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Forecasting the Probability of Cost Overrun Risk of Indian Construction Projects using Fuzzy Model

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ABSTRACT: A fuzzy model for forecasting the probability of cost overrun risk for Indian construction project is developed by identifying, classifying and ranking the cost overrun factors of the construction industries. Fifty five cost overrun factors are identified, classified into eleven clusters through a detailed literature review process and discussion with experts from the Indian construction industry. A questionnaire survey in Indian construction industry was conducted for data collection to calculate Relative Importance Index (RII) of the factors and clusters. On the basis of the relative importance index of the factors and clusters, a model is developed using the fuzzy logic tool box of MATLAB program software. The model is developed in two stages. First the probability of cost overrun due to the clusters of cost overrun factors is determined and the final cost overrun risk probability of the project is determined taking into consideration the probability of all the clusters. Applicability of the fuzzy model has been tested on a real case study in India. With the help of the proposed model, it is possible to guide project managers and decision makers to make more informative decisions such as contingency estimation, mark-up estimation, bid price, selection of optimum procurement route, evaluation of different projects and preparation of project portfolios.

Keywords: Construction industry, Cost overrun, Probability, MATLAB, Fuzzy logic, India.

I. INTRODUCTION

To complete a construction project within stipulated budget is an important factor among all the norms required for the success of the project [1-3], yet construction projects are found to be suffering from the issue of cost overrun. Cost overrun is defined as the increased costs over estimated cost [4]. This issue of cost overruns is critical both for developed as well as developing countries [5-13]. Indian construction projects are also suffering from the problem of cost overrun. A joint study was conducted by PMI and KPMG with the support of MOSPI in India on infrastructure projects in which a total cost overrun of Rs 2.19 lakh crore for 1304 projects was reported in 2018 [14]. Generally the cost overrun risk analysis is ignored in the projects and the cost of a project is determined just by adding some contingency charges, consequently many projects fail to complete the project in stipulated budget. Therefore it is essential to estimate the probability of cost overrun risk for Indian construction projects to determine a reliable cost of the project.

Several theories and methods have been proposed for risk analysis for construction projects. Zhi, (1995) [15] used qualitative method by using P-I matrix of for risk analysis of overseas construction project, Baccarini and Archer (2001) [16] Computed a risk score for cost, time or quality of project by employing P-I model. Hull (1990) [17] proposed various models by using Monte Carlo Simulation (MSC) and PERT theory for the risk analysis of cost, schedule and technical performance. Özta & Ökmen (2004) [18] presented Monte Carlo simulation technique for determining the risks and uncertainties associated with project cost and duration. Thomas *et al*., (2006) [19] used a Fault tree method to model risky scenarios by utilizing linguistic variables to evaluate risk likelihood and impact. Dey (2001) [20] presented risk analysis model based on AHP and decision trees. Dikmen and Birgonul (2006) [21] used AHP for risk and opportunity estimation of international construction projects. Nasir *et al*., (2003) [22] used belief network and MCS for estimating activity duration. Kangari and Riggs (1989) [23] proposed a model for risk analysis by using FST. Tah and Carr (2000) [24] presented a model for hierarchical risk breakdown structure for qualitative risk assessment through the concepts of fuzzy association, fuzzy composition and application of fuzzy logic.

According to a study by Sharma and Goyal [25], it was concluded that each theory has its own advantages, disadvantages and no theory seems to be complete for handling the uncertainty. However, based on the work done earlier it may be suggested that fuzzy theory is more suitable for handling the complex problems in construction industry as the process is based upon experience, assumptions and human judgment. The fuzzy theory has been applied in the different areas of construction projects as decision support tool, enhancing the performance, evaluation and assessment, forecasting and modeling construction risks [26-35, 40].

The previous studies of cost overrun risk analysis in India were very few in which fuzzy techniques were applied. Therefore in this study a fuzzy model for forecasting the probability of cost overrun risk in Indian construction project is developed by identifying, classifying and ranking the cost overrun factors of the construction industries. The construction industry caters to building and other infrastructure development project. Data for the cost overrun factors are collected from medium to large construction industry with turnover varying from 50 crores to 600 crores. Collected data through questionnaire are validated from sample verification technique and expert opinion. Only reliable data are used in the proposed model. With the help of the proposed model, it is possible to guide project managers and decision makers to make more informative decisions such as contingency estimation, mark-up estimation, bid price, selection of optimum procurement route, evaluation of different projects and preparation of project portfolios.

II. METHODOLOGY

The adopted methodology for the development of the model and for obtaining the results of interest is explained diagrammatically in Fig. 1. This model is developed in two stages as shown in Fig.1. First the probability of cost overrun due to each cluster is assessed by the probability level of the factors of respective cluster. The probability of cost overrun of project is assessed by the probability output of each cluster as determined in the previous step. Major components of the methodology are explained in the following sections.

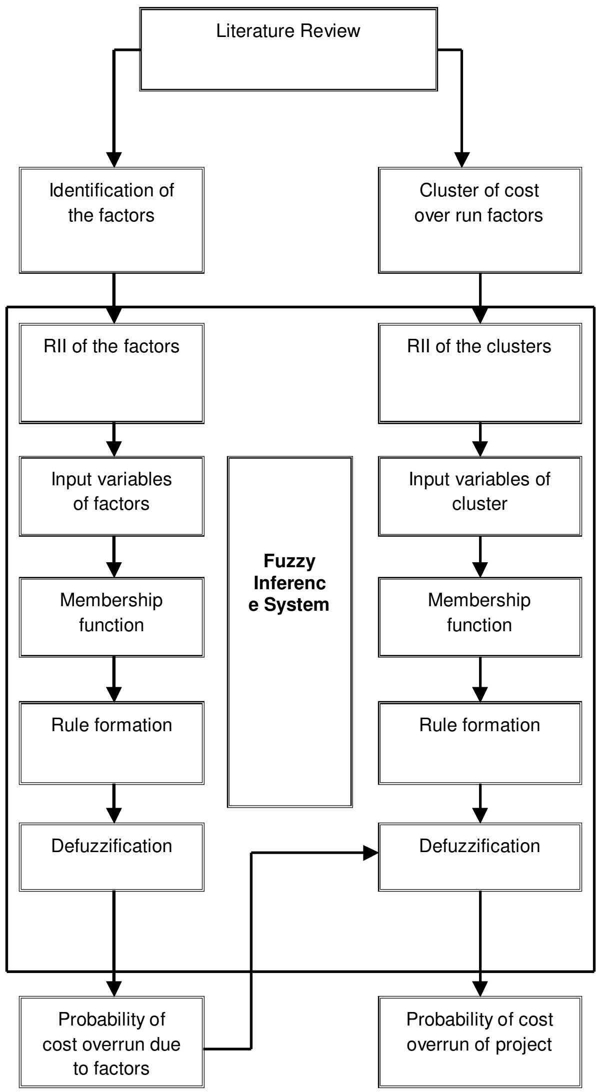

Fig. 1. Methodology.

A. Identification and classification of cost overrun factors

A number of studies conducted on the factors responsible for cost overrun in the construction projects are reviewed [6-14]. The cost escalation causes and their classification are given by Sharma and Goyal (2014) [25] for the construction industry. Fifty five important factors, responsible for cost overrun are identified through intensive literature review. These factors are grouped in eleven clusters named as 'Cluster Owner', 'Cluster Contractor', 'Cluster Consultant', 'Cluster Design', 'Cluster Project', 'Cluster

Material', 'Cluster Labor', 'Cluster Equipment', 'Cluster Contract', 'Cluster Coordination/communication' and 'Cluster External'.

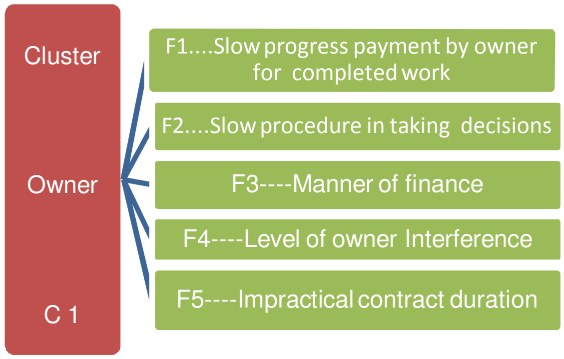

Fig. 2. Cost overrun factors of 'Cluster Owner'.

