uses to reach a given output or even which inferential paths exist. There is only a large system of synchronous or asynchronous nonlinear function. Unlike, say, the adaptive Kalman filter, we cannot appeal to a postulated mathematical model of how the output state depends on the input state. Neural networks. The cost is system inscrutability.

In contrast, fuzzy systems directly encode the linguistic sample (Heavy, Longer) in a dedicated numerical matrix, perhaps of infinite dimensions. For practical problems we need not store a large, perhaps infinite, numerical matrix. Instead we use virtual representation scheme. Numerical point inputs permit this simplification. In general we describe inputs by an uncertainty distribution, probabilistic or fuzzy. Then we must use the entire matrix or reduce the input to a scalar by averaging.

There are also significant differences between neural networks and fuzzy systems. There are formal similarities between them, as Kosko (1992) points out, but they are also very different in detail. The noise and generalization abilities of neural networks grow organically out of the structure of the networks, their dynamics, and their data representation. Fuzzy systems start from highly formalized insights about the psychology of categorization and the structure of categories found in the real world. Therefore, the "theory of fuzziness" as developed is and abstract system that makes no further claims about biological or psychological plausibility. This abstract system may sometimes be easier to use and simpler to apply to a particular problem than neural networks may be. The reverse may also hold. The use of one or another technology depends on the particular application and on good engineering judgment.

Engineering techniques for dealing with uncertainty are sometimes as much statements about human psychology as they are about engineering. Neural networks deal with uncertainty as humans do, not by deliberate design, but as a byproduct of their parallel–distributed structure. It would be equally possible, and perhaps desirable, for us to directly build these insights about categorization into and artificial system. Fuzzy systems take this approach. Due to the inherent imprecision and uncertainty of construction knowledge conceived by construction engineers and managers, the concept of the linguistic variable is very useful for knowledge representation of decision-making problems in construction engineering and management. Moreover, the conceptions of existence or non existence of a linguistic variable are different from one to another. The conventional quantitative crisp measurement is not appropriate for construction knowledge representation in analysis of factors affecting the mark-up size decision problems.

A neural network system learns from cases. In this sense it is similar to the CBR. However, its reasoning process is concealed from the decision maker, operating like a black box. The decision maker cannot trace the reasoning process. For this reason, conclusions derived from the artificial Neural networks are not very convincing to the decision maker (Chua et.al., 2001).

Further, the most of the factors to be considered in the model are of cognitive in nature. The cognitive uncertainties are come generally from the lack of relative distinction or fuzziness. These may be due to human error or judgment, abstract representation of a system, and lack of data. The advantage of using fuzzy logic for the problems in this nature is that the Fuzzy logic can handle cognitive uncertainties very well (Aggrawal et.al., 2003)

Therefore, the proposed methodology adopts the concept of the fuzzy linguistic variable as the scheme for the knowledge representation based on the factors affecting the Competitive Bidding in the construction industry.

3. FUZZY KBS FOR MARK-UP SIZE DECISION

3.1 INTRODUCTION

In this chapter the development of Fuzzy expert system for mark-up size decision on competitive bidding in procurement of Construction contracts is discussed. The development of the system involves Knowledge Acquisition, Knowledge Representation ,Knowledge Encoding, Expert System Testing, Expert System Implementation. It is described in the following sequence

- Conceptual design of the system
- Physical development of the system
- The usage of the system- Limitations

3.2 SYSTEM DEFINITION AND DEVELOPMENT

3.2.1 Conceptual Design of the System

In developing a computer-based expert system, there are two all-important persons or groups involved: the domain expert, who understands the problem at hand and has a good deal of experience in handling such problems; and the knowledge engineer, skilled in computers but not necessarily having any acquaintance with the type of problem being addressed. The knowledge engineer must somehow translate an appreciable amount of the domain experts' pertinent knowledge into computer code, which will assist a less-than-expert person in handling an immediate problem. Establishing effective communication between these two key persons is of the utmost importance

As discussed previously, expert systems are computer programs that emulate the reasoning process of a human expert or perform in an expert manner in a domain for which no human expert exists. An expert system is typically consists of at least three parts; an inference engine, a knowledge base and a global memory.

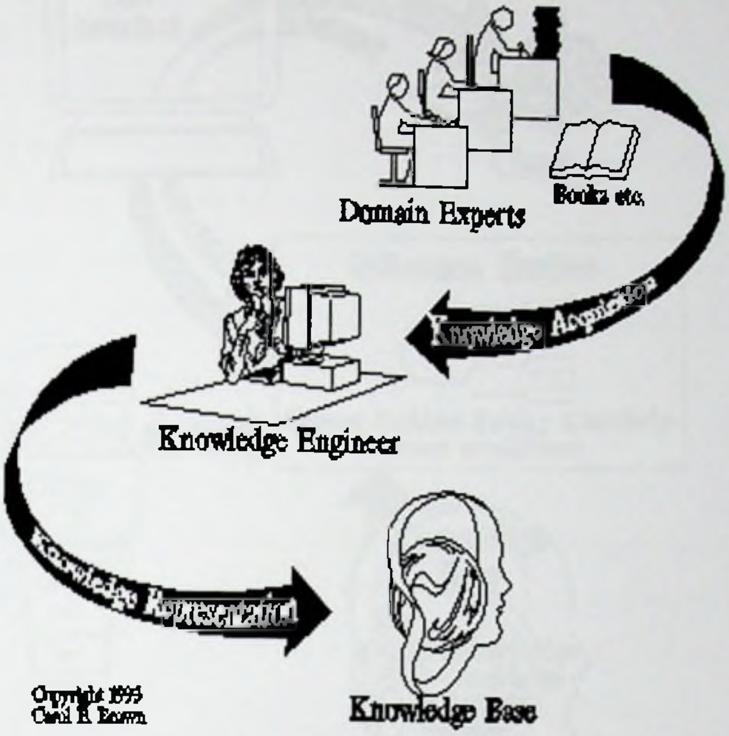


Fig. 14. Flow of Data in a KBS Source : (Rick & Knight 1991)

The knowledge base contains the expert domain knowledge for use in the problem solving. The working memory is used as a starch pad and to store information gained from the user to the system. The inference engine uses the domain knowledge together with the acquired information about a problem to provide an expert solution. However, practical expert systems typically reason with uncertain and imprecise information gathered from the domain experts. The knowledge that they embody is often not exact as the human's knowledge is imperfect. The user-supplied information also may imperfect.

3.2.2 System Development

The development of the system basically consists of three (four) sections. Namely, Fuzzification, Inference Engine, (Composition), and Defuzzification.

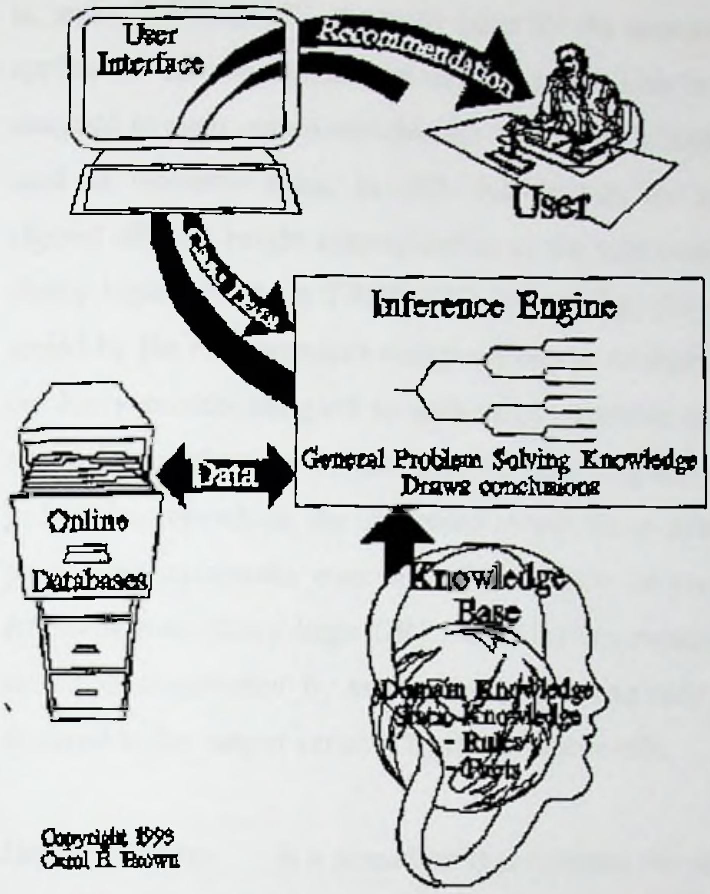


Fig. 15 A model of an Artificial Intelligence (AI) Source : (Rick & Knight 1991)

A certain number of ingredients, in accordance with past experience of handling the job, are classified as input variables and each input variable can be further divided into terms. All the terms are actually fuzzy subsets defined within their mother variable.

Fuzzification : is the procedure that converts the raw data from the practical world into membership functions of those fuzzy subsets. That is, Under FUZZIFICATION, the membership functions defined on the input variables are applied to their actual values, to determine the degree of truth for each rule premise.

The membership functions are then fed into the inference engine, resulting in membership function of the output variables after manipulation in accordance with the standard operation procedures of fuzzy sets. The inference engine consists of a rule base from the knowledge of experienced personnel (i.e. domain experts) the output variables are the possible actions taken or decisions made by the system. That is, under INFERENCE, the truth value for the premise of each rule is computed, and applied to the conclusion part of each rule. This results in one fuzzy subset to be assigned to each output variable for each rule. Usually only MIN or PRODUCT are used as inference rules. In MIN inferencing, the output membership function is clipped off at a height corresponding to the rule premise's computed degree of truth (fuzzy logic AND). In PRODUCT inferencing, the output membership function is scaled by the rule premise's computed degree of truth. Under COMPOSITION, all of the fuzzy subsets assigned to each output variable are combined together to form a single fuzzy subset for each output variable. Again, usually MAX or SUM are used. In MAX composition, the combined output fuzzy subset is constructed by taking the point wise maximum over all of the fuzzy subsets assigned to variable by the inference rule (fuzzy logic OR). In SUM composition, the combined output fuzzy subset is constructed by taking the point wise sum over all of the fuzzy subsets assigned to the output variable by the inference rule.

Defuzzification : is a procedure that converts the member ship functions back into crisp values such that they are meaningful to human users and also uniquely define the solutions. That is , Defuzzification is useful to convert the fuzzy output set to a crisp number. There are more defuzzification methods than you can shake a stick at (at least 30). Two of the more common techniques are the CENTROID and MAXIMUM methods. In the Centroid method, the crisp value of the output variable is computed by finding the variable value of the center of gravity of the membership function for the fuzzy value. In the Maximum method, on of the variable values at which the fuzzy subset has its maximum truth value is chosen as the crisp value for the output variable.

In the physical development phase of this system it is discussed the following.

- Data Collection
- Fuzzification
    - Normalization of the fuzzy control variables
    - Quantification of the fuzzy control variables
    - Mapping of fuzzy membership functions

- Inference
  - Development of the linguistic rule-base
  - Inference by the system
- Defuzzification
  - Defuzzification with Mamdani OR operator

3.2.2.1 *Data Collection.*

Markup size decision of a construction bid will be a function of various factors related to the context of influence. The effects of the factors contribute to the final markup size decision either positively or negatively. Considering the phenomenon and scenario, relevant literature was reviewed. Most of the researchers Shash (1992), Dulaimi and GuoShan (2002), Chua and Li (2000), had ranked the factors they had identified defining an important index, which reflects how much the certain factor many affect the final bid decision on mark up size. They further categorized these in to few groups considering that relevance to Project, the Company the Industry etc

After a comprehensive literature review 10 factors were selected, as input variables considering the relevance of those to the considered context. These were ranked according to the important indices identified in the literature and endorsements from the domain experts were obtained for the identified factors for those compliance. Table 1 shows those factors with the sources with those importance indices.

Each variable is further divided in to three terms as High, Medium, low for clearer representation on the basis of those fuzzy values and all these terms are actually fuzzy subsets defined within their mother variable.

