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Prediction of Construction Cost Overrun in Tamil Nadu- A Statistical Fuzzy Approach

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***Abstract*— This paper aims to identify the topmost factors affecting the construction cost in the construction industries of Tamil Nadu. A list containing 54 factors which are responsible for the cost overrun in the construction industries was prepared based on a vast literature review and they were ranked using Relative Important Index (RII) scale based on the opinion of the engineers by distributing the list in the form of Questionnaire to 60 respondents (30 Government engineers and 30 private engineers).This paper also presents an application of fuzzy logic for developing cost overrun assessment model using Fuzzy toolbox of MATLAB Program Software. The top five factors have been used for this purpose. Graphs showing the variation of cost overrun for different combination of cost overrun factors are obtained. Finally, the model has been validated using four case studies.**

***Index Terms*— construction cost, cost overrun factors, fuzzy logic, Relative Important Index**

I. Introduction

Construction industries are always liable to cost overrun problems. There are several factors which contribute this major problem. Many researchers have studied the risk associated in litigating the cost overruns. But only a few emphasize the responsibility for project cost overruns and the mitigation measures. It has been suggested by most of the researchers, to avoid the cost overrun in construction projects. It is essential to analyze the cost that might result in claims and disputes, the link between the actual tasks undertaken, the time required to complete them, and the ultimate cost estimate of the resources involved in the projects [1-17].

It is well known that cost is considered as an important key parameter for the success of any project. Many researchers have adopted the construction cost as an assessment scale. If the prediction of cost performance in the projects exceeds 30%, it may result in serious sequences like abandonment of projects. Therefore a good forecasting approach is needed at the time of planning itself. Due to the limited availability of information during the early stages of a project, construction managers typically leverage their knowledge, experience and standard estimators to estimate project costs.

The present paper aims to predict a model for the cost overrun percentage estimation in construction building projects in Tamil Nadu state using Fuzzy logic. The building factors which affect the cost overrun were surveyed. A questionnaire survey and relative index ranking technique were used to indicate the most five important factors from the view points of contractors, clients and consultants. To build up Fuzzy logic Model, four Case studies from real executed construction project in Tamil Nadu were collected for the topmost five factors. The results revealed the ability of Fuzzy Model to predict cost estimate to an acceptable degree of accuracy.

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II. LITERATURE SURVEY

Related to the present study many researchers have conducted questionnaire survey in different parts of the world and presented the topmost factors which influences the construction cost overruns in the respective places using a popular statistical analysis SPSS (Statistical Package of Social Sciences).Some of them also suggested some mitigation measures to avoid the risk of cost overrun. Some of them used fuzzy modeling and some of them used regression modeling to predict the percentage of cost overrun.

Sriprasert (2000) in his study clearly stated that cost overrun is caused by ineffective construction management and poorly established cost control systems. Frimpong *et al*. (2003) studied 26 factors that cause cost overruns in construction of ground water projects in Ghana and through his thorough examination, he found that monthly payments difficulties was the most important cost overruns factor which has been indicated by contractors and consultants, and poor contractor management was the most important factor which has been indicated by owners.

Frimpong also stated that 75% of the projects exceeded the original project cost whereas only 25% were completed within the budget in Ghana,. Abdullah *et al*. (2009) mentioned that 90% of large MARA construction project were suffered delay with significant effect of time and cost overrun since 1984.Lee (2008) examined that in 161 completed projects the causes of cost overruns were found as changes in scope, delays during construction, unreasonable estimation and adjustment of project costs and no practical use of the earned value management system in Korean social overhead capital projects.

Olawale and Sun (2010) reported that in most of the construction projects, Only 41% of respondent participating in survey experienced cost overrun less than 10% of their cost projects. This indicates about 59% of respondents experienced cost overrun more than 10%. Zujo *et al*., 2010 made a survey in Bosnia and Herzegovina, and observed out of 177 projects of structures 41.23% of structures contracted price was not met and in his another investigation of 29 building construction structures it was noted that contracted price overruns were noted at 17 (58.62%) of the structures .