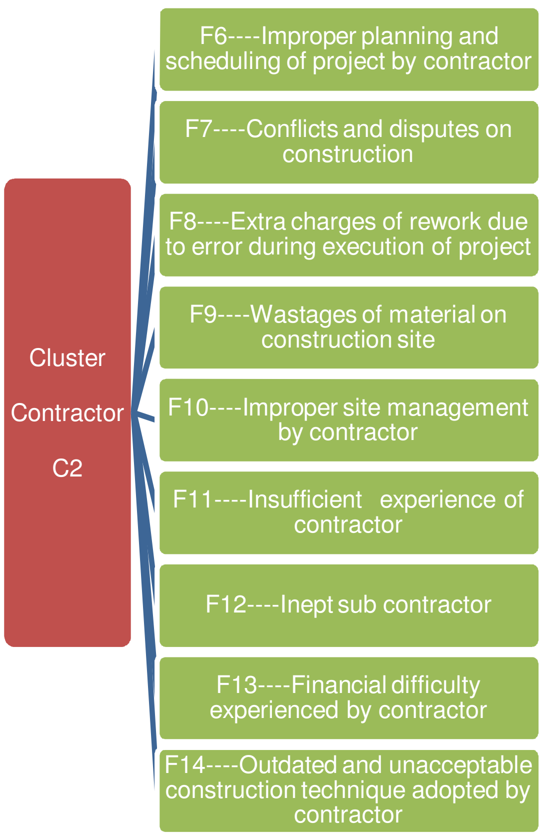

Fig. 3. Cost overrun factors of 'Cluster Contractor'.

All the factors are represented as F1, F2, F3 etc. and clusters are represented as C1, C2, and C3 etc. slow progress payment by owner for completed work, slow procedure in taking decisions, manner of finance, level of owner interference and impracticable contract duration are the factors of 'Cluster Owner' as shown in Fig. 2. improper planning and scheduling of project by contractor, conflicts and disputes on construction sites, extra charges of rework due to error during execution of project, wastages of material on construction site, improper site management by contractor, insufficient experience of contractor, inept sub contractor, financial difficulty experienced by contractor and outdated and unacceptable construction technique adopted by contractor are the factors of 'Cluster Contractor' as shown in Fig. 3.

In correct estimation of time and cost, contract management, delay in inspecting of work, quality assurance & quality control and experience level of consultant are the factors of 'Cluster Consultant' as shown in Fig. 4. In a similar manner all the factors of 'Cluster Design', 'Cluster Project', 'Cluster Material', 'Cluster Labor', 'Cluster Equipment', 'Cluster Contract', 'Cluster Coordination/communication' and 'Cluster External' are shown in Fig. 4-12.

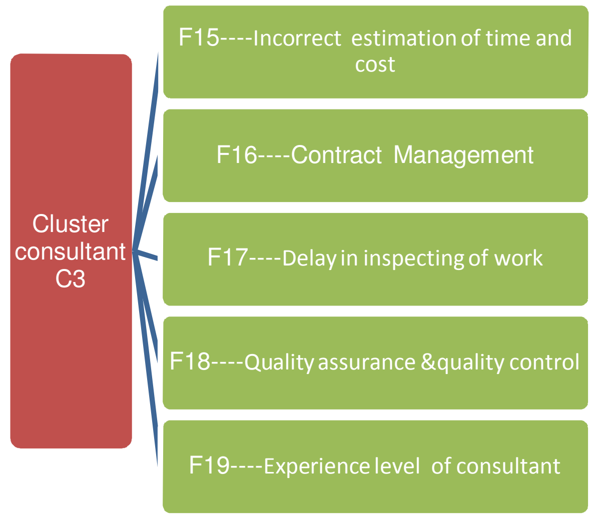

Fig. 4. Cost overrun factors of 'Cluster Consultant'.

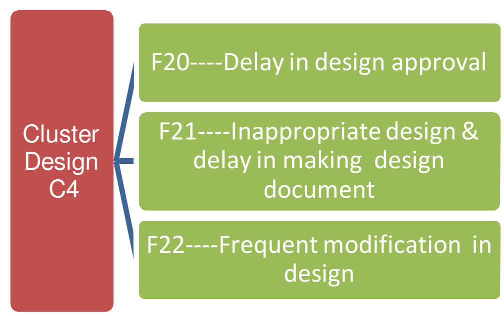

Fig. 5. Cost overrun factors of 'Cluster Design'.

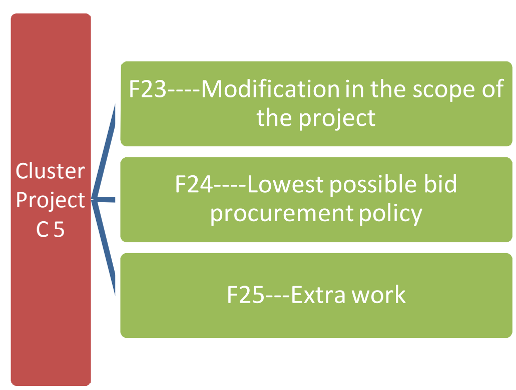

Fig. 6. Cost overrun factors of 'Cluster Project'.

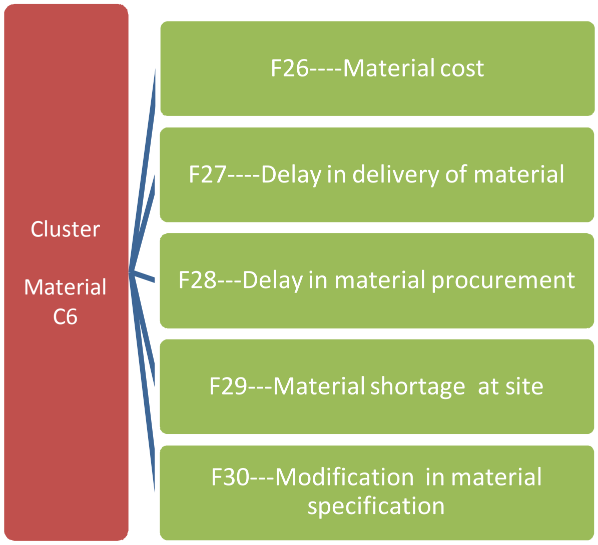

Fig. 7. Cost overrun factors of 'Cluster Material'.

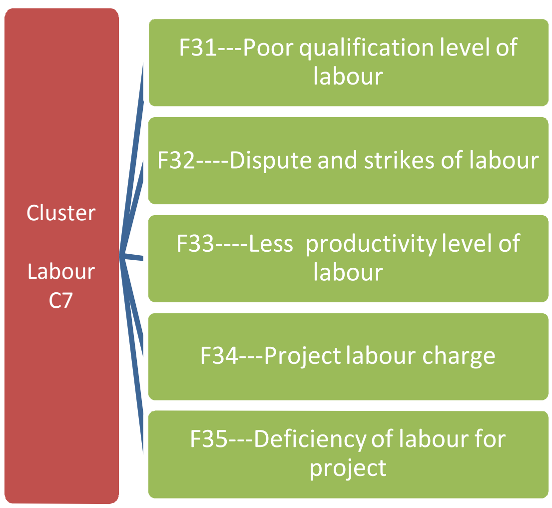

Fig. 8. Cost overrun factors of 'Cluster Labor'.

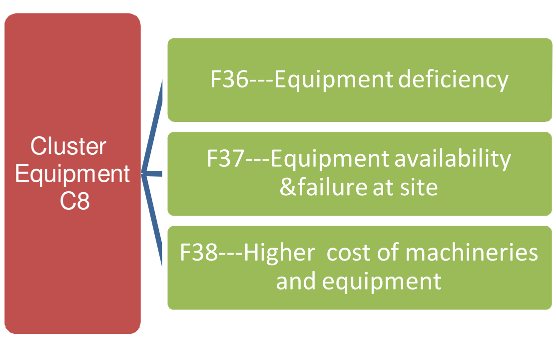

Fig. 9. Cost overrun factors of 'Cluster Equipment'.