By a questionnaire survey answered by the heads of the tendering department of leading construction companies in Sri Lanka, these variables were assigned with percentages based on how those factors affect to a company on its operations, turn over and corporate objective s of the company etc., under high, medium and low categories.

Structured interviews conducted with the experts in the industry; Consultants, Construction Contractors, Quantity surveyors and Engineers professionals were reviewed their rules of experience in competitive bidding considering under what circumstance the make up size would be a higher percentage or otherwise and how influential those selected factors affect in deciding the mark up size in competitive bidding. However, the ranking of those were very difficult as those were subjective, linguistic, and uncertain in nature and may related to the other factors, which are not discussed here. These results were used to develop the rules in the system.

3.2.2.2 Fuzzification

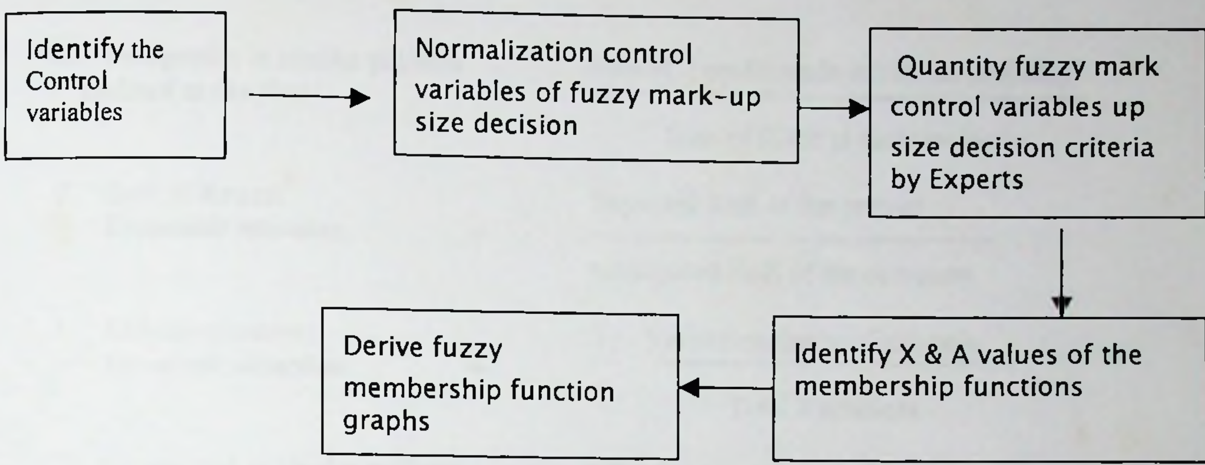
In broader sense the fuzzification is the process that converts raw data which are linguistic in nature, from the real world regarding the input terms in to membership functions belonging to the corresponding fuzzy sub sets. It is generally a mistake to try to resolve the heurist in the values of the data concerned with crisp boundaries, since, descriptors with non zero truth values have some degree of validity; the general rule is to hung on to the ambiguities, since this lends sturdiness of the decision rules.

There are four (4) main methods for establishing the fuzzy membership functions. (Thomas et.at., 2001). These are

i. The horizontal approach
ii. The vertical approach
iii. The pair wise comparison method
iv. The membership function estimation approach with the aid of probabilistic characteristics.

The statistical methods based membership function naturally quantitative, that is, there is a reason to believe that the membership function has a relationship to some physical property of the set. (Boussabaine & Elhag 1999). Therefore the statistically based membership functions were used in this research. This allows the practitioners to develop their own membership functions easily and the problem of discontinuity in the transition from the full membership to absolute exclusion of pure horizontal methods will not appear.

The sequence of the development of the membership function from the identification of variables is given below.



<u>Fig 16 :- Process of formulating fuzzy membership functions</u>

<u>(modified from LAM)</u> Source : (Lam etal 2001)

3.2.2.3 *Normalization of Fuzzy Control Variables*

The fuzzy mark-up size decision criteria were transformed from linguistic definitions in to mathematical formulae based on the findings of literature reviewed and the interpreted knowledge and the experience of the experts in the industry. This is the process that identifies at what value of X in the universe of discourse the membership function reaches the unity, where as in fuzzy linguistic descriptions this requirement may be relaxed. Fuzzy values ought to be convex, just as fuzzy numbers, but not necessarily normal. (Tsoukalas and Uhrig, 1997)

The definitions of the selected factors are given below, which are the normalizations of fuzzy variables for the expert system.

1. Availability of Projects
   Bidding Situation

$$= \frac{\text{\# on going projects to relevant category}}{\text{\# Contractors available in relevant category}}$$

2. Need for work
   (1-Current work Load)
   Related to the firm

$$= 1 - \frac{\text{Total value of the projects in hand}}{\text{Estimated turn over of the company for the considered yr}}$$

3. Owner /Client identity
   Related to the firm = $\dfrac{\text{Past projects completed with the client satisfactorily}}{\text{Projects completed with the client}}$

4. Past profits in similar projects
   Related to the firm = $\dfrac{\text{Sum of (profit made in similar projects)}}{\text{Sum of (Cost in each project)}}$

5. Rate of Return
   Economic situation = $\dfrac{\text{Expected RoR of the project}}{\text{Anticipated RoR of the company}}$

6. Risk involvement
   Economic situation = $1 - \dfrac{\text{Variations due to client only}}{\text{Total Variations}}$

7. Experience in similar projects
   Related to the firm = $\dfrac{\text{\# Similar projects completed in last 5yrs}}{\text{Total \# projects completed in last 5 Yrs}}$

8. Project Cash Flow
   (based on cash flow diagram) =
   Project characteristic $\dfrac{\text{Total Negative cash flow}}{\text{Total cash flow}}$

9. Current work load
   Volume of all current Projects the company has committed = $\dfrac{\text{Total value of Projects in hand}}{\text{Estimated turn over of the company for the considered yr}}$
   Related to the firm

10 Competition
   Bidding situation = $\dfrac{\text{\# Competitors for this particular Project}}{\text{Total \# contractors registered in same category}}$

3.2.2.4 Quantifying of Fuzzy Variables

Determination methods of membership values of a variable break down broadly into the following categories (Roberts, *URL* , 1989).

Subjective evaluation and elicitation: As fuzzy sets are usually intended to model people's cognitive states, they can be determined from either simple or sophisticated elicitation procedures. At they very least, subjects simply draw or otherwise specify different membership curves appropriate to a given problem. These subjects are typically experts in the problem area or they are given a more constrained set of possible curves from which they choose. Under more complex methods, users can be tested using psychological methods.

Ad-hoc forms :While there is a vast (hugely infinite) array of possible membership function forms, most actual fuzzy control operations draw from a very small set of different curves. This simplifies the problem, for example to choosing just the central value and the slope on either side.

Converted frequencies or probabilities : 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.

Physical Measurement :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 .

Learning and Adaptation : Quantification of fuzzy variables in this research was done according to the formula defined above . The expects in the context were requested to provide a numerical value that best illustrates a linguistic variable pertinent to fuzzy mark up size decision criteria with reference to the normal situation. That is the numerical value of each variable will reflects the linguistic representation of High, Medium and Low, on the Questionnaire which was to answered, for example, normal Risk involvement is the usually experience risk in a project of similar nature, where as risk involvement – medium is a linguistic variable one might specify as the desired (allowable a absorbable) Hence, a contractor may conceive a value compared to normal risk involvement, being the risk involvement – medium in the purpose of deciding the size of the make-up in competitive bidding.

The gathered data from structured interviews were analyzed and arrived at a reasonable mean value for each variable. The mean value of the numerical values of each term in variable is considered as the value for which the member ship function reaches the unity. The results obtained from the calculations are given in Table 10.

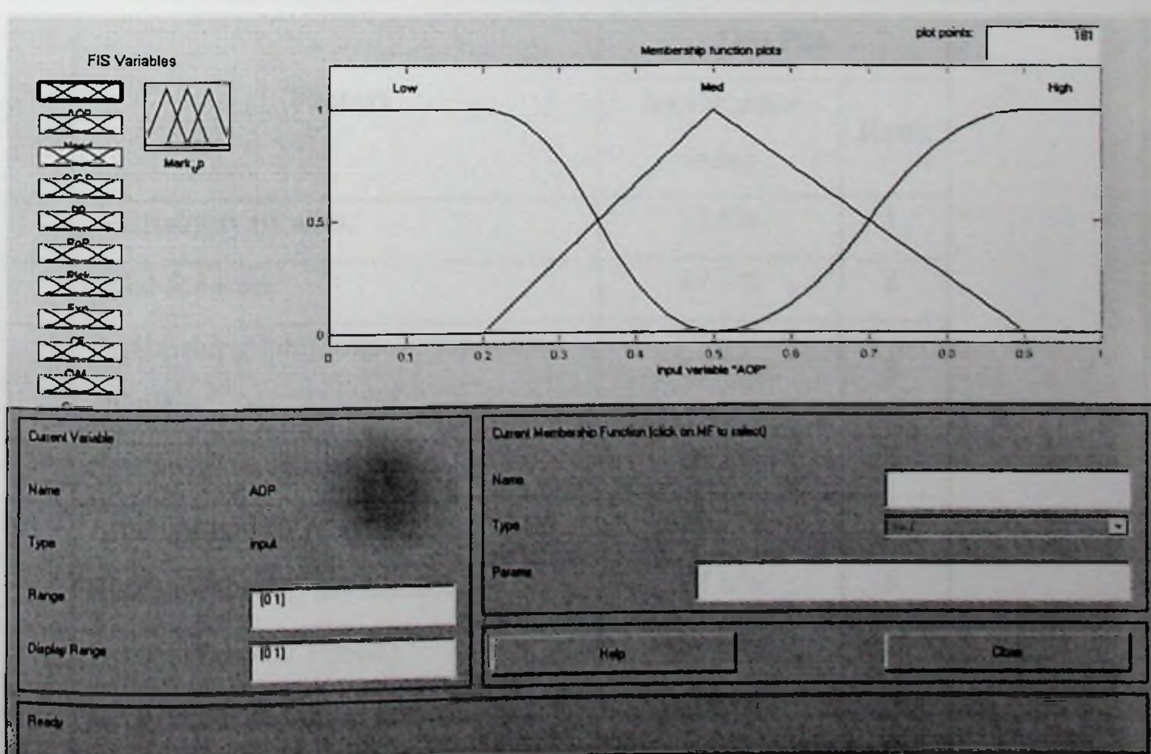
Table 10 . Values obtained from interviews

No.	Factor	Importance Index (%)	Rank	Value Drawn
1	Availability of Projects	93.8	High	70
			Medium	50
			Low	20
2	Need for Work	87.7	High	75
			Medium	50
			Low	10
3	Owner /Client relation	87.7	High	90
			Medium	40
			Low	20
4	Past Profits from similar Projects	86.2	High	10
			Medium	6
			Low	3
5	Rate of Return from the Project	86.2	High	75
			Medium	50
			Low	20
6	Risk Involvement in Investment	84.2	High	60
			Medium	30
			Low	15
7	Experience in similar Projects	80	High	70
			Medium	50
			Low	10
8	Cash Flow (Negative)	78.5	High	15
			Medium	5
			Low	2
9	Current Work Load	78.5	High	80
			Medium	45
			Low	15
10	Competition	73.8	High	65
			Medium	35
			Low	10

3.2.2.5 *Mapping of Fuzzy Membership Functions*

The most important step in the design of fuzzy decision support system is the determination of membership function of the sets. The mapping of numeric values on to confidence levels for word descriptions usually involves ambiguities in order to facilitate expects views in a given variable the overlapping membership functions to be used, so that word descriptors would carry non zero truth values for adjacent membership functions of a given variable.

The values of each term in variable are then extracted from the table 10 for the derivation of membership function for the mapping of it. The x-axis represent the value of each term in universe of discourse and the member ship grade is represented in—y(M) Axis with, unity is numerical value in the table 10 for each terms of the considered variable . The graphs were developed as the slope of the graphs changes unity to zero gradually. The variable term Medium considered to be result in a triangular shaped membership function while for High and Low it was used S -shaped and Z -shaped membership function respectively. A typical membership function of a variable for these three High, Medium and Low parameters are given below



Source : Matlab Tool Box

Fig. 17 A Membership Function

3.2.2.6 *Fuzzy Rule-Base*

A Fuzzy Expert System is an expert system that uses a collection of fuzzy membership function and rules, to reason about data. It used to express the thinking in terms of rules and has hide applicability and great flexibility. Especially, data driven rules are powerful; that is, the order in which rules are fired is determined by the data, and has a little or no effect with the order in which the rules are written. However to determine the relative effect of the factors considered the importance index for each factor has calculated as follows.