III. RESEARCH METHODOLOGY

The methodology of the study is as follows:

1. A thorough literature review was done and also the expert opinions from industry experts were taken, through which a number of cost overrun causes were identified in Tamil Nadu construction industry scenario. In total fifty four factors were finalized to make part of the survey questionnaire.
2. A Questionnaire form which is consisting of two parts A and B has been developed. In Part A personal Information of the respondents (for e.g. work experience, organization, annual volume of construction work) was asked. Part B was aimed to obtain information about causes of cost overrun in TamilNadu construction industry. It was asked to rate those initially identified 54 factors according to their severity level on the given scale, information regarding maximum, average and minimum cost overrun ranges experienced over large projects and average overruns over small projects were asked.
3. Thirty (30) private Engineers and Thirty (30) Government Engineers have been approached for this study.
4. Analysis has been carried out using SPSS (Statistical package for social sciences) using the assessment of feedback from questionnaire survey.
5. Through the analysis the topmost five factors have been selected and used in the fuzzy logic analysis to predict the percentage of cost overruns in the construction industries.

IV. DATA COLLECTION AND ANALYSIS

Data collection was carried out by conducting a questionnaire survey for identifying significant factors affecting construction cost performance among contractors and Engineers for accessing the significant factors of the factors. A five point likert scale of 1-5 was adopted to assess the degree of agreement of each cause where 1 represents “Strongly disagree”, 2 - disagree, 3- moderately agree, 4-agree and 5-strongly agree. A total of 60 respondents participated in the survey process. Statistical package for social sciences was used to analyze the data. Data was checked for reliability prior to ranking the factors. This four-point scale was converted to a Relative Importance Index (RII) for each individual factor,

Using the following formula, as adopted by Kumaraswamy and Chan (1997, 1998),and Assaf et al (1995)

Relative importance index

$$(RII) = \Sigma W \div (H \times N) \qquad (1)$$

Where ΣW is the total weight given to each factor by the respondents, which ranges from 1 to 5 and is calculated by an addition of the various weightings given to a factor by the entire respondent, H is the highest ranking available (i.e. 5 in this case) and N is the total number of respondents that have answered the question. Demographic characteristics of respondents are District engineers and private contractors of Thiruvannamalai, Cuddalore, Chengalpattu and Chennai. From Table 1, the total year’s experience of the respondents is 1350 with an average of 22.5. Out of the 54 factors, five topmost factors were selected according to the RII value and the RII values of the top five factors were used to predict the percentage of cost overrun in construction industry.

Table. 1: Preliminary Ranking of the Factors affecting Construction Cost

Sl. No	Factors affecting Construction Cost	District Engineers		Private Engineers	
		RII	RANK	RII	RANK
1	Complexity of project design	0.785	13	0.914	15
2	Incompetent Project team (designers and contractors)	0.771	16	0.921	13
3	Incomplete design at the time of tender	0.690	33	0.844	44
4	Lack of coordination at design phase	0.775	15	0.919	14
5	Improvements to standard drawings during construction stage	0.821	9	0.928	9
6	Incorrect planning and scheduling by contractors	0.838	8	0.930	8
7	Lack of cost planning/monitoring during pre and post contract stages	0.780	14	0.910	16
8	Lack of experience of local regulation	0.664	43	0.847	43
9	Lack of experience of project type	0.690	33	0.849	42
10	Underestimate project duration	0.662	45	0.840	46
11	Absenteeism of labour	0.769	17	0.904	19
12	Personal conflicts among labor	0.661	46	0.864	36
13	Low motivation and morale of labor	0.663	44	0.851	41
14	Works postponed due to Strike	0.660	47	0.872	32
15	Unqualified / inadequate experienced labor	0.881	4	0.941	3
16	Frequent equipment breakdowns	0.685	34	0.874	31
17	Inadequate modern equipment	0.680	37	0.869	34
18	Low efficiency of equipment	0.684	35	0.871	33