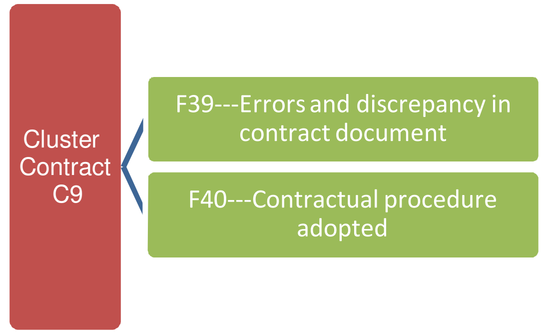

Fig. 10. Cost overrun factors of 'Cluster Contract'.

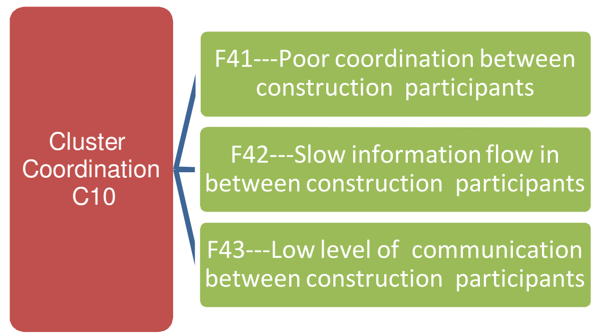

Fig. 11. Cost overrun factors of 'Cluster Coordination'.

B. Relative importance index of factors and clusters

For ranking the cost overrun factors and cluster relative importance index (RII) is calculated by collecting data through a questionnaire survey in Indian construction. The population for survey was drawn from the practitioners of the Indian construction industry, which included owners comprising government sectors (key decision makers), contractors and consultants. A non-probability sampling technique known as convenience and snow ball is used to collect the sample. The questionnaire was distributed through friend and referral network. Personal interviews were also conducted for obtaining the response quickly. Total 250 questionnaires were distributed to the potential respondents within the Indian construction company comprising owner, contractor and consultant. 100 questionnaire set to owner, 100 questionnaire set to contractor and 50 questionnaire set to consultant were distributed. Out of 250 questionnaire set, only 135 responses were returned. Out of total respondents, 62 (45%) of the respondents are working in clients' organization while 47 (34.81%) and 26 (19.2%) respondents are professionals that work in contracting and consulting organizations respectively.

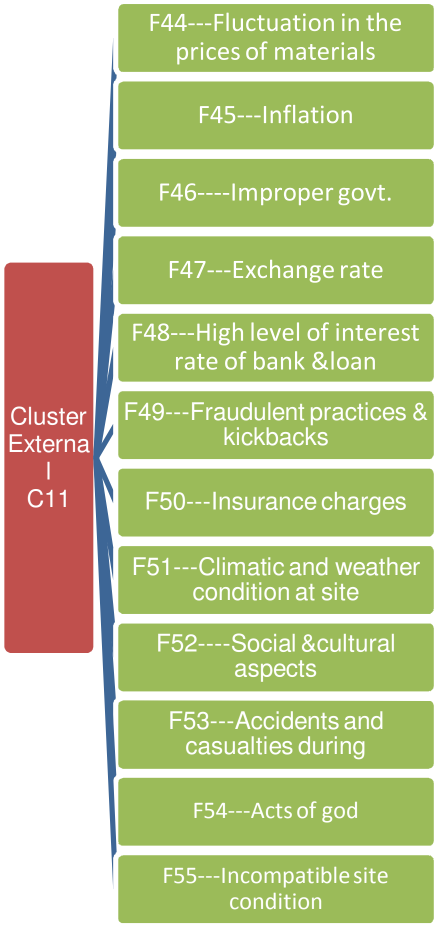

Fig. 12. Cost overrun factors of 'Cluster External'.

The respondents were asked for judging the importance level of identified cost overrun factors. A likert scale of 1 to 5 was used to evaluate the importance level of each factor. These numbers were allocated to the respondents' score as '1 = Very low; 2=Low; 3=Medium; 4=High; 5=Very high'. For ranking these cost overrun factors and clusters the following relation was used to determine the relative importance index (RII)

$$RII = \sum W / (A*N) \quad (1)$$

where W is the weighting for each factor provided by the respondent (it ranges from 1 to 5), A is the maximum weight and N is the number of overall respondents.

C. Model development using fuzzy theory

The fuzzy model to assess the probability of cost overrun is developed in fuzzy inference system (FIS) of MATLAB [36]. Fuzzy inference is a procedure where application of fuzzy logic is employed for mapping from a set of given input to obtain an output. The important features of fuzzy inference system have been explained here in brief.

Fuzzy set. The notion of fuzzy logic was originally pioneered by Zadeh in a seminal article on fuzzy sets theory in 1965 [37]. The concept of the theory is founded on multiple-valued logic; it processes and introduces interpretations which are expressed in vague linguistic terms rather than exact and precise crisp value. The theory is very useful for handling the partial truth issues.

A fuzzy set A of a universe of discourse X can be defined through Eqn. (2):

$$A = \{(x, \mu_A(x)) \mid x \in A, \mu_A(x), \in [0, 1]\} \quad (2)$$

where μ_A (x) is the membership function which provides X a membership values in the interval of 0 to 1.

Fuzzy inference system. As per litreture review Mamdani and Sugeno type of fuzzy inference methods are generally employed. For this research study, Mamdani type fuzzy inference is used because of its wide application [38]. The system of fuzzy inference is basically a rule-based. The crisp input members are fuzzified first to convert them into fuzzy sets by defining the membership functions. After that inference engine of the fuzzy logic system repossesses the knowledge contained in a rule-base where all inputs are combined as per the constructed fuzzy rules. The output fuzzy sets obtained through this process then aggregated and defuzzified where they are converted from a fuzzy set to obtain a crisp number.

The model is developed in two stages as shown in Fig. 2. First the probability of cost overrun due to each cluster is assessed by the probability level of the factors of respective cluster. The probability of cost overrun of project is assessed by the probability output of each cluster as determined in the previous step. The process of fuzzy inference system is applied for both the stages.

The various steps of fuzzy inference process employed for model development are outlined below:

1. The first step of fuzzy inference system is to define all input and output variables for model development. For the first stage of model development the various 'factors' are taken as the input variables and output is the 'probability of cost overrun due to cluster'. For the second stage various clusters are taken as the input variables and 'Probability of cost overrun of project' which is abbreviated as 'PCOP' is defined as the output variable.

2. The input variables are then fuzzified with the help of membership function in this step. The membership function is the fuzziness degree and gives a mathematical value to all input variables. Different shapes of membership functions such as trapezoidal, triangular, bell-shaped, piecewise-linear, Gaussian, g bell-shaped etc. can be used. in this study, g bell-shaped are used as Gaussian and bell membership functions have the advantage of being smooth and nonzero at all points [39]. It can be graphically represented as shown in Fig. 13.

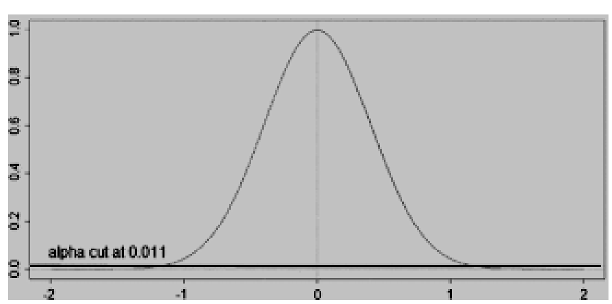

Fig. 13. Gbell-shaped fuzzy membership functions.

3. Fuzzy rules are defined in this step to perform the inference. Fuzzy rules are logical inference and connect

the input variables to output variables. IF-THEN forms of fuzzy rules are used here in this research study. Fuzzy rule for the input linguistic variables x_1, x_2 with their corresponding fuzzy values A_1, A_2 and output linguistic variable y with B as its fuzzy value, can be explained as follows.

If x_1 is A_1 AND x_2 is A_2 then y is B

If part of this rule "x_1 is A_1 AND x_2 is A_2" is called antecedent and then part of the rule "y is B" is known as consequent.

Fuzzy operators "AND", "OR" and "NOT" are also incorporated to construct fuzzy rules.

The estimated values of relative importance for the cost overrun factors are allocated as fuzzy rules weight. An interview was developed with the experts of construction industry in India for the construction of fuzzy rules for forecasting the probability of cost overrun.