$\Sigma(ax) \times 100/5$

Where a= constant expressing the weighting given to each response. The weighting ranges from 1 to 5 where 1 is the least important and 5 is the most important:

X=n/N;

n= the frequency of the responses for a given factor ;

N= total number of responses.

The indices calculated for the factors considered in this research are given below

Table 11. Factors considered with Importance Indices and Rank Order

	Factors	Out Put	
		Importance index	Rank
	Availability of work	93.8%	1
	Need for work	87.7%	2
	Establishing long relationship with clients	87.7%	3
	Past profit in similar job	86.2%	4
	Anticipated rate of return on project	86.2%	5
	Risk involved in investment	84.6%	6
	Owner (Private/ Public)	80.0%	7
	Experience in similar project	80.0%	8
	Project cash flow	78.5%	9
	Current work load	78.5%	10

As an expert in your domain, you have probably not found it necessary to formalize your thinking processes, except when trying to explain to a junior person how you reached some conclusion. *But the computer requires defining your thinking in some formal way.* Various formalisms have been tried. The one which has shown the greatest flexibility and similarity to human thought processes is the *rule*, although other formalisms have been used, mostly in very special cases. The formalism used by expert production systems is a set of rules of the type of

If X is LOW **and/or** Y is HIGH **then** Z is MEDIUM

where X & Y are input variables (names for known data values) and z is the output variable (a name for data value to be computed)
Low, High, & Medium are the membership function defined to x, y & z respectively and/or_ is the operator.

Further, If (the data meets certain specified conditions) Then (take the specified actions, including modifying old data or asserting new data)

The left-hand side of the rule, or the IF part, is known technically as the *antecedent, or LHS; the right-hand side, or the THEN part, is called the consequent*, or RHS. The antecedent consists of tests to be made on existing data; the consequent holds actions to be taken if the data pass the tests in the antecedent. Concerning the antecedent, the statements IF certain patterns are found in the data and IF the data pass certain tests are quite equivalent.

Since we will be using fuzzy systems theory, it is possible to qualify all data with the confidence that the data are in fact true. For specific data, which satisfy the antecedent (more or less), our inference process will compute the confidence that the entire antecedent (LHS) is true. This antecedent confidence, together with our confidence in the rule itself, will become the confidence with which actions specified by the consequent (RHS) are taken. In particular, any data modified or created by the consequent will have that confidence attached

In a fuzzy rule-based system, the confidence with which the data match the antecedent is calculated; if this antecedent confidence is at least equal to a specified threshold value, the rule is said to be fireable. When a rule is fired, the consequent actions are carried out. The confidence with which these actions are taken depends on both the antecedent confidence and the confidence placed in the rule itself; this net confidence is the fuzzy AND (or minimum) of the antecedent and the rule confidences, and is called the posterior confidence.

The antecedent confidence and rule-firing threshold determine whether an instance of a rule is fireable; a rule instance if fireable if the antecedent confidence equals or exceeds the threshold. The posterior confidence is the confidence with which the consequent is executed, and is normally the confidence value stored with any data made or modified by the rule.

The set of rules in a Fuzzy expert system is known as the rules base or knowledge base.

Rules

1. **IF** Availability of Projects is ***High*** **(or)**
   Need for work is **Low (or)**
   Owner-Client identity is **Low_(or)**
   Past profits in similar projects is **Low_(or)**
   Rate of Return is **Low_(or)**
   Risk involvement is ***High*** **(or)**
   Experience in similar projects is **Low** **(or)**
   Project (negative) cash flow is ***High*** _ **(or)**
   Current Work load is ***High*** **(or)**
   Competition is **Low THEN** Mark-up size is **Very Very *High* ELSE.**

2. **IF** Availability of Projects is ***High*** **(or)**
   Need for work is **Low_(or)**
   Owner-Client identity is **Low_(or)**
   Past profits in similar projects is ***Medium*** **(or)**
   Rate of Return is **Low_(or)**

Risk involvement is ***Medium*** **(or)**

Experience in similar projects is **Low (or)**

Project (negative) cash flow is ***High*** **(or)**

Current Work load is ***High*** _ **(or)**

Competition is **Low THEN** - Mark-up size is_**Very *High* ELSE.**

3. **IF** Availability of Projects is ***High*** **(or)**

   Need for work is **Low_(or)**

   Owner-Client identity is ***Medium*** **(or)**

   Past profits in similar projects is ***Medium*** **(or)**

   Rate of Return is **Low_(or)**

   Risk involvement is ***Medium*** **(or)**

   Experience in similar projects is **Low (or)**

   Project (negative) cash flow is ***Medium*** **(or)**

   Current Work load is ***High*** _ **(or)**

   Competition is **Low THEN** - Mark-up size is_***High*** **ELSE.**

4. **IF** Availability of Projects is ***Medium*** **(or)**

   Need for work is ***Medium*** **(or)**

   Owner-Client identity is ***Medium*** **(or)**

   Past profits in similar projects is ***Medium*** **(or)**

   Rate of Return is ***Medium*** **(or)**

   Risk involvement is ***Medium*** **(or)**

   Experience in similar projects is ***Medium*** **(or)**

   Project (negative) cash flow is ***Medium*** **(or)**

   Current Work load is ***Medium*** **(or)**

   Competition is ***Medium*** **THEN** Mark-up size is ***Medium*** **ELSE**

5. **IF** Availability of Projects is **Low (or)**

   Need for work is ***High*** **(or)**

   Owner-Client identity is ***Medium*** **(or)**

   Past profits in similar projects is ***Medium*** **(or)**

   Rate of Return is ***High*** **(or)**

   Risk involvement is ***Medium*** **(or)**

Experience in similar projects is ***High*** **(or)**
Project (negative) cash flow is ***Medium*** **(or)**
Current Work load is **Low (or)**
Competition is ***High*** **THE** - Mark-up size is **Low ELSE.**

6. **IF** Availability of Projects is **Low (or)**
   Need for work is ***High*** **(or)**
   Owner-Client identity is ***High*** **(or)**
   Past profits in similar projects is ***Medium*** **(or)**
   Rate of Return is ***High*** **(or)**
   Risk involvement is ***Medium*** **(or)**
   Experience in similar projects is ***High*** **(or)**
   Project (negative) cash flow is **Low_ (or)**
   Current Work load is **Low (or)**
   Competition is High **THEN** - Mark-up size is_**Very Low_ELSE.**

7. **IF** Availability of Projects is **Low (or)**
   Need for work is ***High*** **(or)**
   Owner-Client identity is ***High*** **(or)**
   Past profits in similar projects is ***High*** **(or)**
   Rate of Return is ***High*** **(or)**
   Risk involvement is Low **(or)**
   Experience in similar projects is ***High*** **(or)**
   Project (negative) cash flow is **Low (or)**
   Current Work load is **Low (or)**
   Competition is High **THEN** - Mark-up size is **Very Very Low ELSE.**

3.2.2.7 *Inference by the system*

Fuzzy inference refers to the computational procedures used for evaluating Fuzzy linguistic descriptions. There are two important inference procedures; (Tsoukalas and Uhrig, 1997)

- GMP – Generalized Modulus Ponens
- GMT – Generalized Modulus Tollens

In GMT, a rule and a fuzzy value approximately matching its consequent is given and it is desired to infer the Antecedent, whereas in GMP it is desired to infer the consequent for known antecedents. That is GMP works in a manner analogous to evaluating a Function and GMT is analogous to finding the inverse (Papis and Sugeno, 1985).

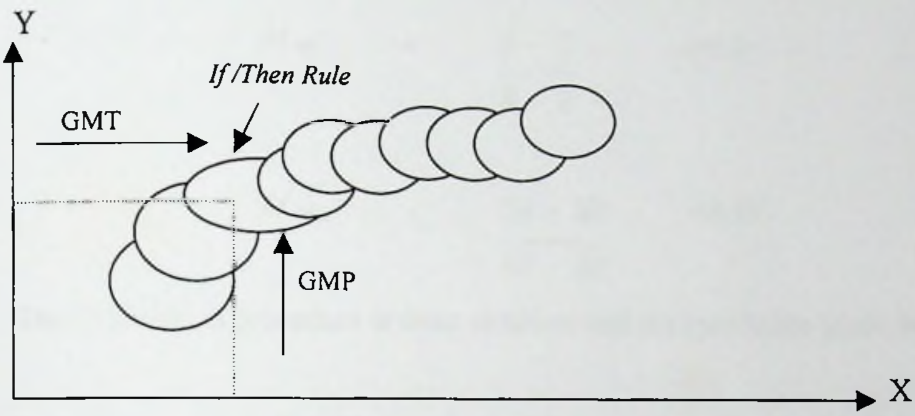


Fig 18. GMP and GMT evaluation of Fuzzy linguistic descriptions

In this research the data converted by the fuzzification for the inferencing by Mamdani method. That is the rule base is modeled through the Mamdani implication operator.

Consider, the following set of crisp values assigned to each input variable in a given instance.

Table 12. Sample set of Crisp Values

Avail Of projects	Need for work	Owner/ Client Identity	Past profits	Rate of Return	Risk Involved	Experience On similar projects	Negative Cash flow	Work load	Compe-tition
50%	50%	50%	05%	50%	50%	50%	50%	30%	50%

The process of inference according to the Mamdani OR implication operator will be discussed in latter stage.

The crisp values for Owner Client Identity (O/C ID), Past profits in Similar Projects (PP) and Risk Involvement (Risk) fire the membership functions Medium, Medium, Medium respectively, of those antecedent variables according to Rule 3. The resultant *M* for a given input value can be calculated for mark-up size as follows,

$$M_c = \frac{100 - 50}{100 - 30} = 0.71$$

$$M_{pp} = \frac{5 - 2}{8 - 2} = 0.5$$

$$M_{risk} = \frac{50 - 20}{60 - 20} = 0.75$$

The Calculation procedure is done as above and the results are given below

Table 13. Results of Inference using an example

Owner Client ID	*Past Profits in Similar projects*	*Risk involved*
0.71	*0.50*	*0.75*

Then Mamdani rule pick the maximum value of *M* as we use the OR operator for inference.

3.2.2.8 *Defuzzification*

Defuzzification is the reverse process of fuzzification. We have confidences in a fuzzy set of word descriptors, and we wish to convert these into a real number. This is necessary as we wish to output a number to the user. Defuzzification is the process of converting the linguistic values in to a single crisp value.

Fuzzy control engineers have many different ways of defuzzifying; fuzzy reasoning, however, can usually use quite simple methods. It is intuitive that fuzzification and defuzzification should be reversible; that is, if we fuzzify a number into a fuzzy set and immediately defuzzfy it, we should get the same number back again. If defuzzification is to take place, this has implications for the shape of membership functions used to fuzzify input variables into fuzzy sets used in the reasoning process, which ultimately results in defuzzifying an output fuzzy set

More generally, we define membership functions for our output fuzzy set, and use the defuzzification through the system. There are very many defuzzification procedures available for fuzzy control, but fuzzy reasoning applications can usually be satisfied with many fewer options. The most widely used strategies are (Lee,1990)

- The maximum criterion method
- The mean of maximum method (MOM)
- The center of area method (COA)

The decision as to which to use is a fairly technical matter. However, based on the detailed analysis done on different defuzzification methods by the Braae and Rutherford (1978), concluded that the Center of area (COA) method results more reliable outputs. It has further justified by Lee (1990) stating that a fuzzy logic controller based on the COA generally yields a lower mean square error than that based on MOM. (Perera and Imriyas, 2003).

the Centroid method, looks at the membership functions differently. Seeing that the function for ZERO is one-sided, the portion of the membership function to the left of the point at which the membership function is unity would not be considered. The function for MEDIUM is two-sided, but may be asymmetrical; the centroid method would first clip the membership function at the confidence of MEDIUM. We would then select the value for OUTPUT at the center of gravity of the clipped membership function and arrive at a typical value based on the membership function. The function for HIGH is one-sided, so the centroid method would select the value at the maximum end of universe of discourse as the representative value.