19	Shortage of equipment	0.864	5	0.937	5
20	Slow mobilization of equipment	0.864	5	0.937	5
21	Accidents during construction	0.656	48	0.866	35
22	Delay in obtaining permits from municipality	0.791	12	0.925	11
23	Natural disasters (flood, hurricane, earthquake)	0.849	7	0.934	6
24	Slow site clearance	0.672	40	0.904	19
25	Delay in providing services from utilities (such as water, electricity)	0.670	41	0.864	36
26	Change orders	0.750	18	0.862	37
27	Delay in progress payments	0.850	6	0.932	7
28	Lack of experience of owner in construction projects	0.731	20	0.856	39
29	Slowness in decision making	0.682	36	0.860	38
30	Suspension of work by owner	0.85	6	0.932	7
31	Complexity of the project	0.721	23	0.853	40
32	Legal disputes between project participants	0.608	42	0.906	18
33	Unfavorable contract clauses	0.674	39	0.878	29
34	Original contract duration is short	0.654	49	0.842	45
35	Ineffective delay penalties	0.675	38	0.908	17
36	Changes in material types and specifications during construction	0.694	31	0.902	20
37	Damage of sorted materials	0.748	19	0.900	21
38	Escalation of material prices	0.95	1	0.980	1
39	Poor quality of construction materials	0.901	2	0.960	2
40	Unreliable suppliers	0.901	2	0.960	2
41	Lack of experience of consultant in construction projects	0.704	29	0.851	41
42	Conflicts between consultant and design engineer	0.800	11	0.923	12
43	Inaccurate site investigation	0.712	27	0.896	22
44	Late in reviewing and approving design documents	0.708	28	0.876	30
45	Delay in approving major changes in the scope of work by consultant	0.731	20	0.894	23
46	Frequent change of subcontractors	0.695	30	0.890	25
47	Inadequate contractor experience	0.692	32	0.869	34
48	Inappropriate construction methods	0.812	10	0.926	10
49	Poor site management and supervision	0.890	3	0.939	4
50	Rework due to errors	0.725	22	0.882	27
51	Unreliable subcontractors	0.718	25	0.842	45
52	Obsolete technology	0.720	24	0.891	24
53	Ineffective project planning and scheduling	0.729	21	0.880	28
54	Poor communication and coordination with other parties	0.715	26	0.886	26

Table. 2: Five Topmost Factors Affecting Construction Cost

Sl. No	**Factors of cost overruns**	**RANK**	**RII of District Engineers**	**RII of Private Engineers**	**Average RII**
1	Escalation of material prices	1	0.95	0.980	0.965
2	Poor quality of materials and unreliable suppliers	2	0.901	0.960	0.9305
3	Poor site management and supervision	3	0.890	0.939	0.9145
4	Unqualified/ inexperienced labour	4	0.881	0.941	0.911
5	Shortage and slow mobilization of equipment	**5**	0.864	0.937	0.90

V. FUZZY LOGIC CONTROLLER

The concept of fuzzy logic was first introduced in 1965 by Zadeh. The term "fuzzy" refers to the fact that the logic involved can deal with concepts that cannot be expressed as the "true" or "false" but rather as "partially true". A fuzzy logic system (FLS) can be defined as the nonlinear mapping of an input data set to a scalar output data. A FLS consists of four main parts: fuzzifier, rules, inference engine, and defuzzifier. These components and the general architecture of a FLS is shown in Fig. 1.Firstly, a crisp set of input data are gathered and converted to a fuzzy set using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. This step is known as fuzzification. Afterwards, an inference is made based on a set of rules. Lastly, the resulting fuzzy output is mapped to a crisp output using the membership functions, in the defuzzification.

Fuzzy Sets and Membership Functions

Membership functions are used in the fuzzification and defuzzification steps of a FLS, to map the non-fuzzy input values to fuzzy linguistic terms and vice versa. A membership function is used to quantify a linguistic term. In a fuzzy set, each object has its own membership value, which determines the degree to which the object belongs to a fuzzy set. Membership values range between 0 and 1. Fuzzy set proposed a theory from ordinary crisp sets with a membership value of either 0 or 1. In fuzzy sets linguistic values are quantified by the implementation of fuzzy rules. A membership function is a curve in which input space is sometimes referred to as the universe of discourse, defining how each point in the input space is mapped to a membership value between 0 and 1. Triangular, angular and trapezoidal shape membership functions are different types of membership functions.

Fuzzy Rules

In a FLS, a rule base is constructed to control the output variable. A fuzzy rule is a simple IF-THEN rule with a condition and a conclusion.

Fuzzy Set Operations

The evaluations of the fuzzy rules and the combination of the results of the individual rules are performed using fuzzy set operations. The operations on fuzzy sets are different than the operations on non-fuzzy sets. The classical set has a sharp boundary, which means that a member either belongs to that set or does not. Also, this classical set can be mapped to a function with two elements, 0 or 1. In other words, this ‘fully belonging to’ can be mapped as a member of set *A* with degree of 1, and ‘not belong to’ can be mapped as a member of set *A* with degree of 0. This mapping is similar to a black-and-white binary categorization. Compared with a classical set, a fuzzy set allows members to have a smooth boundary. In other words, a fuzzy set allows a member to belong to a set to some partial degree. For instance, still using the temperature as an example, the temperature can be divided into three categories: LOW (0 ~30ºF), MEDIUM (30ºF ~ 70 ºF) and HIGH (70 ~ 120 ºF) from the point of view of the classical set, which is shown in Figure 2.