4. Defuzzification process takes place finally, where the fuzzy results of the inference engine are converted into a crisp one. Different types of defuzzification methods have been recommended in literature. In this study 'centroid of area' method is applied to forecast 'the probability of cost overrun of the project'. This method of 'centroid of area' calculates the weighted average of a fuzzy set. The outcome of defuzzification to a fuzzy conclusion by using this method can be expressed by the formula

$$Z_{COA} = \left(\int_Z \mu_A(Z)\, Z\, dz\right) / \left(\int_Z \mu_A(Z)\, dz\right) \quad (3)$$

where Z_{COA} is the crisp output, $\mu_A(Z)$ is the aggregated membership function and z is the output variable.

D. Model validation

To test the reliability of the proposed fuzzy cost overrun assessment model, it is tested in a real case study. For this purpose an interview was conducted with a team of the experts of a leading Indian construction company. The panel of the experts included top 10 executive engineers, project managers and site engineers of the company. The experts were requested to examine the cost overrun factors considered for this research and filled in the required information regarding cost overrun factors to assess the proposed model. They were also requested to estimate the cost risk level of the project.

III. NUMERICAL STUDY AND RESULTS

The summary of the calculated, relative importance index (RII) of the cost overrun factors in Indian construction industry and the proposed fuzzy model for these factors has been discussed in the following sections:

A. RII of cost overrun factors and important cost overrun factors in Indian construction industry

The data collected in the questionnaire are analyzed from owner, contractor and consultant's perspective**.** The relative importance index (RII) is computed for each factor causing cost overrun to determine the important factors causing cost overrun in Indian construction industry.

RII of Cluster Owner. RII of the factors slow progress payment by owner for completed work, slow procedure in taking decisions, manner of finance, level of owner interference and impracticable contract duration are 0.498, 0.522, 0.425, 0.357 and 0.676 respectively as shown in Fig. 14.

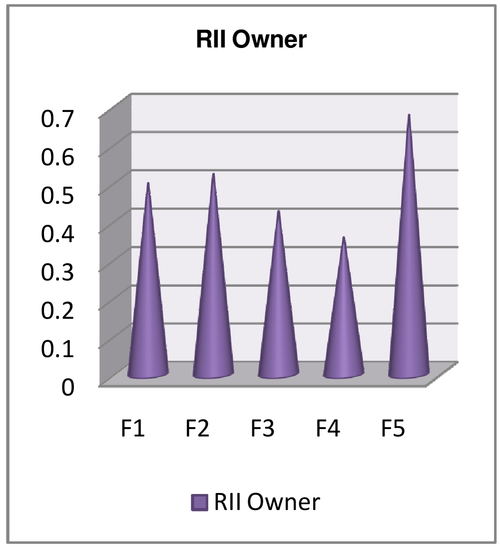

Fig. 14. RII of cluster owner.

RII of Cluster Contractor. RII of the factors improper planning and scheduling of project by contractor, conflicts and disputes on construction sites, extra charges of rework due to error during execution of project, wastages of material on construction site, improper site management by contractor, insufficient experience of contractor, inept sub contractor, financial difficulty experienced by contractor and outdated and unacceptable construction technique adopted by contractor are 0.670, 0.548, 0.495, 0.445, 0.385, 0.352, 0.413, 0.675 and 0.320 respectively as shown in Fig. 15.

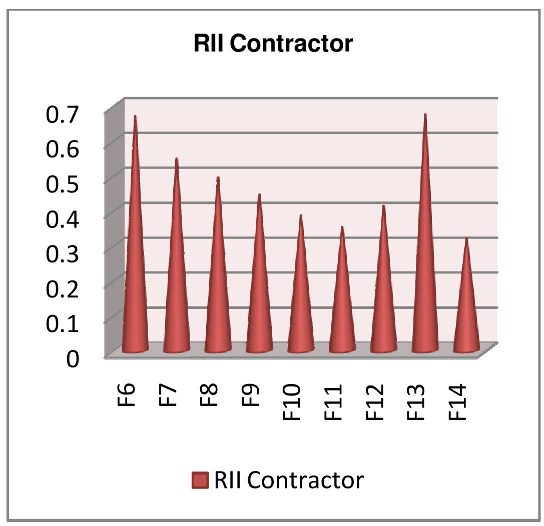

Fig. 15. RII of cluster Contractor.

RII of Cluster Consultant. RII of the factors incorrect estimation of time and cost, contract management, delay in inspecting of work, quality assurance & quality control and experience level of consultant are 0.742, 0.556, 0.391, 0.430 and 0.394 respectively as shown in Fig. 16.

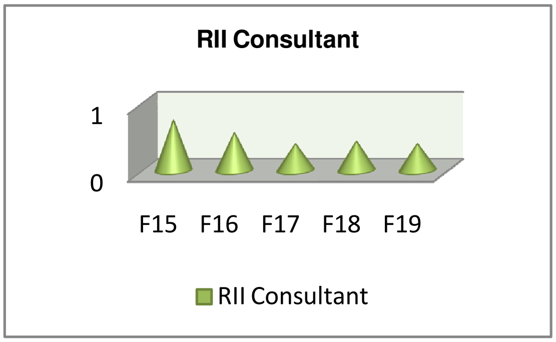

Fig. 16. RII of cluster Consultant

RII of Cluster Design. RII of the factors delay in design approval, inappropriate design & delay in making design document and frequent modification in design are 0.442, 0.478 and 0.704 respectively as shown in Fig. 17.

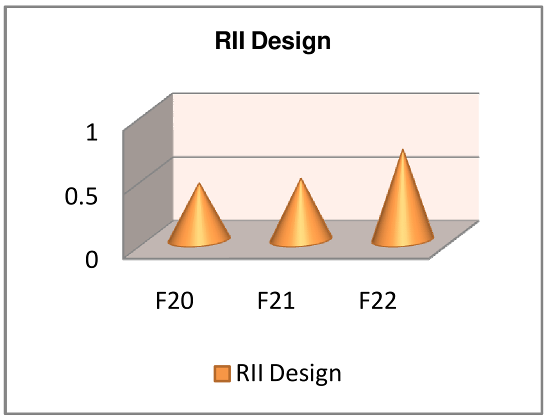

Fig. 17. RII of cluster Design.

RII of cluster Project. RII of the factors modification in the scope of the project, lowest possible bid procurement policy and quantity of extra work done are 0.556, 0.800 and 0.724 respectively as shown in Fig. 18.

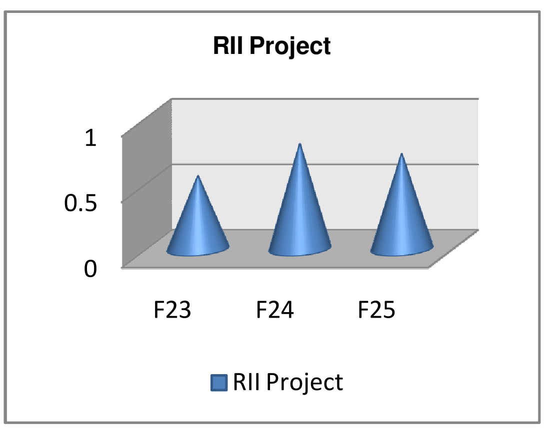

Fig. 18. RII of cluster Project.

RII of cluster Material. RII of the factors material cost, delay in delivery of material, delay in material procurement, material shortage at site and modification in material specification are 0.565, 0.343, 0.317, 0.371 and 0.411 respectively as shown in Fig. 19.

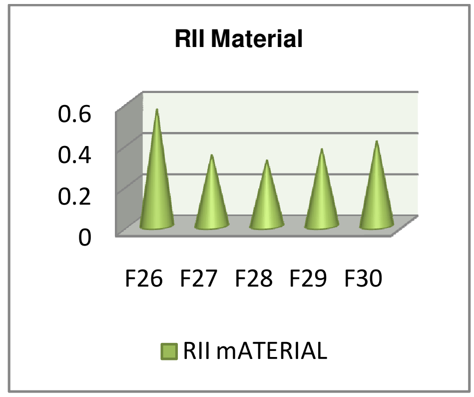

Fig. 19. RII of cluster Material.