That is the process of defuzzifying a fuzzy set requires knowing representative values that correspond to each fuzzy set member. The representative value for each fuzzy set member is multiplied by the confidence in that member, the products summed, and the sum divided by the sum of the confidences.

This system too uses the COA method in defuzzification, which generates the COA of the possibility distribution of the predicted values of the bid mark-up size. This method uses the following equation:

$$COA = \int (x.Adx) / \int (Adx$$

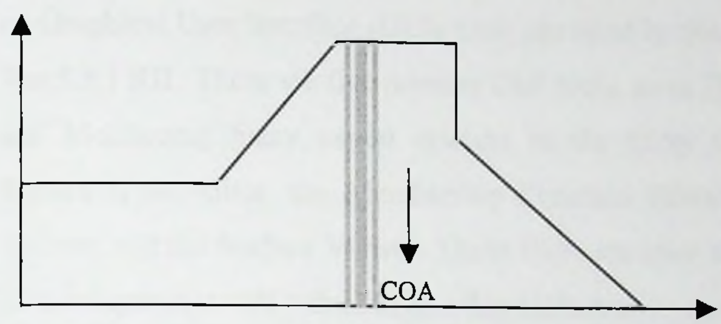
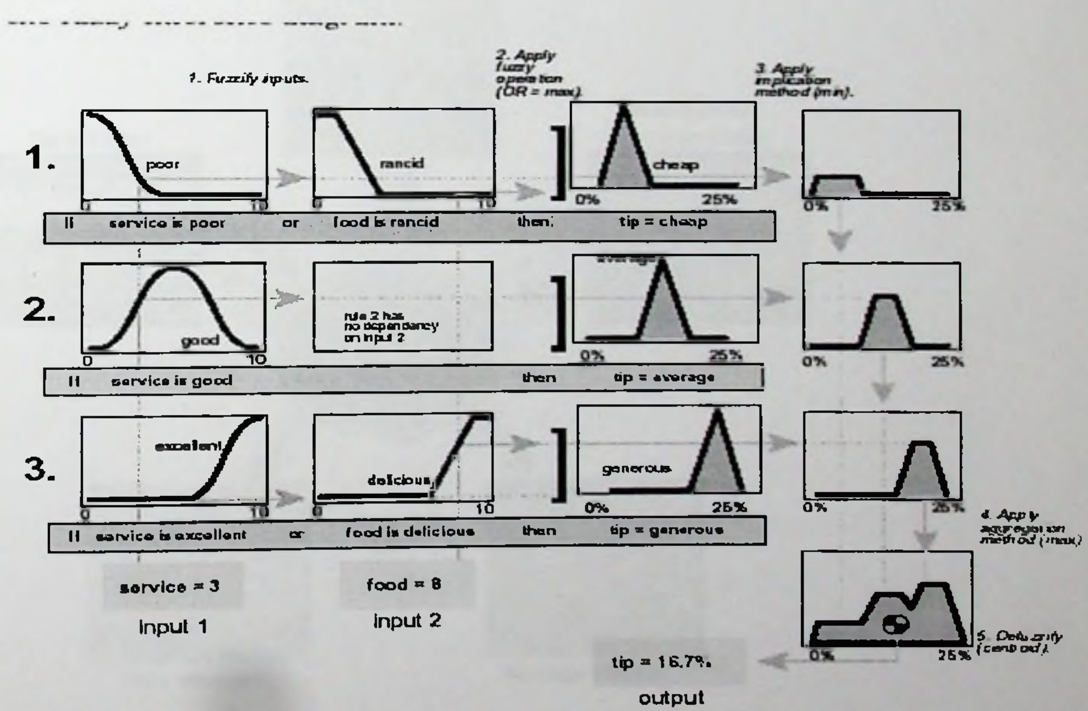


Figure 19 a : De- fuzzification with COA



Source Fuzzy Logic Tutorial

Figure 19 b : De- fuzzification (descriptive)

3.3 KBS FOR FOR BID MARK-UP SIZE (CombiD)

3.3.1 Components of the ComBiD

The proposed fuzzy expert system developed on mark-up size decision was developed on Graphical User Interface (GUI) tools provided by fuzzy logic toolbox in MATLAB Ver 5.3.1 Rl1. There are five primary GUI tools, as in Fig 19 for Developing, Editing, and Monitoring fuzzy expert systems in the fuzzy toolbox: the Fuzzy Inference System (FIS) editor, the Membership Function Editor, the Rule Editor, The Rule Viewer, and the Surface Viewer. These GUIs are inter connected, i.e. any amendment of the above tool will reflect in all other tools too.

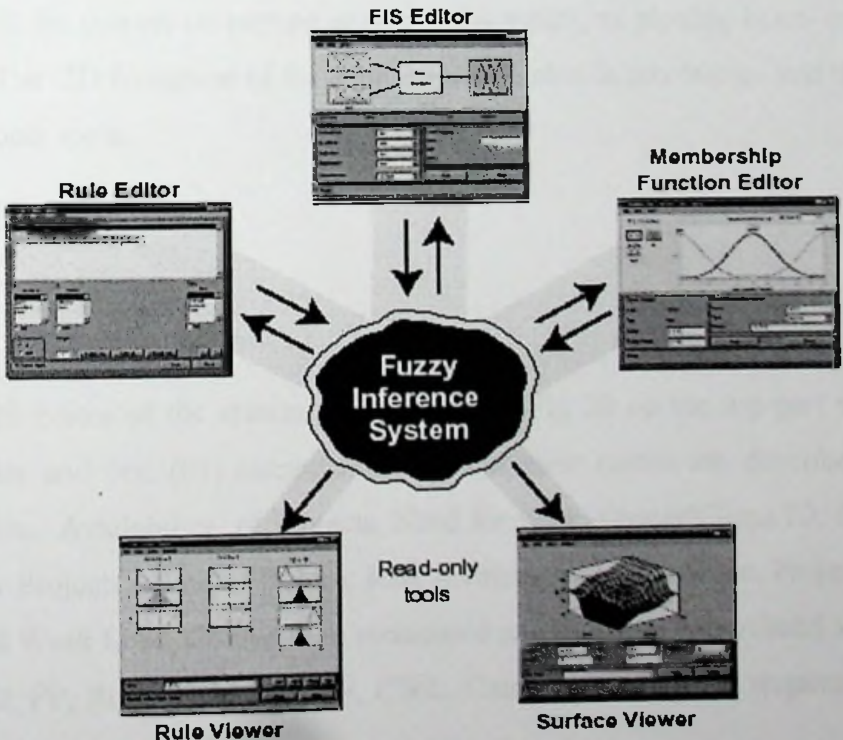


Fig. 20 : Fuzzy Inference System

Source; Fuzzy logic tool box

- *The FIS Editor:* this tools deals with crucial / high-level issues for the system: Such as Number of input variables and output variables ? What are those? What is the de- fuzzification method of the system etc.

- *The Membership Function Editor:* This is used to define the shapes of the membership functions incorporated in each variable.

- *The Rule Editor* : This helps for defining the collection of rules that define the behavior of the system

- *The Rule viewer and the Surface viewer* : These are used for monitor, as opposed to editing, the expert system. The Rule Viewer is a display of fuzzy inference diagram. The surface viewer is used to display the dependency of one of the outputs on anyone or two of the inputs, as plotting in co- ordinate axes. The 3D formation of the diagram is available in this feature and these are read only tools.

3.3.1.1 FIS Editor

The FIS Editor of the system is illustrated in Fig 20 on the top part ten (10) input variables and one (01) output variable with their names are described. The input variables; Availability of Projects, Need for work, Owner/Client ID, Past Profits in Similar Projects , Rate of Return, Risk Involvement, Experience, Project Cash Flow, Current Work Load, Competition considered and those are abbreviated as AOP, Need, O/C ID, PP, RoR, Risk, Exp, CF, CWL, Comp and Mark Up respectively to avoid congestion on the window.

The bottom part defines the inference options and centroid de- fuzzification method.