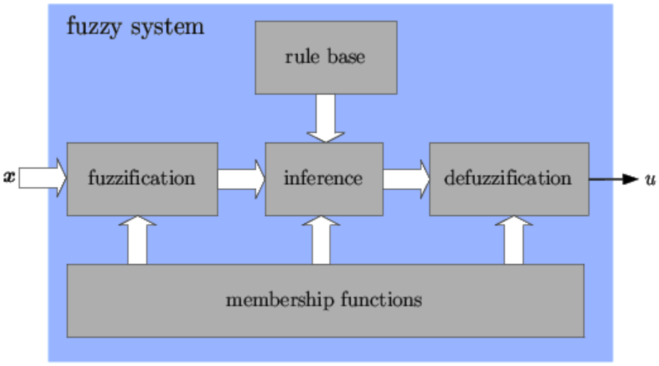

Fig.1:A Fuzzy Logic System.

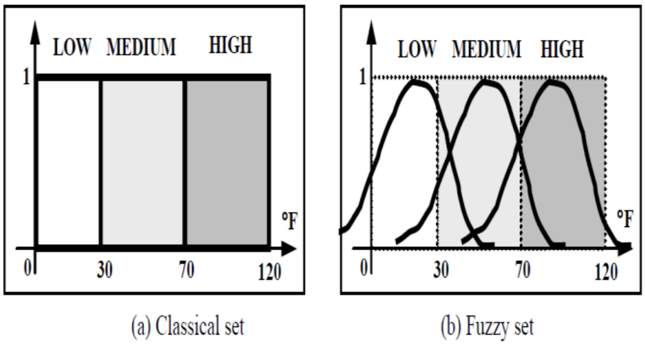

Fig. 2: Representations of classical and fuzzy sets

In the classical set, any temperature can only be categorized into one subset, LOW, MEDIUM or HIGH, and the boundary is crystal clear. But in the fuzzy set becomes vague or smooth. One temperature can be categorized into two or maybe even three subsets simultaneously. For example, the temperature 40 ºF can be considered to belong to LOW to a certain degree, say 0.5 degree, but at the same time it can belong to MEDIUM to about 0.7 degree. Another interesting thing is the temperature 50 ºF, which can be considered to belong to LOW and HIGH to around 0.2 degree and belong to MEDIUM to almost 1 degree. It is clear that a fuzzy set contains elements which have varying degrees of membership in the set, and this is contrasted with the classical or crisp sets because members of a classical set cannot be members unless their membership is full or complete in that set. A fuzzy set allows a member to have a partial degree of membership and this partial degree membership can be mapped into a function or a universe of membership values.

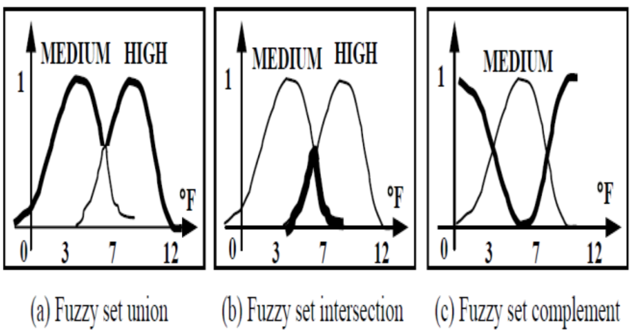

Fig.3:Fuzzy set operations.

The basic fuzzy set operations also include intersection, union and complement, and those operations are defined as

Union: $A \cup B = \mu_A(x) \cup \mu_B(x) = \max(\mu_A(x), \mu_B(x))$
Intersection: $A \cap B = \mu_A(x) \cap \mu_B(x) = \min(\mu_A(x), \mu_B(x))$
Complement: $A^C = F \setminus A$

Where *A* and *B* are two fuzzy sets and *x* is an element in the universe of discourse, X. The graphical illustrations of those operations are shown in Fig. 3.According to the definition of fuzzy set operations, a fuzzy set union operation is exactly equivalent to select the maximum member from those members in the sets, and the intersection operation is selecting the minimum member from the sets.

VI. STEPS INVOLVED IN THE FUZY LOGIC ANALYSIS

To develop the model, following steps are performed on fuzzy logic tool box of MATLAB.