RII of cluster Labor. RII of the factors poor qualification level of labor, dispute and strikes of labor, Less productivity level of labor, project labor charge and deficiency of labor for project are 0.341, 0.328, 0.352, 0.628 and 0.370 respectively as shown in Fig. 20.

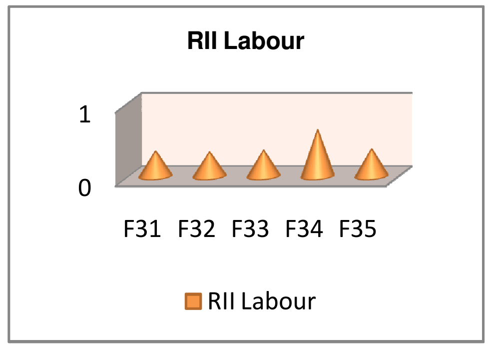

Fig. 20. RII of cluster Labour.

RII of cluster Equipment. RII of the factors equipment deficiency, equipment availability & failure at site and higher cost of machineries and equipment are 0.317, 0.302 and 0.582 respectively as shown in Fig. 21.

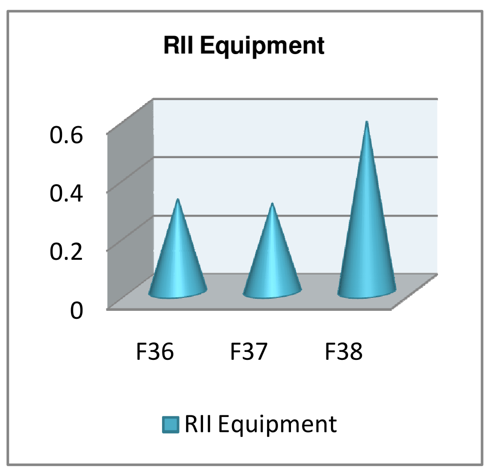

Fig. 21. RII of cluster Equipment.

RII of cluster Contract. RII of the factors errors and discrepancy in contract document and contractual procedure adopted are 0.728 and 0.410 respectively as shown in Fig. 22.

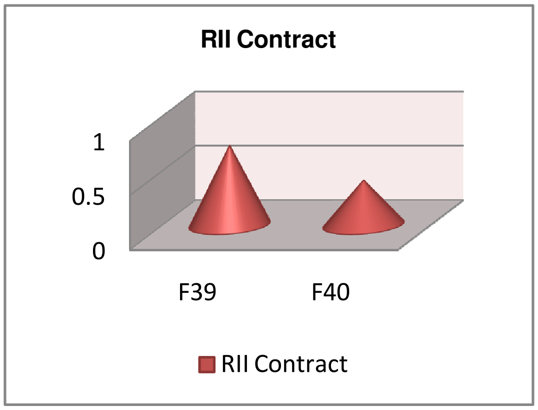

Fig. 22. RII of cluster Contract.

RII of cluster Coordination. RII of the factors are Poor coordination between construction participants, slow information flow in between construction participants and Low level of communication between construction participants are 0.659, 0.440 and 0.430 respectively as shown in Fig. 23.

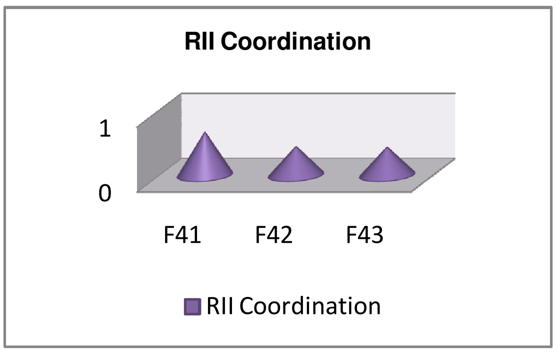

Fig. 23. RII of cluster Coordination.

RII of cluster External. RII of the factors fluctuation in the prices of materials, inflation, improper govt. policy, exchange rate, high level of interest rate of bank &loan, fraudulent practices & kickbacks, insurance charges of project, climatic and weather condition at site, social & cultural aspects, accidents and casualties during construction period, acts of god and incompatible site condition are 0.829, 0.788, 0.780, 0.621, 0.560, 0.520, 0.490, 0.485, 0.423, 0.370, 0.321 and 0.665.

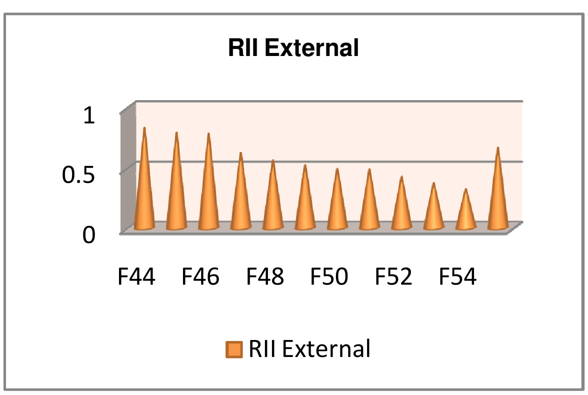

Fig. 24. RII of cluster External.

RII of the clusters. The RII of the clusters is shown in Fig. 25. RII of the clusters of ' Cluster Owner', 'Cluster Contractor', 'Cluster Consultant', 'Cluster Design', 'Cluster Project', 'Cluster Material', 'Cluster Labor', 'Cluster Equipment', 'Cluster Contract', 'Cluster Coordination/communication' and 'Cluster External' are 0.495, 0.477, 0.502, 0.541, 0.693, 0.401, 0.391, 0.4, 0.569, 0.509 and 0.570 respectively.

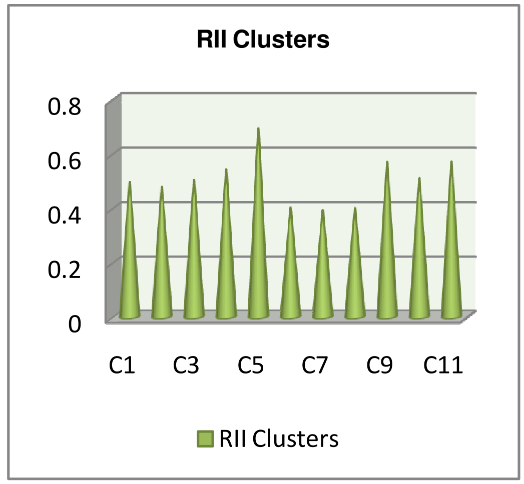

Fig. 25. RII of clusters.

B. Model development

The model is developed in two stages. First the probability of cost overrun due to each cluster is assessed by the probability level of the factors of respective cluster such as the probability of cost overrun due to the 'Cluster Owner' is estimated by probability of cost overrun due to the factors of 'Cluster Owner'.

The probability of cost overrun of project is then assessed by the probability output of each cluster as determined in the previous step.

Define input and output variables. For the first stage of the model development the cost overrun factors are taken as the input variables and output probability of cost overrun due to the cluster is determined from the model. The input and output variables for 'Cluster Owner' are described in Table 1. The various factors of cost overrun of 'Cluster Owner' are Slow progress payment by owner for completed work, Slow procedure in taking decisions, Manner of finance, Level of owner interference and Impracticable contract duration. These factors are considered as input variable for determining the output 'the probability of cost overrun due to the 'Cluster Owner'. During model development these factors are considered as F1, F2, F3, F4, and F5. And the output variable is abbreviated as 'POC1'. Similarly, probability of cost overrun due to the 'Cluster Contractor', 'Cluster Consultant', 'Cluster Design', 'Cluster Project', 'Cluster Material', 'Cluster Labor', 'Cluster Equipment', 'Cluster Contract', 'Cluster Coordination/communication' and 'Cluster External' is determined using factors related to that cluster.

As mentioned earlier the cost overrun probability of the project is determined taking into consideration the probability of all the clusters. Therefore for the second stage of model development clusters such as 'Clusters Owner', 'Cluster Contractor', 'Cluster Consultant', 'Cluster Design', 'Cluster Project', 'Cluster Material', ‘Cluster Labor’, ‘Cluster Equipment’, ‘Cluster Contract’, ‘Cluster Coordination/communication’ and ‘Cluster External’ are considered as input variables.