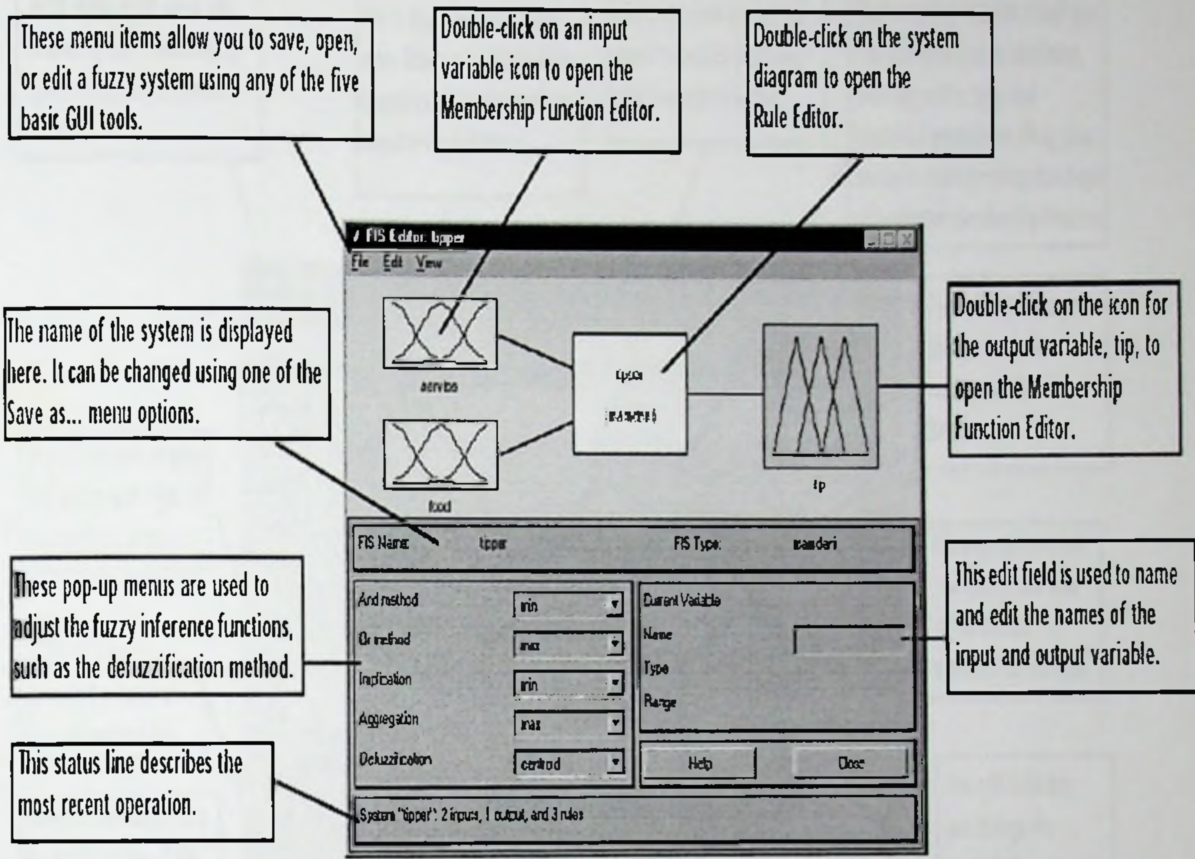


Fig 21 a. FIS Editor with its features

Source; Fuzzy logic tool box

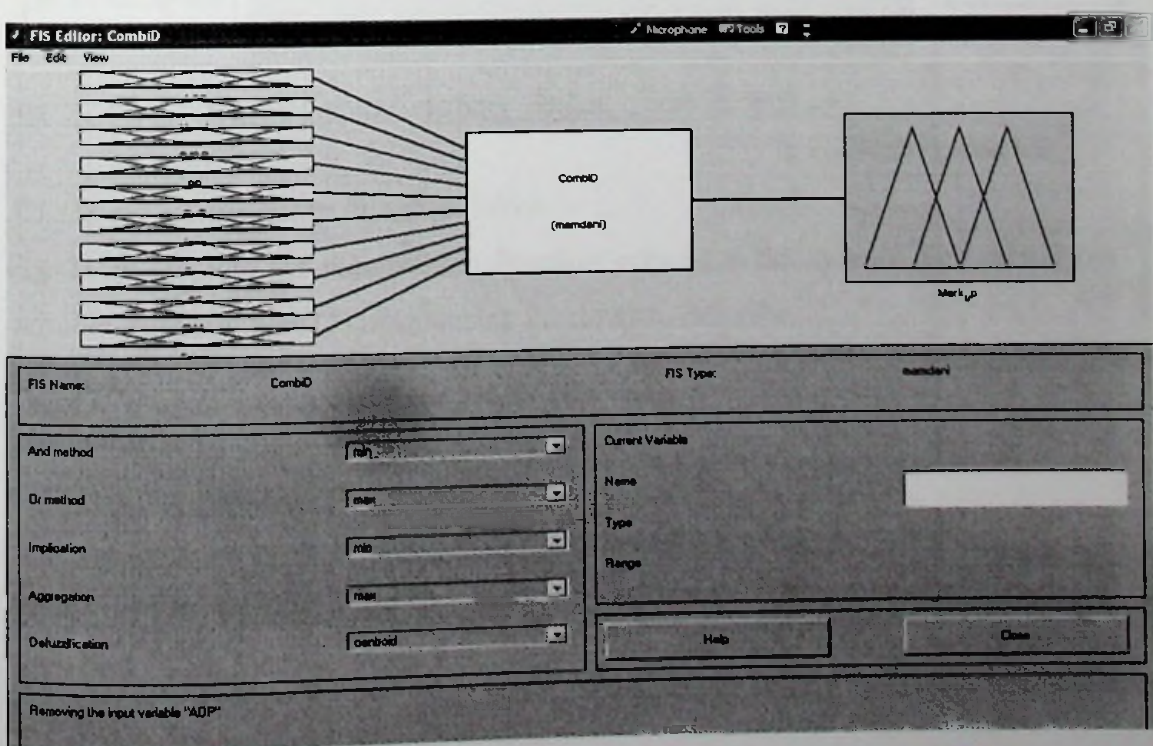


Fig 21 b. FIS Editor of CombiD

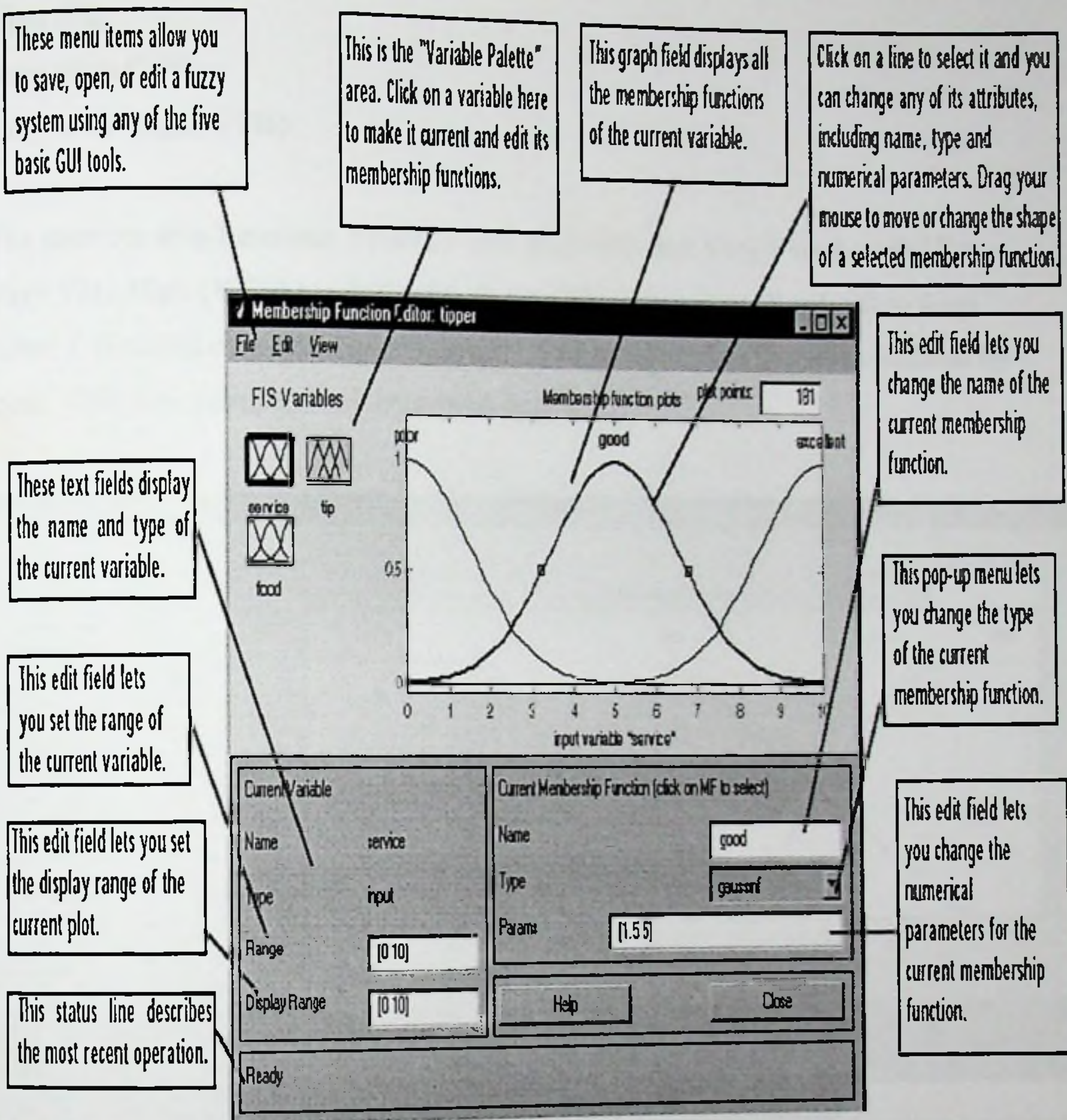


Fig 22 a. Membership function Editor with its features

Source; Fuzzy logic tool box

3.3.1.2 *Membership Function Editor*

Fig 21 b depicts the membership function editor for the system. For each input variable there are three (3) membership functions to describe

Low (L),

Medium(M),

High (H) for different range of X values.

Whereas there are seven (7) membership functions for the Output variable

Very Very Low (VVL),

Very Low (VL),

Low (L),

Medium(M),

High (H),

Very High (VH),

Very Very High (VVH).

The member ship functions Low (L) and High (H) and Very Very Low(VVL), Very Very High (VVH) are defined with two (02) data points (X values) to form either Z-function or S-function, while rest of the membership functions defined by three (03) data points to form triangular function.

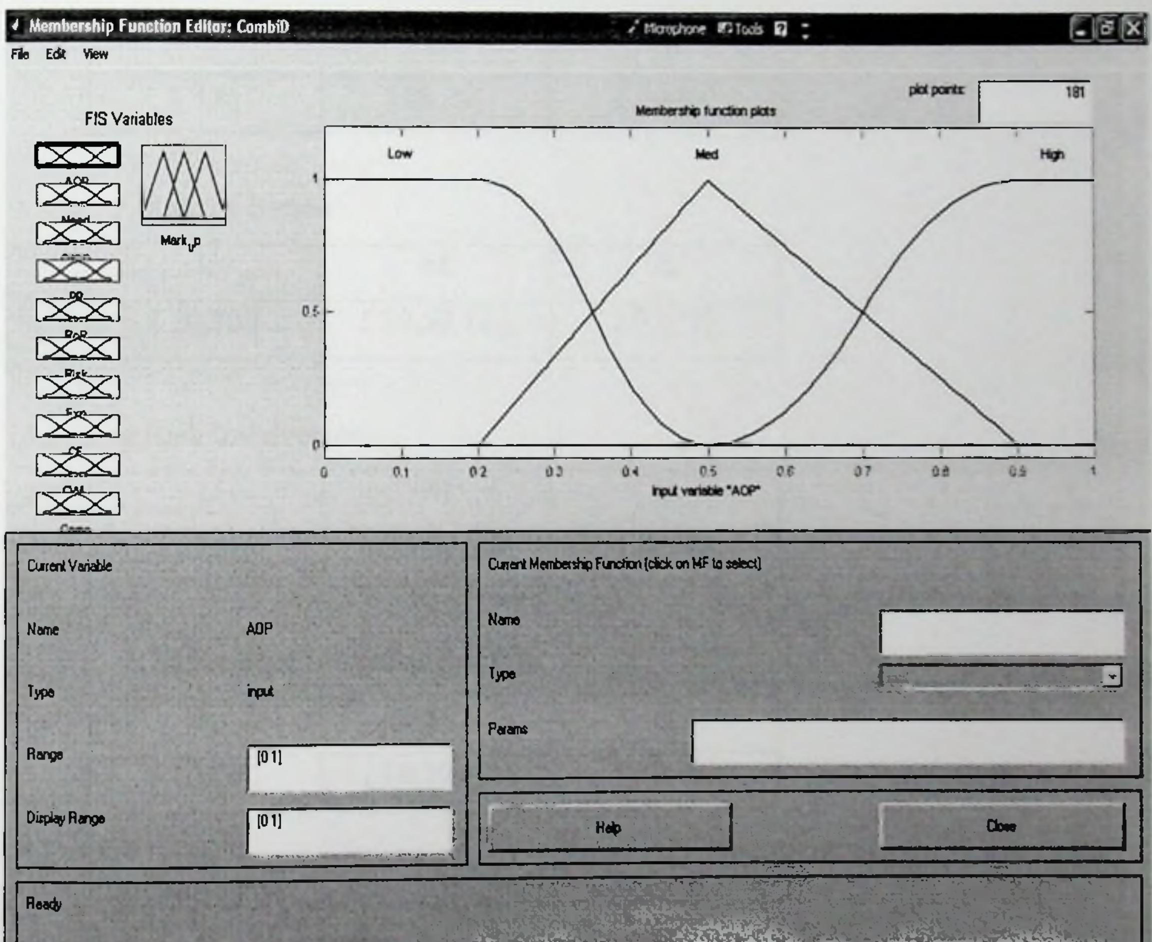


Fig. 22b Membership Function Editor

The data range for each variable for different membership functions are given below.

1. Availability of Projects

L	M	H
[20, 50]	[20, 50, 70]	[50,70]

2. Need For Work

L	M	H
[10,50]	[10,50,75]	[50,75]

3. Owner Client Identity

L	M	H
[20,40]	[20,40,90]	[40,90]

4. Past Profits in similar Projects

L	M	H
[3,6]	[3,6,10]	[6,10]

5. Rate of Return

L	M	H
[20,50]	[20,50,75]	[50,75]

6. Risk Involvement

L	M	H
[15,30]	[15,30,60]	[30,60]

7. Experience in similar Projects

L	M	H
[10,50]	[10,50,70]	[50,70]

8. Cash Flow

L	M	H
[2,10]	[2,10,20]	[10,20]

9. Current Work Load

L	M	H
[15,45]	[15,45,80]	[45,80]

10. Competition

L	M	H
[10,35] .	[10,35,65]	[35,65]

11. Mark –Up size

VVL	**VL**	L	M	H	**VH**	**VVH**
[3,8]	**[3,8,12]**	**[8,12,16]**	**[12,16,20]**	**[16,20,24]**	**[20,24,28]**	**[24,28]**