(i) Construct a five input and one output system in the FIS editor. The identified cost overrun factors and "cost overrun" are entered as input members and output member respectively.
(ii) Membership functions associated with all of the input and output variables are defined in membership function editor.
(iii) In order to perform fuzzy inference, rules which connect input variables to output variables are defined. For the present model 35 rules are constructed in the form of IF-THEN. Five of them are given below.

Rule1: if the probability of Escalation of material prices is very low the cost overrun is very low
Rule2: if the probability of Escalation of material prices is low the cost overrun is low
Rule3: if the probability of Escalation of material prices is medium the cost overrun is medium
Rule4: if the probability of Escalation of material prices is high the cost overrun is high
Rule5: if the probability Escalation of material prices is very high the cost overrun is very high

(iv) The relative importance indices (RII"s) of cost overrun factors are assigned as weightage to the fuzzy rules to develop the assessment model to estimate the probability of cost overrun.
(v) Since the RII"s of the cost overrun factors have different values, the fuzzy rules weights will differ accordingly. So that each if-then rule will have different weights, showing relative importance of fuzzy rules.

Cost Overrun Using Fuzzy Controller

The main causes of cost overruns were studied in this work, the fuzzy controller involved to analyzing and predicting the cost overrun based on the top five factors. The five input and one output fuzzy based cost over-run is discussed here. Table.3 shows the linguistic variables used in model and their membership function**.** The overall impacts of topmost factors in cost overrun and its corresponding weight factors are tabulated in Table 4.
The five top most factors are used as inputs and cost overrun as output of the fuzzy controller. In fuzzy logic controller, all membership functions are considered as triangular membership functions with five segments. The fuzzy subsets are Very Low (VL), Low (L), Medium (M), High (H) and Very High (VH). The mamdani inference engine is used in the fuzzy controller. Fig.4 shows the Flow diagram for the development of cost assessment model in fuzzy inference system.The fuzzy inference system is shown in Fig.5 and the membership function editor for cost overrun is shown in Fig 6.

Table.3: Linguistic variables used in model and their membership function

Variables	Range	MFs	No of MFs	Name of the parameters
Escalation of material prices	[0 -1]	trimf	5	1.very low 2.low 3.medium 4.high 5.very high
Poor quality of materials and unreliable suppliers	[0 -1]	trimf	5	1.very low 2.low 3.medium 4.high 5.very high
Poor site management and supervision	[0 -1]	trimf	5	1.very low 2.low 3.medium 4.high 5.very high
Unqualified/ inexperienced labour	[0 -1]	trimf	5	1.very low 2.low 3.medium 4.high

				5.very high
Shortage and slow mobilization of equipment	[0 -1]	trimf	5	1.very low 2.low 3.medium 4.high 5.very high

Table. 4: Sample fuzzy rules for the of cost assessment model and rules weight

S.No	Rules	Rule weight (Average RII)
1	If the probability of Escalation of material prices is very low the cost overrun is very low	0.965
2	If the probability of Poor quality of materials and unreliable suppliers is very low the cost overrun is very low	0.9305
3	If the probability of Poor site management and supervision is very low the cost overrun is very low	0.9145
4	If the probability of Unqualified/ inexperienced labour is very low the cost overrun is very low	0.911
5	If the probability of Shortage and slow mobilization of equipment is very low the cost overrun is very low	0.90