Table 1: Input and output variables for determining ‘probability of cost overrun due to cluster ‘Owner’.

Input variables		Output variable
F1	Slow progress payment by owner for completed work	probability of cost overrun due to cluster’ C1 (Owner) POC1
F2	Slow procedure in taking decisions	
F3	Manner of finance	
F4	Level of owner interference	
F5	Impracticable contract duration	

And the output variable is ‘probability of cost overrun of project’ as shown in Table 2. During model development these clusters are considered as C1, C2, C3, C4, C5, C6, C7, C8, C9, C10 and C11.and the output variable is ‘Probability of cost overrun of project’ which is abbreviated as **‘PCOP’.**

Table 2: Input and output variables for determining the probability of cost overrun of project.

Input variables		Output variable
C1	Owner	Probability of cost overrun of project (PCOP)
C2	Contractor	
C3	Consultant	
C4	Design	
C5	Project	
C6	Material	
C7	Labour	
C8	Equipment	
C9	Contract	
C10	Coordination	
C11	External	

The input variables in the form of factors and output probability of owner related ‘POC1’ cluster are shown in the FIS Editor window of Fuzzy Logic tool box of MATLAB Program Software in Fig. 26.

Fuzzy Membership Functions. The membership function of input variables in the form of factors and clusters of factors and output variable Probability of cost overrun of project ‘PCOP ‘were generated using the membership function editor in the Matlab fuzzy logic toolbox as shown in Fig. 27.

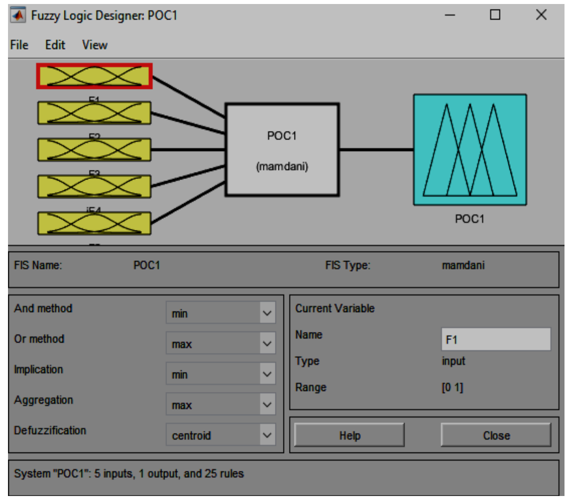

Fig. 26. Defining Input and output variables.

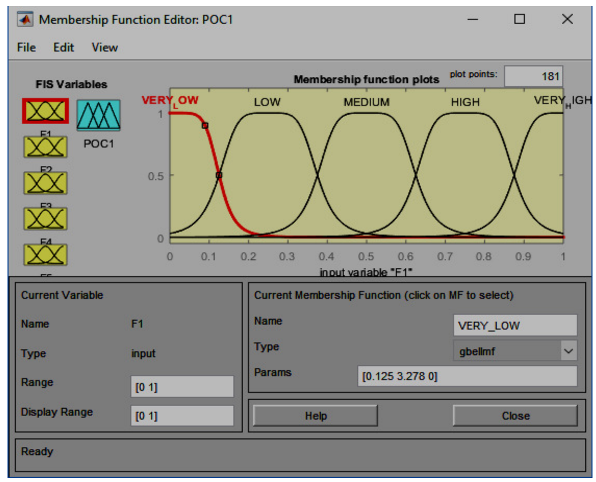

Fig. 27. Defining membership of Input and output variables.

Fuzzy rules and weighting of rules. Considering 55 cost overrun factors, total 275 rules are formed. Samples of the fuzzy rules of cluster ‘Owner’ are presented in Table 3.

Table 3: Sample fuzzy rules of factors of ‘Cluster Owner’.

Rule	Antecedent	consequence	weighting
1	If the probability of cost overrun due to the factor ‘Slow progress payment by owner for completed work ’ is very low	Then the probability of cost overrun due to Cluster ‘owner’ is very low	0.498
6	If the probability of cost overrun due to the factor ‘Slow procedure in taking decisions’ is very low	Then the probability of cost overrun due to Cluster ‘owner’ is very low	0.522
11	If the probability of cost overrun due to the factor ‘Manner of finance ’ is very low	Then the probability of cost overrun due to Cluster ‘owner’ is very low	0.425
16	If the probability of cost overrun due to the factor ‘Level of owner interference’ is very low	Then the probability of cost overrun due to Cluster ‘owner’ is very low	0.357
21	If the probability of cost overrun due to the factor ‘Impracticable contract duration’ is very low	Then the probability of cost overrun due to Cluster ‘owner’ is very low	0.676

Table 4: Sample Fuzzy rules for estimating the probability of cost overrun of the project.

Rule	Antecedent	Consequence	Weighting
1	If the probability of the cost overrun due to 'Cluster Owner' is very low	Then the 'probability of cost overrun of the project' is very low	0.495
6	If the probability of the cost overrun due to the 'Cluster Contractor' is very low	Then the 'probability of cost overrun of the project' is very low	0.477
11	If the probability of the cost overrun due to the 'Cluster Consultan' is very low	Then the 'probability of cost overrun of the project' is very low	0.502
16	If the probability of the cost overrun due to the 'Cluster Design' is very low	Then the 'probability of cost overrun of the project' is very low	0.541
21	If the probability of the cost overrun due to the 'Cluster Project' is very low	Then the 'probability of cost overrun of the project' is very low	0.693
26	If the probability of the cost overrun due to the 'Cluster Material' is very low	Then the 'probability of cost overrun of the project' is very low	0.401
31	If the probability of the cost overrun due to the 'Cluster Labour' is very low	Then the 'probability of cost overrun of the project' is very low	0.391
36	If the probability of the cost overrun due to the 'Cluster Equipment' is very low	Then the 'probability of cost overrun of the project' is very low	0.4
41	If the probability of the cost overrun due to the 'Cluster Contract' is very low	Then the 'probability of cost overrun of the project' is very low	0.569

Since the probability of cost overrun due to the cluster 'Owner' is directly related to the probability of cost overrun due to slow progress payment by owner for completed work, slow procedure in taking decisions, Manner of finance, Level of owner interference and Impracticable contract duration, therefore the probability of cost overrun of these factors will influence the probability of cost overrun due to the cluster 'Owner'. The calculated RII of the factors are the weighting of the rules.

Considering 11 clusters of cost overrun factors, total 55 rules are formed. Since the probability of cost overrun of the project is directly related to the probability of cost overrun due to the 'Clusters Owner', 'Cluster Contractor', 'Cluster Consultant', 'Cluster Design', 'Cluster Project', 'Cluster Material', 'Cluster Labor', 'Cluster Equipment', 'Cluster Contract', 'Cluster Coordination/communication' and 'Cluster External'. Therefore the probability of cost overrun due to these clusters will influence the probability of cost overrun of the project. Fuzzy rules for estimating the probability of cost overrun of the project are presented in Table 4.

For fuzzy inference the rules are made as follows:

If F1 is 'very low' then POC1 is 'very low': Which means that if the probability of cost overrun due to the factor 'slow payment of complete work by owner' is 'very low' then the probability of cost overrun due to Cluster 'Owner' is 'very low'. The rule editor window of Fuzzy Logic tool box of MATLAB Program Software is shown in Fig. 28.

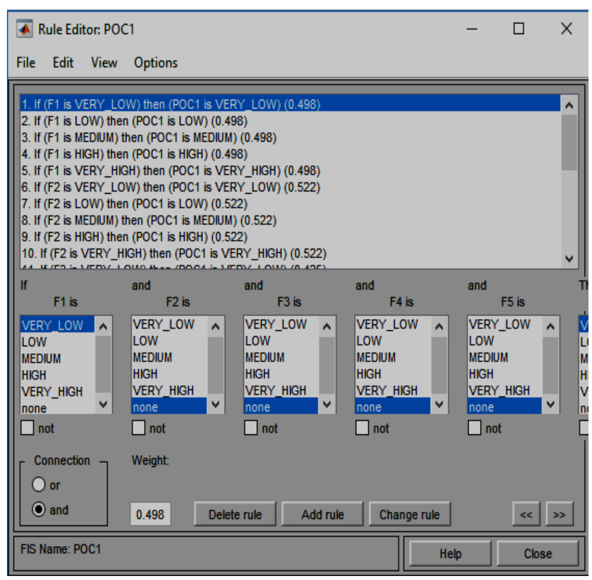

Fig. 28. Rule formation.