3.3.1.3 The Rule Editor

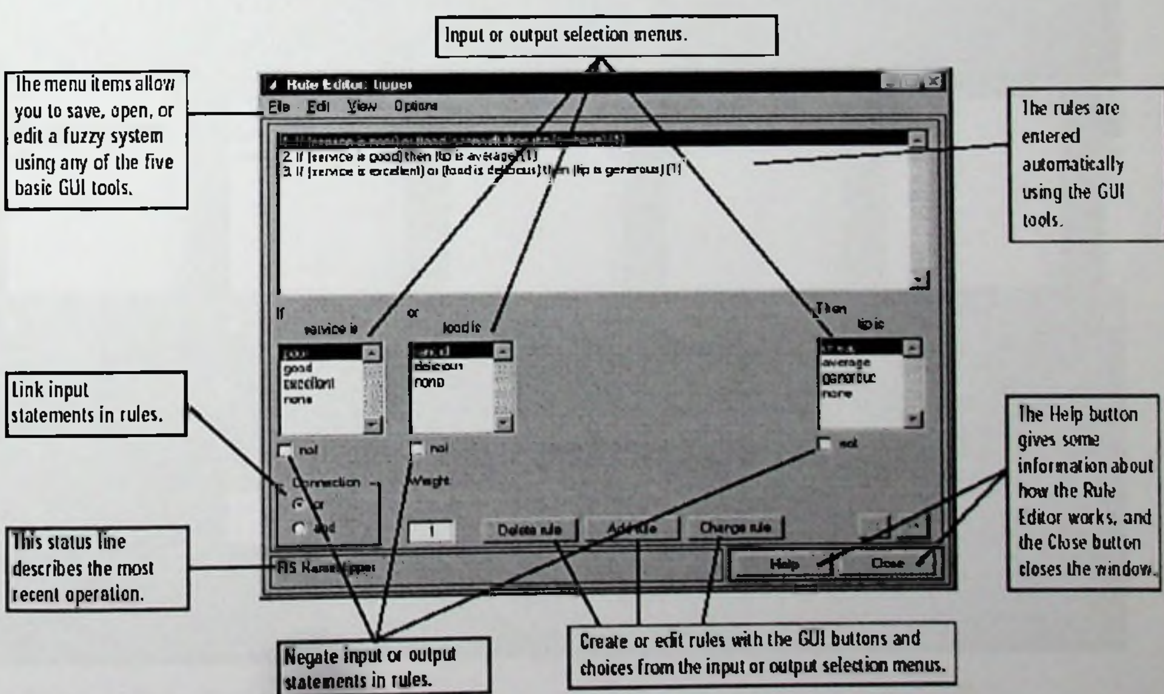


Fig 23 a. Rule Editor with its features Source; Fuzzy logic tool box

The rule editor allows to construct the fuzzy rule statement by considering the descriptions of the input and output variables defined with the FIS editor and Membership Function Editor, by clicking on and selecting one item in each input variable box, one item in each output box, and one connection item. Choosing 'none' as one of the variables qualities excludes that variable from a given rule. Fig 22 b depicts method of choosing variables and their qualities for the proposed system for the prediction of the mark –up size in Competitive bidding.

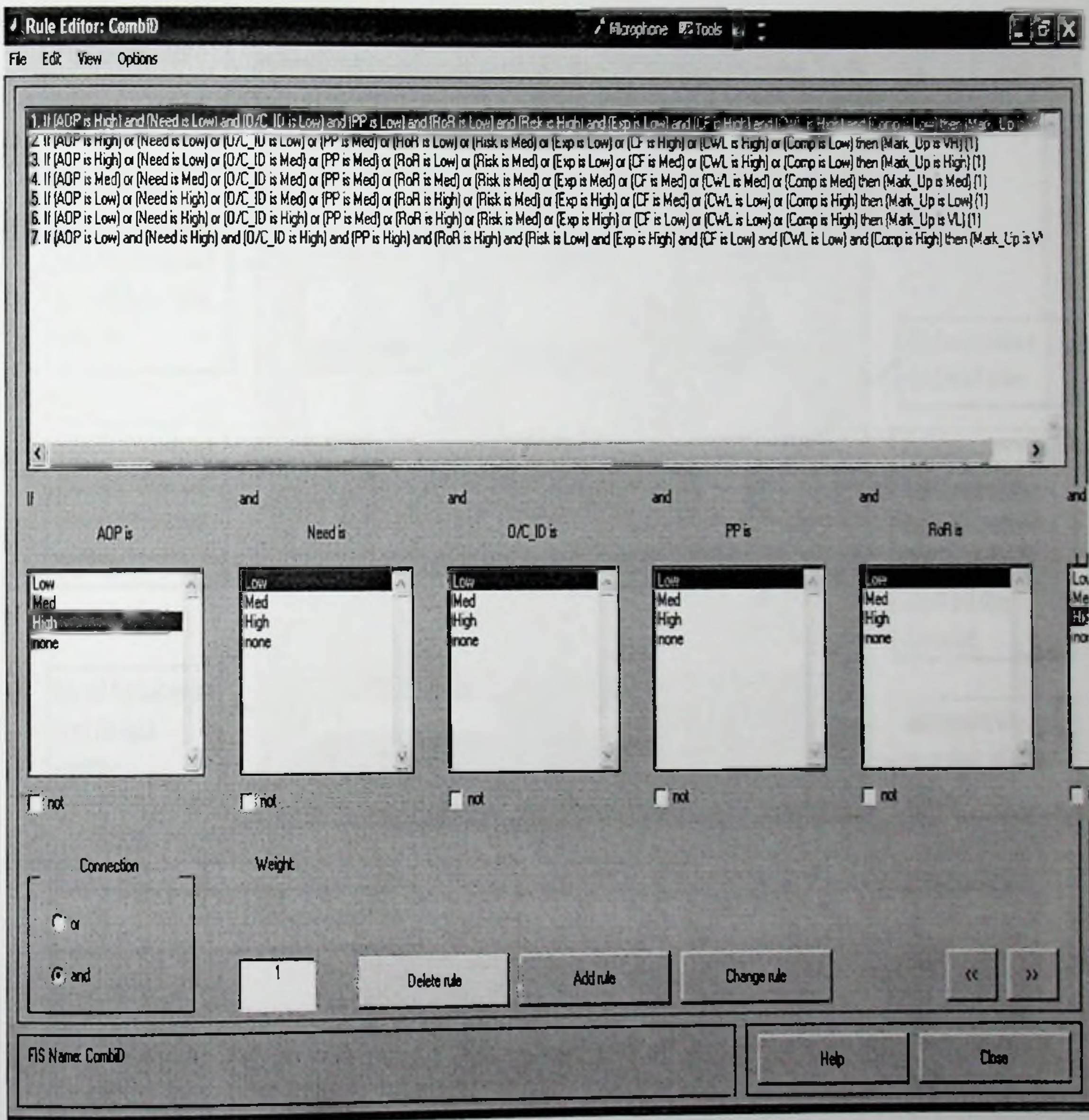


Fig. 23 b. Rule Editor

3.3.1.3 The Rule Viewer

The rule viewer displays the interpretation of the whole fuzzy inference process of the proposed system. The influence of the shape of certain membership functions to the overall result also can be monitored in this window.