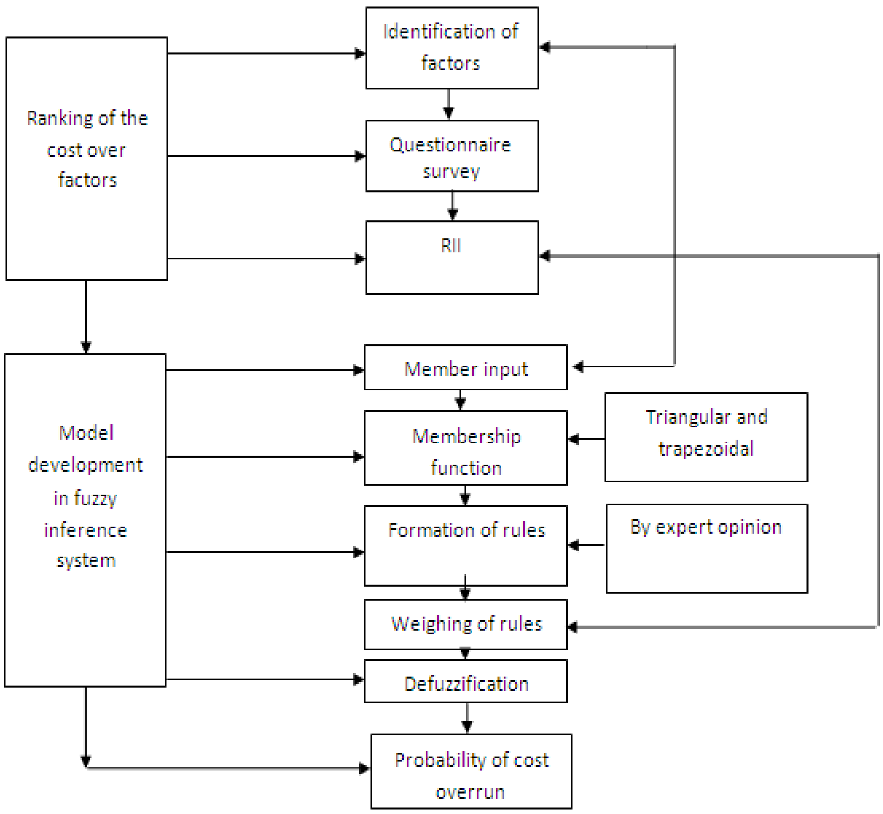

Fig.4: Flow diagram for the development of cost assessment model in fuzzy inference system

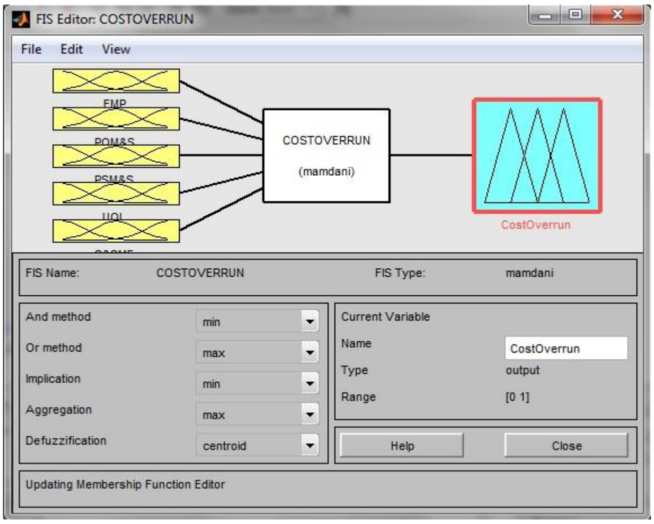

Fig.5: Fuzzy Inference System

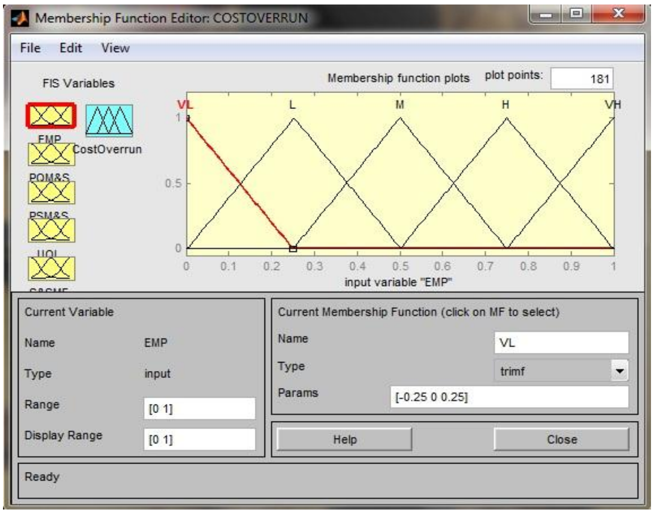

Fig.6:Membership Function Editor

The surface view of the inputs Escalation of Material Prices (EMP), Poor Quality of Materials and Unreliable Suppliers (PQM) and its corresponding output Cost Overrun (COR) were given in the form of graphs. The quantization factor and the scaling factor play a significant role in the performance of the fuzzy controller. The command rules are set upto achieve the best functioning of the fuzzy controller and the rules and are presented in Fig. 7.Fig.8 shows the surface review showing the Variation of Escalation of material prices(EMP) and Poor Quality of Materials and Unreliable Suppliers (PQM) with respect to cost overrun. Fig.9 shows the Variation of Unqualified/ inexperienced labour (UQL) and Poor site management and supervision (PSM&S) with respect to cost overrun. Fig. 10 shows the Variation of Escalation of material prices (EMP) and Shortage and slow mobilization of equipment (S&SME) with respect to cost overrun Fig.11depicts the Run Editor.