Defuzzification. Finally the 'probability of cost overrun due to Cluster 'Owner' PCO1 and 'probability of cost overrun' of project' is estimated by defuzzification by 'centroid of area' method as shown in Fig. 29.

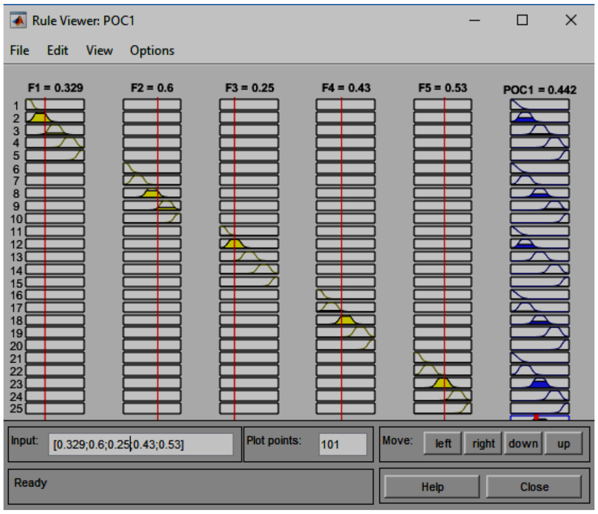

Fig. 29. Defuzzification process.

C. Testing of the model

To test the reliability of the proposed fuzzy cost overrun assessment model**,** an interview has been conducted with a team of the experts of a leading Indian construction company. The panel of the experts consists of the top 10 executive engineers, project managers and site engineers of the company. The experts were requested to examine the cost overrun factors considered for this research and filled in the required information regarding cost overrun factors to assess the proposed model. They were also requested to estimate the probability of cost overrun of the project. The information provided by the group of the experts are presented as shown in the following table in the Table 5.

Table 5: Information provided by the group of the expert.

S.No.	Factors	Probability of occurrence of factor
1	F1	0.329
2	F2	0.6
3	F3	0.25
4	F4	0.43
5	F5	0.53
6	F6	0.4
7	F7	0.3
8	F8	0.25
9	F9	0.3
10	F10	0.5
11	F11	0.35
12	F12	0.25
13	F13	0.55
14	F14	0.25
15	F15	0.42
16	F16	0.36
17	F17	0.27
18	F18	0.38
19	F19	0.23
20	F20	0.35
21	F21	0.62
22	F22	0.58
23	F23	0.22
24	F24	0.8
25	F25	0.5
26	F26	0.6
27	F27	0.33
28	F28	0.28
29	F29	0.15
30	F30	0.24
31	F31	0.27
32	F32	0.16
33	F33	0.23
34	F34	0.32
35	F35	0.21
36	F36	0.18
37	F37	0.21
38	F38	0.23
39	F39	0.25
40	F40	0.27
41	F41	0.56
42	F42	0.42
43	F43	0.38
44	F44	0.87
45	F45	0.82
46	F46	0.93
47	F47	0.62
48	F48	0.72
49	F49	0.4
50	F50	0.43
51	F51	0.85
52	F52	0.35
53	F53	0.27
54	F54	0.23
55	F55	0.74

The determined probabilities of cost overrun due to clusters by model are given in Table 6.

Table 6: Probability level of clusters.

S.No.	Cluster	Name of cluster	Probability of cost overrun due to cluster	Probability of cost overrun of the project
1	C1	Owner	0.442	
2	C2	Contractor	0.405	
3	C3	Consultant	0.406	
4	C4	Design	0.476	
5	C5	Project	0.524	
6	C6	Material	0.436	0.435
7	C7	Labour	0.289	
8	C8	Equipment	0.26	
9	C9	Contract	0.263	
10	C10	Coordination	0.465	
11	C11	External	0.609	

The probability of cost overrun of the project was calculated by the experts was in the range of 0.35-0.50. Provided information was tested using the proposed model and The probability of cost overrun of the project obtained was 0.435 as shown in Fig. 30, which is much closer to the estimated cost risk level of the project estimated by the panel of the experts of the company.

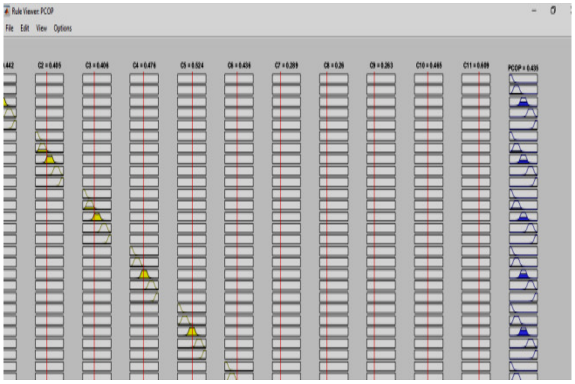

Fig. 30. Probability of cost overrun of the project.

V. CONCLUSION

It is observed that very few projects get completed within stipulated costs in India, despite the importance of economy in construction projects. The cost of a project is calculated just by adding some contingency charges and proper analysis of cost overrun risk is ignored, consequently many projects fail to complete the project in stipulated budget. Therefore in this study a fuzzy model for forecasting the probability of cost overrun risk in Indian construction project is developed by identifying, classifying and ranking of the factors responsible for the cost overrun in the construction industries. The fuzzy theory is chosen for developing the model as the theory is found suitable for quantifying the probability of cost overrun risk of the construction project when the variables regarding the cost overrun factors are expressed in linguistic terms. The fuzzy set theory (FST) is equipped to take care of imprecise, incomplete and uncertain data expressed in linguistic form. Through an extensive literature survey and discussion with the experts of the Indian construction industry, fifty five cost overrun factors were identified and then classified into eleven clusters. A questionnaire survey was conducted in Indian construction industry for data collection to calculate relative importance index (RII) of the recognized factors causing cost overrun and clusters. Total 250 questionnaires were distributed to the potential respondents within the Indian construction company comprising owner, contractor and consultant. Out of 250 questionnaire set, only 135 responses were returned. The calculated relative importance index of the factors and clusters was used to develop model using the fuzzy logic tool box of MATLAB program software. First the probability of cost overrun due to the clusters of cost overrun factors is determined. The final cost overrun risk probability of the project is then determined taking into consideration the probability of all the clusters. For all input and output linguistic variables five membership functions are defined using g-bell shaped fuzzy numbers. Fuzzy rules for estimating the probability of cost overrun of the project are constructed with the discussion of experts of the Indian construction industry in the simple forms of the Mamdani-style. The calculated RII of the factors and clusters are taken as the weighting of the rules. Centre of area (COA) method is chosen for defuzzification. The model has been tested by taking into consideration a real case study in India. To test the model an interview was conducted with a team of the experts of a leading Indian construction company. The panel of the experts consisted of the top 10 executive engineers, project managers and site engineers of the company. The experts were requested to examine the cost overrun factors considered for this research and filled in the required information regarding cost overrun factors to assess the proposed model. They were also requested to estimate the cost risk level of the project. The probability of cost overrun of the project was calculated by the experts was in the range of 0.35-0.50. Provided information was tested using the proposed model and The probability of cost overrun of the project obtained was 0.435, which is much closer to the estimated cost risk level of the project estimated by the panel of the experts of the company. With the help of the proposed model, it is possible to guide project managers and decision makers to make more informative decisions such as contingency estimation, mark-up estimation, bid price, selection of optimum procurement route, evaluation of different projects and preparation of project portfolios.

VI. LIMITATION OF APPROACH AND FUTURE SCOPE

The following are the limitations of the proposed model:
The sample size of population for the identification cost overrun factors is very small as compared to the size of construction industry. Therefore the calculated the relative importance index (RII) does not represent a true picture of actual cost overrun scenario. The model can differ as per the shapes and number of membership function adopted in fuzzy logic tool. The constructed rules for fuzzy model are based on expert opinion. It is based on subjectivity. For different attitudes of the experts rules can also be changed and in this condition the model will produce different result. Results can vary according to the defuzzification method adopted for obtaining output. Fuzzy rules are based on literature survey findings expert judgment and, it is clear that a completely different model may be proposed by other researchers based on different expert opinions. The model could also be developed for estimating the performance and delay probability in construction and other industrial projects using fuzzy logic theory.