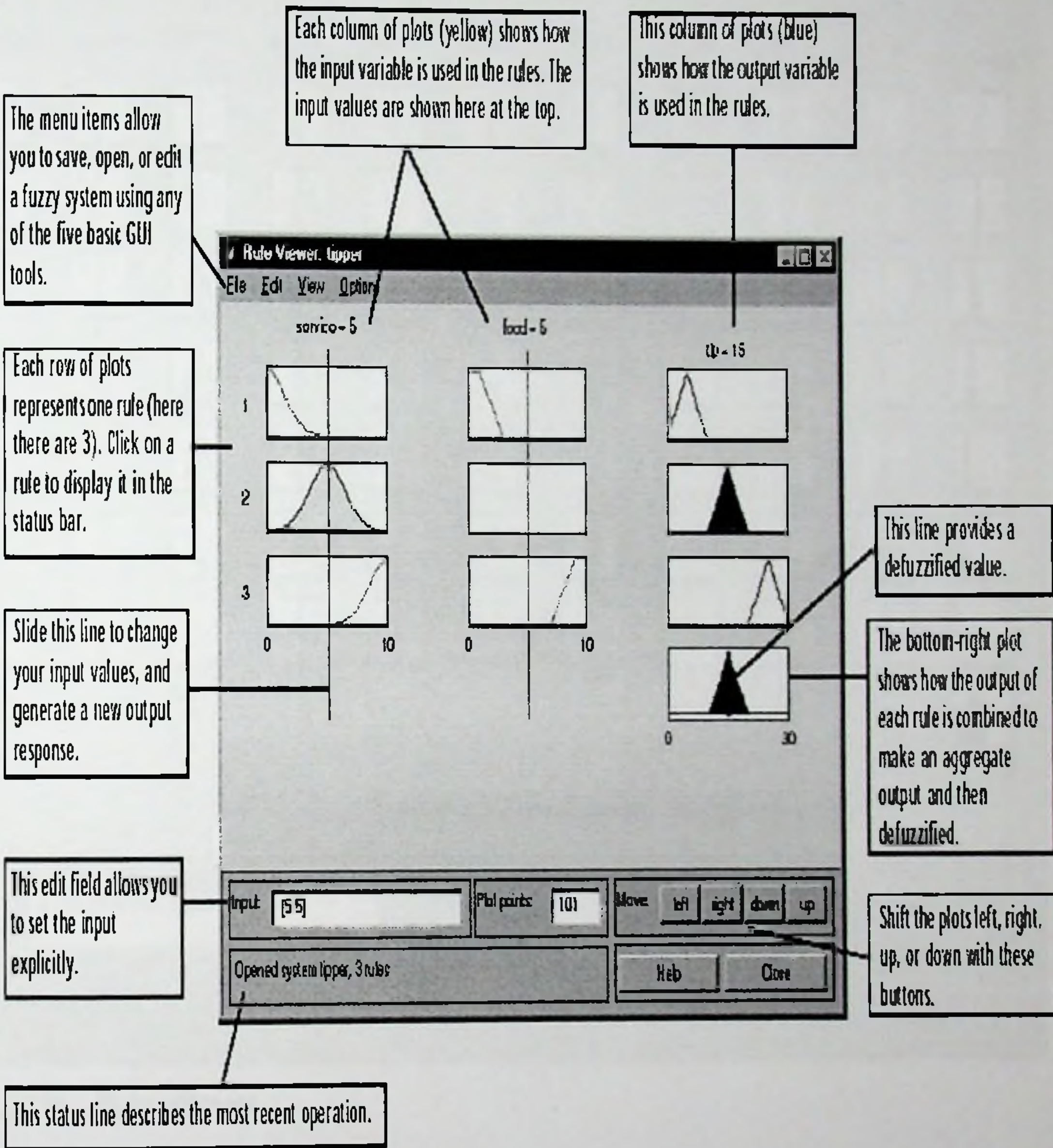


Fig 24 a. Rule Viewer with its features

Source; Fuzzy logic tool box

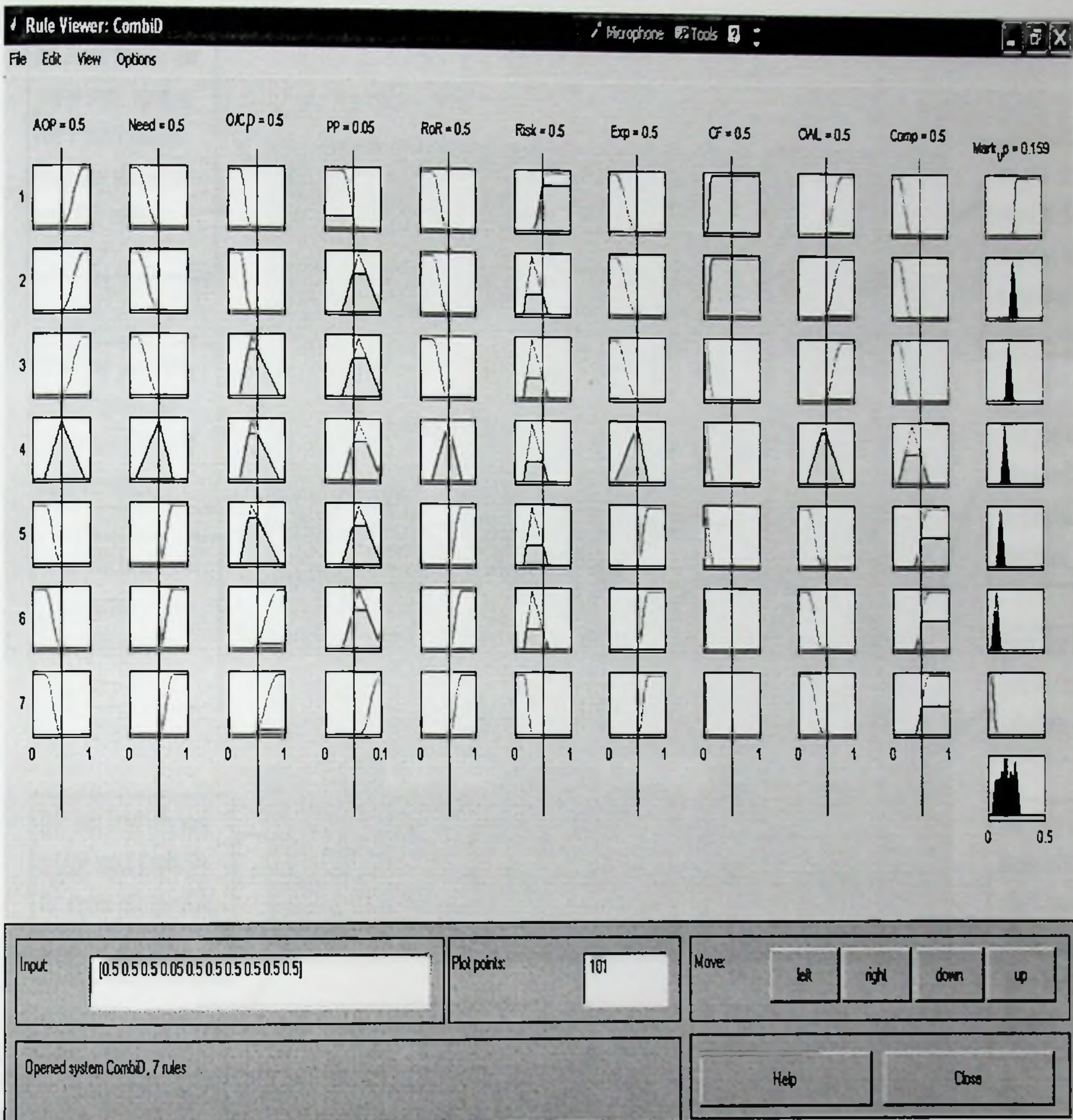


Fig. 24 b . Rule viewer

3.3.1.5 *Surface Viewer*

A quick walk through of each of the precedent variables could be checked using the surface view window of the system. Fig. 24 b illustrates how Size of the mark-up varies according to its parameters respectively.

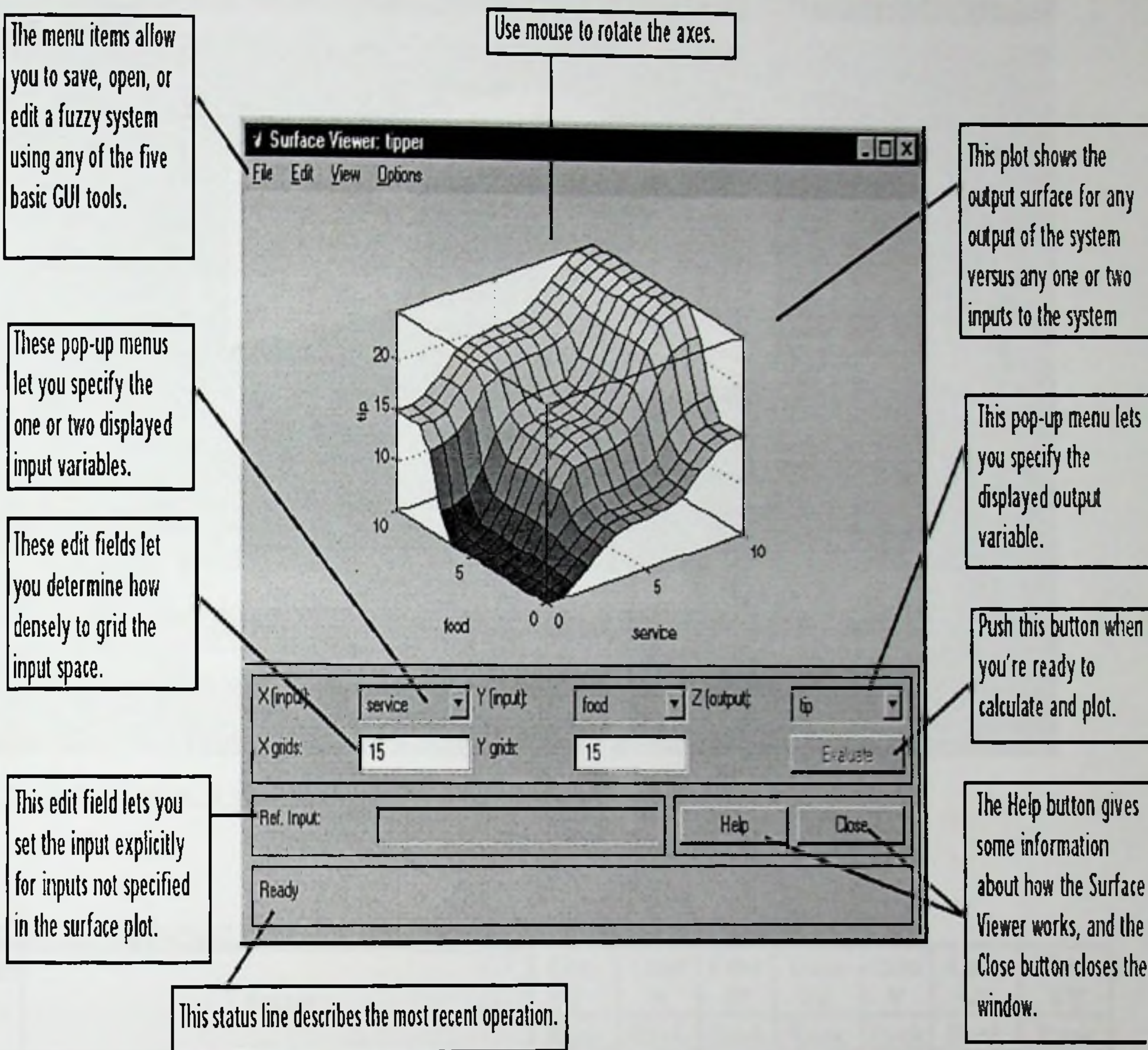


Fig 25 a. Surface Viewer with its features

Source; Fuzzy logic tool box

3.3.2 Testing of the System

The applicability of the predictions of the system was tested with real sets of data. Seven recently tendered projects were selected from a reputed company who were participated in the data collection too. The sets of data considered were only referred to the construction of buildings as all the feedback of the Questionnaire were provided with reference to the building construction. The data required to input to the KBS were obtained in the linguistic form, which is the case for most estimators, tender decision makers as the crisp straight forward values are difficult to predict.

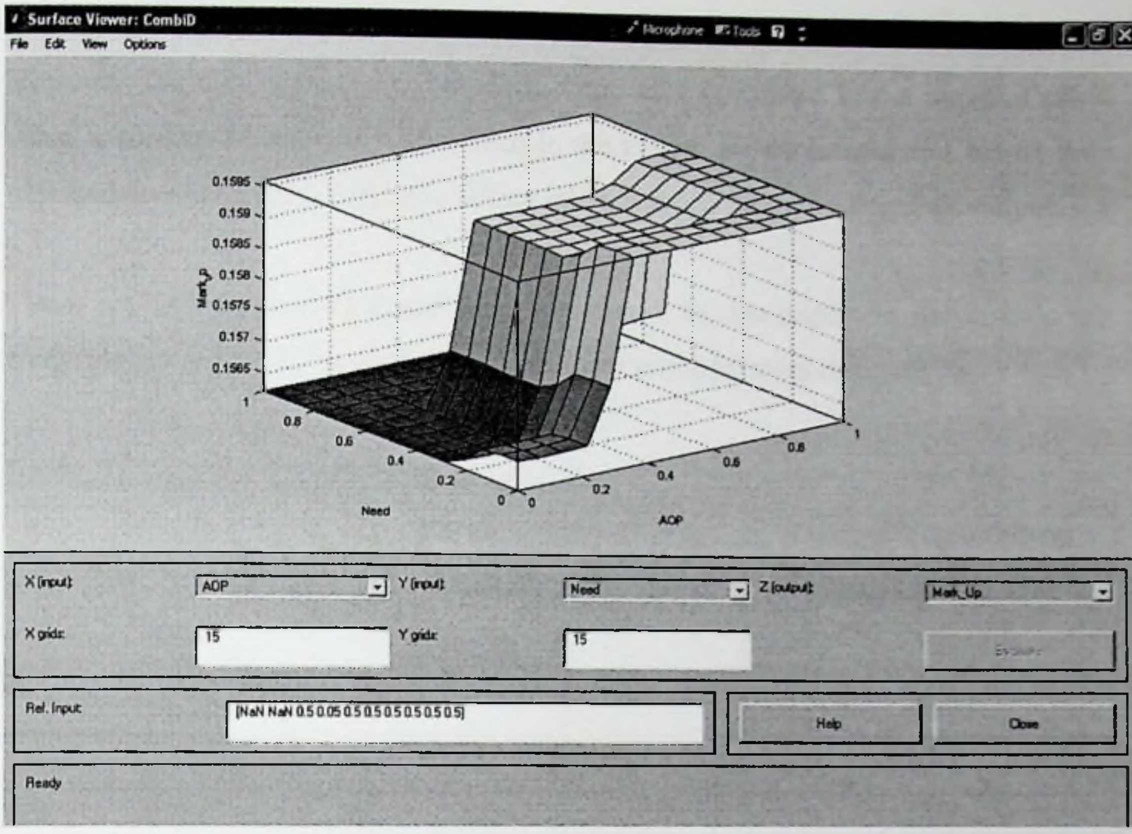


Fig 25 b. Surface viewer

Table 14. Assigned ranks by the Expert

No.	Factor	Case I	Case II	Case III	Case IV	Case V	Case VI	Case VII
		Rank	Rank	Rank	Rank	Rank	Rank	Rank
1	Availability of Projects	H	L	M	M	M	H	L
2	Need for Work	L	H	M	H	L	L	H
3	Owner /Client relation	L	H	M	M	M	L	H
4	Past Profits from similar Projects	L	H	M	H	L	M	H
5	Rate of Return from the Project	L	M	M	H	M	M	H
6	Risk Involvement in Investment	H	L	M	M	H	M	L
7	Experience in similar Projects	L	M	M	M	M	M	H
8	Cash Flow (Negative)	H	L	M	H	M	L	L
9	Current Work Load	H	M	M	L	M	M	L
10	Competition	L	L	M	M	H	L	H

However, the data collected in linguistic form were converted into a range of crisp value according to the intervals defined in the system for each input and output was obtained as a crisp value, which is falling into a interval reflects a linguistic output.

Those are compared with actual ranges preferred by the expert in the domain on tendering and are given in table 15 and the comparison is given in figure 26.

Table 15. Results of the Testing of System

Case No.	Expert's Prediction on Mark –Up size (%)	CombiD Prediction on Mark –Up size (%)
Case I	8	6.7
Case II	18	21.3
Case III	21	26.3
Case IV	23	28.0
Case V	22	29.2
Case VI	23	26.4
Case VII	38	34.7

The data collection experienced a great difficulty, as most of the organizations do not keep any trace of the situation in the industry and their own organization at the time of bid decision on any given project, for future reference.

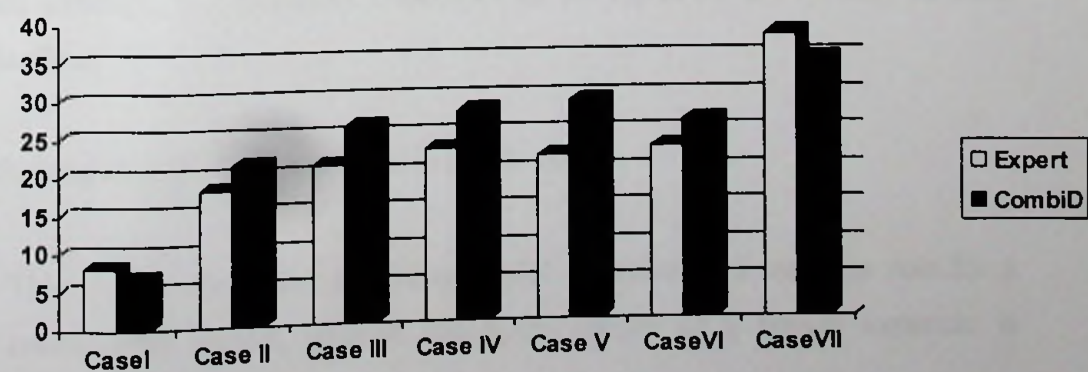


Fig 26. Comparison of Results

All it is emphasized the use of experience and expertise of the team of the decision makers of the organizations.