VII. MODEL VALIDATION

A detailed case study analysis of four building construction projects was carried out to validate the survey findings on most significant factors contributing to cost overrun. The case study research includes interviews, discussions with construction managers, detailed study of project documents and contracts. Table.5 presents the Details of the projects that have been considered for validation and Table.6 shows the impact of top five factors in construction projects in terms of loss percentage.

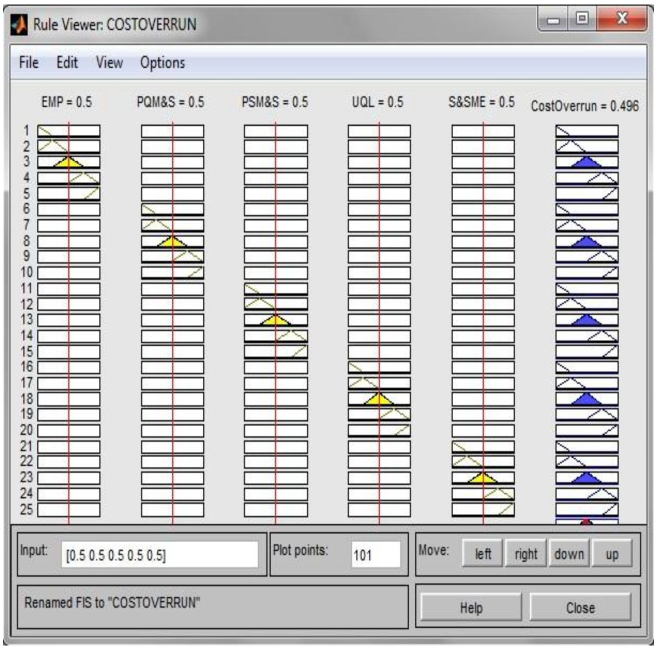

Fig.7:Rule View

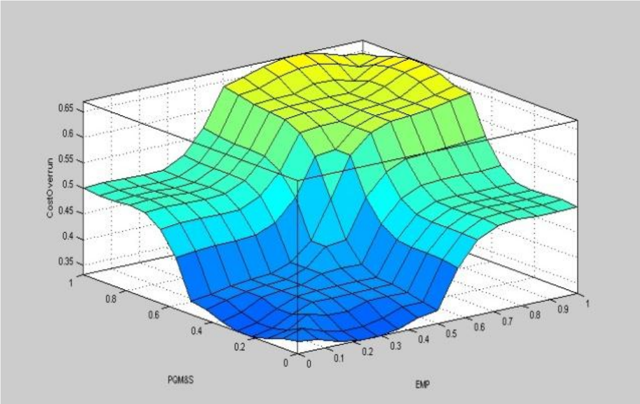

Fig.8:Variation of Escalation of material prices(EMP) and Poor Quality of Materials and Unreliable Suppliers (PQM) with respect to cost overrun

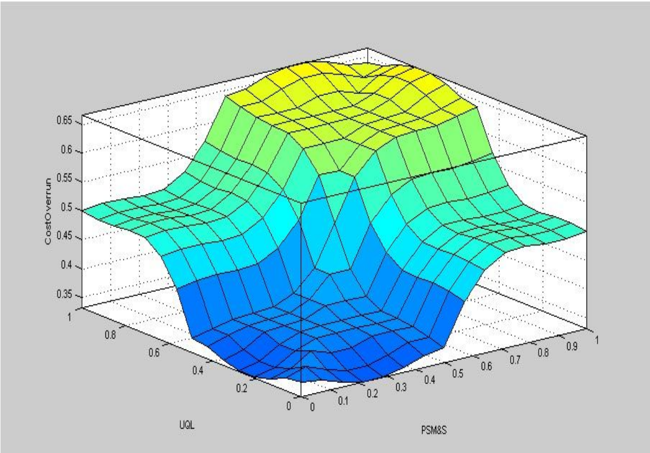

Fig.9:Variation of Unqualified/ inexperienced labour (UQL) and Poor site management and supervision (PSM&S) with respect to cost overrun