Conflict of Interest. No.

REFERENCES

[1]. Hajarat, A.D., & Smith J. N. (1993). Exposure envelopes: an assessment of the exposure to time and cost overruns during construction projects. *Int. J. Proj. Manag., 11*(4), 227–231.

[2]. Azhar, N., Farooqui R.U., & Ahmed, S.M. (2008). Cost overrun factors in construction industry of Pakistan. In: Paper presented at the first international conference on construction in developing countries (ICCIDC-I). Advancing and integrating construction education, research & practice.

[3]. Memon, A.H., Rahman, I.A., Asmi, A., & Azis, A. (2010). Factors Affecting Construction Cost in Mara Large Construction Project: Perspective of Project Management Consultant. *International Journal of Sustainable Construction Engineering & Technology, 1*(2), 41-54.

[4]. Akinci, B., & Fischer, M. (1998). Factors affecting contractors' risk of cost overburden, *Journal of Management in Engineering, 14*(1), 67-76.
[5]. Reina, P., & Angelo, W. J. (2002). Megaprojects need more study up front to avoid cost overruns. *ENR*, *249*(3).
[6]. Frame, J. D. (1997). Establishing project risk assessment teams. In: K. Kähkönen & K. Artto (eds.), Managing risks in projects, London: E & FN Spon, 17-19.
[7]. Jackson, S. (2002). Project cost overrun and risk management in Greenwood. In: Proceedings of Association of Researchers in Construction Management, 18th Annual ARCOM Conference, Newcastle, Northumber University, UK, 2-4.
[8]. Chang, A.S.T. (2002). Reasons for Cost and Schedule Increase for Engineering Design Projects. *Journal of Management in Engineering, 18*(1), 29–36
[9]. Olawale, Y.A., & Sun, M. (2010). Cost and time control of construction projects: Inhibiting factors and mitigating measures in practice. *Construction Management and Economics, 28*(5), 509–526.
[10]. Cantarelli, C.C., Flyvbjerg B., Molin, E.J.E., & Wee, B. V. (2010). Cost *Overruns* in Large-Scale Transportation Infrastructure Projects: Explanations and Their *Theoretical* Embeddednes. *European Journal of Transport and Infrastructure Research*, *10*(1), 5-18.
[11]. Koushki P.A., Al-Rashid, K., & Kartam, N. (2005). Delays and cost increases in the construction of private residential projects in Kuwait. *Construction Management and Economics*, *23*(3), 285–294.
[12]. Gupta, N. (2009). Avoiding Time and Cost Overruns in the Construction of Rohtang Tunnel. Institute for Defence Studies and Analyses.
[13]. Frimpong, Y., Oluwoye, J., & Crawford, L. (2003). Causes of delays and cost overruns in construction of groundwater projects in developing countries; Ghana as a case study. *International Journal of Project Management, 21*, 321-326.
[14]. KPMG (2019). Study on Assessment of infrastructure projects and corrective recommendations for performance. A joint study conducted by PMI and KPMG in India on infrastructure projects in India, supported by Ministry of Statistics and Programme Implementation (MoSPI).
[15]. Zhi, H. (1995). Risk management for overseas construction projects. *International Journal of Project Management, 13*(4), 231-237.
[16]. Baccarini D., & Archer, R. (2001). The risk ranking of projects: a methodology. *International Journal of Project Management 19*(3), 139-145.
[17]. Hull, J. (1990). Application of risk analysis techniques in proposal assessment. *International Journal of Project Management, 8*(3), 152-157.
[18]. Özta, A, & Ökmen, Ö (2004). Risk analysis in fixed-price design-build construction projects. *Building and environment* 39(2)**,** 229-237.
[19]. Thomas, A., Kalidindi, S., & Ganesh, L. (2006). Modelling and assessment of critical risks in BOT road projects. *Construction Management and Economics, 24*(4)**,** 407-424
[20]. Dey P K (2001). Decision support system for risk management: a case study. *Management Decision, 39*(8): 634-649.
[21]. Dikmen, I., Birgonul, & M. T. (2006). An analytic hierarchy process based model for risk and opportunity assessment of international construction projects. *Canadian Journal of Civil Engineering, 33*(1): 58-68.
[22]. Nasir, D., McCabe, B., & Hartono, L. (2003). Evaluating Risk in Construction–Schedule Model (ERIC–S): Construction Schedule Risk Model. *Journal of Construction Engineering and Management, 129*, 518.
[23]. Kangari, R., & Riggs, L. S. (1989). Construction risk assessment by linguistics. *IEEE transactions on engineering management*, *36*(2), 126-131.
[24]. Tah, J., & Carr, V. (2000). A proposal for construction project risk assessment using fuzzy logic. *Construction Management and Economics, 18*(4), 491-500.
[25]. Sharma, S., & Goyal, P. K. (2014). Cost overrun factors and project cost risk assessment in construction industry- a state of the art review. *International journal of civil engineering, 3*(3), 139-154.
[26]. Oliveros, A. V. O., & Fayek, A. R. (2005). Fuzzy logic approach for activity delay analysis and schedule updating. *J. Constr. Eng. Manage*, *131*(1), 42–51.
[27]. Dikmen, I., Birgonul, M.T., & Han, S. (2007b). Using fuzzy risk assessment to rate cost overrun risk in international construction projects. *International Journal of Project Management, 25*(5), 494-505.
[28]. KarimiAzari, A., Mousavi, N., Mousavi, S. F., & Hosseini, S. (2011). Risk assessment model selection in construction industry. *Expert Systems with Applications*, *38*(8), 9105-9111.
[29]. Nieto-Morote, A., & Ruz-Vila, F. (2011). A fuzzy approach to construction project risk assessment. *International Journal of Project Management, 29*, 220–231.
[30]. Yeung, J., Chan, A., & Chan, D. (2012). Fuzzy set theory approach for measuring the performance of relationship-based construction projects in Australia. *J. Manage. Eng.,* 10.1061/(ASCE)ME.1943-5479 .0000083, 181–192.
[31]. San Cristobal, J. (2013). Critical path definition using multi criteria decision making: The PROMETHEE method. *J. Manage. Eng.,* 10.1061/(ASCE)ME.1943-5479.0000135, 158–163.
[32]. Gunduz, M., Nielsen, Y., & Ozdemir, M. (2015). Fuzzy Assessment Model to Estimate the Probability of Delay in Turkish Construction Projects. *Journal of Management in Engineering, ASCE,* DOI: 10.1061/(ASCE)ME.1943-5479.0000261
[33]. Shaktawat, A., & Vadhera, S. (2016, December). Fuzzy logic based determination of cost overrun of hydro power plant. In *2016 International Conference on Electrical Power and Energy Systems (ICEPES)* (pp. 301-304). IEEE.
[34]. Khalek, H. A. E., Aziz, R. F. & Kamel, H. M. (2016). Risk and Uncertainty Assessment Model in Construction Projects Using Fuzzy Logic. *American journal of civil engineering, 4*(1), 24-39.
[35]. Manoliadis, O. (2018). The Assessment of Construction Project Risks with the Use of Fuzzy Delphi Methodology- Case Study Photovoltaic Project in Greece. *International Journal of Management and Fuzzy Systems, 4*(1), 7-14.
[36]. Fuzzy Logic Toolbox™ 2 User's Guide (2008), MATLAB, The MathWorks, Inc.
[37]. Zadeh, L.A. (1965). Fuzzy sets. *Information and control, 8*(3), 338-353.
[38]. Mamdani, E. H., & Assilian, S. (1975). An experiment in linguistic synthesis with a fuzzy logic controller. *International Journal of Man-Machine Studies*, *7*, 1-13.
[39]. Mittal, H., & Bhatia, P. (2007). Optimization criteria for effort estimation using fuzzy technique. *CLEI Electronic Journal*, *10*(1), 1-11.
[40]. Sharma, S. and Goyal, P. K. (2019). Applying "Fuzzy Techniques" in construction project management. *International Journal on Emerging Technologies*, *Research Trend, 10*(2): 384-391.

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