Surprisingly some of the companies compare only the mark –up value of the lowest bid of past similar projects, for which they too had competed. Some of the organizations were not paying the much needed importance of reviewing the high ranking factors which affects the bid value; instead they normally do a trial and error.

It was highly a rigorous task to obtain the data from the estimating departments of the organizations considered, a few of them are not interested at all and the others do not have the required data readily available. Hence, it may be noted that the data collected, the predictions by the system and the real figures in consistent and may also have a bearing in the deviations. Thus the reliable, representative data capturing becomes very important to implement any KBS.

3.3.3 Advantages of the System

The advantages of the system starts from the data considered in developing the system as the practitioners in the industry will realize the importance of the critical evaluation and review of the factors affecting in bidding and their distinct contribution for arrive at a justifiable mark-up to win the project.

The practitioners further recognize the importance of being equipped with the set of data that attributes to the factors considered as the inputs of the system, for their future tenders.

The following also are few advantageous of this system.

- This is a multi-variant reasoning model to arrive at a mark-up size for a construction project, without which the service of a human expertise is essential

- It is not necessary to avail with specific crisp values for any input variable , instead a general idea of the range (e.g. High, Medium, Low) in linguistic form will suffice the requirement of the system to obtain a reasonable output.
- For given input values all possible out puts are fired by the system and the appropriate resultant will be the recommended output for the given set of data.
- The system is simple and easy to manipulate, but will produces reliable outputs.
- A reasonable decision support may be obtained from vague or partial set of data in linguistic form.

3.3.4 Limitations of the system

- Difficulty in defining accurate membership functions as the variables are subjective and vague.
- As the membership functions of this system has only three functions (High, Medium, Low), representation of information may be vague and may be less sensitive.
- The set of data used in this model mostly related to construction of buildings, hence the system generated results maybe more relevant to such projects.
- This model may not give reasonable predictions in unique, extraordinary problem situation, whereas domain experts may do.
- The model to be updated in reasonable intervals considering to the sensitivity of the factors to the industry, whereas human experts update their knowledge simultaneous to the changes.

4. CONCLUSIONS AND RECOMMENDATIONS

4.1 CONCLUSIONS

In the context of Construction Industry the decision on Mark-up size in Competitive Bidding is vital to survive in the Industry and to obtain the anticipated benefits from the investment on a project. It is widely held that the Bidding is a both Science and an Art.

While emphasizing it will never be possible to remove uncertainty of the Bidding process the tendency is to increase the Science portion of it and reduce the Art in it creating a Win-Win situation for both Client and Contractor and eventually the Construction industry at large. It is well understood that attribute to the construction industry is so high in number that it may be a tedious effort to confined to a generalized framework.

A considerable number of researches in the area of competitive bidding can be found due to its very nature of uncertainty. The history of the research has been progressing since 1950s. Even though there were number of bidding strategy models developed since then but the acceptance of those by the industry is not convincing. The need for new models remains, for which are designs to suit the actual practices of the construction contractors and following features are identified as most crucial factors to be addressed in a potential model.

- Consideration of a wide range of factors and multiple objectives in bidding, besides profit maximization and the competition, that effects the margin-size decision, to more realistically capture the decision making process.
- The use of qualitative and subjective contractor judgment in interpreting out puts.
- Consideration of other factors, besides price, that affects a contractor's success in winning projects, since contracts are not always awarded to the lowest bidder

- Less reliance on historical project and competitor data for training or use, since data of sufficient quality and quantity are difficult and time-consuming to obtain or may not be available
- Quickness and ease of use, to suit the time-constrained nature of the competitive bidding process

The problem in Friedman's strategy lies in determining the probability of winning as a function of the mark-up. His solution was to establish the competitors' 'bidding patterns' by calculating the ratios between their tenders and the cost estimate. Provided there have been a sufficient number of previous encounters, it is then possible to establish the probabilities of winning with different mark-up against each competitor and, through aggregation, against each possible combination of competitors.

Gates, being less clear, does not state his assumptions explicitly, but uses empirical data derived over a period of several years to establish the probability of success, and a technique which explicitly excludes the possibilities of systematic changes in the mark-up as a method for calculating the probabilities of success at different mark-ups. After having calculated the optimum mark-up for competition with considered firms. Gates states that this optimum mark-up is constant over a time, which is not realistic in most of the time. Tendering theory as proposed by Gates assumes constant mark-ups unaffected by variations in demand. The price is calculated as costs plus a constant mark-up, and there are no counter-strategies by other competitors. Any differences between different competitors arise from the necessity to estimate the cost prior to the execution of the contract, caused by the process of submitting a single, unchangeable bid rather than the more conventional method of pricing the bid when the cost is known.

On the other hand the models done on Case Based Reasoning (CBR) by researchers get more acceptance as those have certain obvious advantages in a dynamically changing, highly unstructured process of bidding. The experts experienced obtained from past similar cases are modeled in CBR system. It has been admitted that, in practice, humans resolve such unstructured problems primarily based on their experience with similar previous cases. CBR systems augment the memory of humans by recalling similar situations. The decision is then resolved by adapting the past solutions found in the recalled situations to suit the new situation.

The user reviews the suggested markup level, makes comparisons with the previous solutions, which are more closely matched with the current problem with other similar cases, and makes heuristic adjustments over the markup level, if necessary. He can also draw on likely competitor's bidding profiles to make further adaptation

It must be pointed out, however, that the main problem with this system might be the collection of cases, which are of good quality that represents the real situation, to develop the case library.

In line with the technological development the use of Artificial Intelligence (AI) in heuristic, uncertain, subjective problem are initiated. A carefully crafted model with AI will assist the users on decision support: reminding information or options to an experienced decision maker; commonly, used in medicine. decision making: allowing an unqualified person to make a decision beyond his or her level or training or expertise commonly used in a industrial systems .The use of AI is more convinced as it has its own characteristics, which can be used more readily address to the problem of mark-up size in Competitive Bidding too.

1. Experts need not be present for a consultation:
2. Expert systems do not suffer from some of the shortcomings of human beings
3. The techniques inherent in the technology of expert systems minimize the recollection of information by requesting only relevant data from the user or appropriate databases
4. Expert knowledge is saved and readily available because the expert system can become a repository for undocumented knowledge that might otherwise be lost
5. The development of expert systems forces documentation of consistent decision-making policies. The clear definition of these policies makes the overall decision-making process transparent and the implementation of policy changes instant and simultaneous at all sites.

The construction industry is very complex as stated above as it involves virtually an entire cross section of the society. After finalizing the estimated bid price the fixing of reasonable mark –up size to obtain the maximum benefit to the construction company is crucial. A vast knowledge of factors affecting in bidding and their behaviour under particular project at a given scenario is essential to arrive at a best suited mark-up securing it in competition by the smallest possible margin; and on the best commercial terms procurable.

The factors affecting in mark-up size can be broadly categorized as general input factors and project specific input factors. The general inputs deals with assessment of Economic environment, and assessment of company's characteristics whereas, Project specific factors deals with assessment of Bidding situation, assessment of project procedures, assessment of project characteristics, assessment of project relationships, assessment of project specific resources.

It was noted that a similar set of factors identified as factors affecting in bidding, by various researchers with slight differences of those importance indices. The difference in importance varies according to the scale of the contracting organization; turn over, financial capability, technological capability etc. and with the bidding scenario; economic environment, bidding situation etc. it was further noted that most of contractors depend on subjective assessment in not only deciding on mark-up size but also on the decision of bid or not to bid. They evaluate these influencing factors whenever they make either decision. Some factors are considered seriously in both decisions whereas others for only one of the above decisions.

More than fifty number of factors selected and analyzed in different scenario and ten most crucial factors were identified for the context of construction for assessing of mark-up size; Availability of projects, Need for work, Owner /client identity, Past profits in similar projects, Rate of return (anticipated), Risk involvement, Experience in similar projects, Project cash flow, Current work load and competition by the competing contractors for the project.

The selected ten factors were processed on the fuzzy logic platform, which is a sub branch of AI as the fuzzy logic is conceptually easy to understand, flexible, more tolerant with imprecise data. Most importantly the fuzzy logic is based on natural language; the basis of fuzzy logic is the basis of human communication hence the linguistic interpretations are easy to incorporate and can be built on top of the experience of the domain experts. That is the fuzzy logic lets the uses to rely on the experience of the people who already understands the system. Mamdani approach was used to obtain the reasonable prediction for the mark-up size of a given project by the system.

The model developed has given out puts which are most of the time in line with the human expertise on the size of mark-up for the given sets of data. Even though the predictions of the system meaningful it may be noticed deviations too. These may be due to the fact that the data available in the industry are highly unstructured in nature and most of those were obtained in linguistic form.

However, the system is advantageous in situations where the data available are multi variant and heuristic. Such set of data is hard to structure to useful information to arrive at a meaningful output without a human expertise or without a system of this kind.

This system will be more useful for the non-technical decision makers as the comments from the expertise may be more expensive.

4.2 RECOMMENDATIONS TO FURTHER RESEARCH

It is recommended to extend this research with more sensitive input variables having at least five membership functions for an input.

The increase in number of input variables may affect on predictions.

Further, this research may be extended to other relevant fields where procurement of projects is done by competitive bidding procedure.

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Appendix

Development of Expert System for Mark-up Size in Competitive Bidding

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Notes:

- Please answer the following questions on your experience in the industry
- The information provided by you will only be used for the develop an Expert system on mark-up size decision and will not be exposed to others
- The questions are about the factors those affects the decision on bidding and most of these are of uncertain type

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Details of your Firm :

Name :..
Address :..
....

ICTAD grade of registration (if any) :..
Relevant field :..

Name of the respondent :..
Designation :..

PERCENTAGES

1. Availability of Projects
Bidding Situation

$$= \frac{\text{\# on going projects to relevant category}}{\text{\# Contractors available in relevant category}} \times 100\%$$

H	M	L

2. Need for work
(1- Current work Load)
Related to the firm

$$= 1 - \frac{\text{Total value of the projects in hand}}{\text{Estimated turn over of the company for the considered yr}} \times 100\%$$

H	M	L

3. Owner /Client identity
Related to the firm

$$= \frac{\text{Past projects completed with the client satisfactorily}}{\text{Projects completed with the client}} \times 100\%$$

H	M	L

4. Past profits in similar projects
Related to the firm

$$= \frac{\text{sum of (profit made in similar projects)}}{\text{Sum of (Cost in each project)}} \times 100\%$$

H	M	L

5. Rate of Return
Economic situation

$$= \frac{\text{Expected RoR of the project}}{\text{Anticipated RoR of the company}} \times 100\%$$

H	M	L

6. Risk involvement
Economic situation

$$= 1 - \frac{\text{Variations due to client only}}{\text{Total Variations}} \times 100\%$$

H	M	L

7. Experience in similar projects
Related to the firm

$$= \frac{\text{\# Similar projects completed in last 5yrs}}{\text{Total \# projects completed in last 5 Yrs}} \times 100\%$$

H	M	L

8. Project Cash Flow
(based on cash flow diagram)
Project characteristic

$$= \frac{\text{Total Negative cash flow}}{\text{Total cash flow}} \times 100\%$$

H	M	L

9. Current work load
Volume of all current Projects the company has committed
Related to the firm

$$= \frac{\text{Total value of Projects in hand}}{\text{Estimated turn over of the company for the considered yr}} \times 100\%$$

H	M	L

10 Competition
Bidding situation

$$= \frac{\text{\# Competitors for this particular Project}}{\text{Total \# contractors registered in same category}} \times 100\%$$

H	M	L