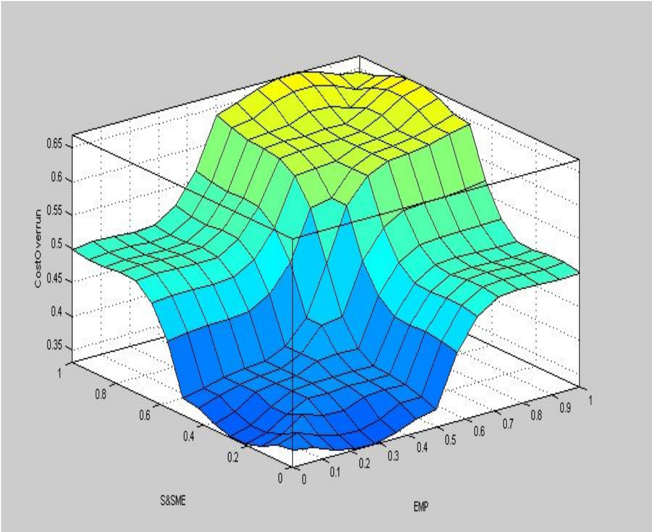

Fig.10: Variation of Escalation of material prices(EMP) and Shortage and slow mobilization of equipment (S&SME)with respect to cost overrun

Fig.11: Run Editor

The percentage error calculated for each project was lesser than 20%.Therefore it has been concluded that the model holds good to predict the percentage of cost overrun in any construction project.

Table.5: Details of the projects considered for validation

Project details	**Project 1**	**Project 2**	**Project 3**	**Project 4**
Type of Project	Residential building	Residential buiding	Tamil Nadu police housing Corporation buiding	Hospital Building
Location	Cuddalore	Chennai	Coimbatore	Chennai
Form of contract	Desire Designs	Pranav construction	Thiruchitrambalam Projects limited	L& T
Number of floors	G+3	G+4	G+3	G+5
Estmated value	10,000,000	8,50,00,000	80,000,00	7,00,000,000
Final Value	12,150,000	10,28,50,000	10,000,000	8,82,000,000

factors in construction projects

Project details	**Project 1**	**Project 2**	**Project 3**	**Project 4**
Type of Project	**Residential building**	**Residential building**	**Police housing Corporation building**	**Hospital Building**
Escalation of material prices	20% loss	22% loss	15% loss	26% loss
Poor quality of materials and unreliable suppliers	10% loss	10% loss	8% loss	6% loss
Poor site management and supervision	10% loss	15% loss	13% loss	10% loss
Unqualified/ inexperienced labour	10% loss	12% loss	15% loss	10% loss
Shortage and slow mobilization of equipment	5% loss	5% loss	5% loss	10% loss
Cost overrun(estimated)	20.879	20.975	20.382	22.3
Cost overrun (Actual)	21.5	21	22.5	26
% error [(Actual-Estimated)/ Estimated]*100	3%	0.12	10.4%	16.6%

VIII. CONCLUSION

Cost overruns occur in every construction project and the magnitude varies considerably from project to project. Only some projects are being completed within the budget. So it is essential to define the actual causes of cost overrun in order to minimize the impact of the increase in cost in any construction project.

The first objective of this research was to identify the main causes of cost overrun in construction project. A literature review was conducted to identify the causes of cost overruns stipulated in the literature. From the literature review, the various factors influencing construction cost overrun were identified. A questionnaire has been prepared and distributed to 30 Private and 30 Government Engineers. Using SPSS,the factors were ranked.

The second objective of this paper is to create a fuzzy logic model to predict the percentage of cost overrun. The reason why fuzzy set theory has been selected as the reliable analysis technique is that, it may handle the subjectivity which resides during risk assessment of international construction projects. Moreover, it can handle multiple inputs easily and quantify more realistically the classical problem analysis. On the other hand, prior knowledge of this theory is required. Therefore, if a case is missed, the fuzzy logic controller will not work properly. The top five factors were used in this paper to develop the model in fuzzy inference system (FIS).Different graphs can be plotted to show the variation of different combination of cost overrun factors with respect to the cost overrun.

The third objective is to validate the predicted model with the help of four construction projects of Tamil Nadu. The average percentage error for each project is lesser than 20%.Therefore the predicted model in this paper is considered as the best model to predict the cost overrun that occurs in the construction projects at the planning stage itself and the suitable preventive measures can be adopted to overcome the situations.

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