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Fuzzy MATLAB Approach to Construction Contractor Selection

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Abstract: ***Contractor selection is the process of selecting the most appropriate contractor to deliver the project as specified. Construction clients are becoming more aware of the fact that selection of a contractor based on tender price alone is quite risky and may lead to the failure of the project in terms of time delay and poor quality standards. Contractor prequalification involves the screening of contractors by a project owner, according to a given set of criteria, in order to determine their competence to perform the work, if awarded. This study presents an approach to prioritize competitive contractors at the pre bidding stage for construction projects by utilizing fuzzy inference system. Initially, the main quantitative and qualitative criteria affecting the contractor selection process are identified and studied. The effective criteria in the selection process were obtained from experts and literatures. A structured questionnaire was designed and sent to experts in construction projects in Kerala. The fuzzy weightage was used to prioritize these criteria and a case study for the construction of an apartment was conducted to illustrate the most important criteria obtained from the questionnaire. Subsequently, fuzzy mat lab was utilized to develop the selection model.The applicability of the proposed model was tested using a real case of apartment construction projects. It was concluded that using the lowest bid price as a sole criterion for selecting the best contractors may not result in an optimum solution. One major advantage of the proposed method is that it makes the selection process more systematic and realistic as the use of fuzzy set theory allows the decision maker to express their assessment on contractors' performance in linguistic terms rather than a crisp value.***

Key words: construction, contractor, prequalification, bidding, fuzzy, membership function

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1. Introduction

Construction industry is considered as one of the most dynamic and risky industrial sector. Many construction projects do not attain all their desired goals due to the presence of risks and uncertainties intrinsic in the project. These lead to failure of project in terms of project delay, cost over runs and poor quality. To minimize or optimize all these risks, selection of an appropriate contractor to deliver the project under consideration as per requirements is the most crucial challenge faced by any construction client. To address those issues, this research identified the main criteria that affect the contractor selection process in Kerala.The criteria affecting are selected based on experts' opinions and from the literature. The importance of each criterion is found by conducting a questionnaire survey and fuzzy weightage was used to rank the criteria. The main objective of this study is to present a contractor selection model using fuzzy mat lab.

1.1 Objectives of the study

Selection of suitable contractor in construction project is one of the significant criteria of defining the success of construction projects. The propose and objectives of identification of critical factors affecting selection of construction contractor in construction projects is to make sure that projects will be finished within scheduled time, cost and quality. However, selection of contractor in construction projects is frequently affected by many factors. The aim of this study is to analyze the various factors influencing the selection of contractor in construction projects. The aim of this study is divided into the following objectives.

- To identify the most important criteria that are used to evaluate contractor's selection by conducting questionnaire survey and to rank them using fuzzy.
- To compare the survey data with case study of construction project and find out the similar factors.
- To develop a simulation model for construction contractor selection process using fuzzy mat lab.
- To validate the developed model by conducting a case study of the construction projects in nearby area.

1.2 Need for the study

The selection of construction contractors are conducted during tendering. Tendering gives a client a choice in awarding contract to a company which proposes the lowest price and short construction cycles, but usually they do not allow to precisely evaluating a tender. On the other hand, the previous research results show that the cheapest tenders often have problems with completing the project. Accepting the lowest price is the basic cause of the project completion problems and lowering the price means lowering the quality. It is true in some cases. The above conditions make that it is especially important to properly evaluate the contactor's capabilities.

Selecting the most suitable contractor for a construction project is a crucial decision for owners and project managers. To minimize risk of the contract failure and to enhance the performance, clients can apply prequalification procedures before they ask for bids. Contractor prequalification involves a screening procedure based on a set of criteria set- forth by each individual owner. Prequalification is a pre-tender process used to investigate and assess the ability of a contractor to fulfill contract requirements in a satisfactory way should it be awarded to them.

To address those issues, this study aims to identify the main criteria that affect the contractor selection process in Kerala. The criteria affecting are selected based on expert's opinions and from the literature. The importance of each criterion is found by conducting a questionnaire survey and fuzzy weightage was used to rank the criteria. Therefore, this study aims to find out the most important criteria to be considered for the selection of construction project contractors in Kerala for better evaluation of construction both technically and financially. The main objective of this study is to present a contractor selection model using fuzzy mat lab.

2. Methodology

First identified the research gap in this area.Then the factors affecting the construction contractor were identified through the extensive literature review and with the help of expert's opinion. These factors are then ranked and assessed for their fuzzy weightage. After ranking the factors, model is developed in fuzzy inference system. The criteria weights obtained from fuzzy analysis were then used as input for the proposed simulation model for construction contractor selection. Finally, the developed model was tested using a real case study.

2.1 Data collection

A list of the most influential factors was prepared from literature survey and a structured questionnaire was designed and distributed to experts in construction. The questionnaire respondents had a minimum of 4 years of practical experience. The questionnaires were distributed to professionals (who are involved in tender evaluation and selection of contractors) working for clients' organizations within the construction industry in Kerala. In administering the questionnaires, respondents were asked to rate the level of importance of a list of criteria used by clients in the selection of contractors in kerala. The rating was based on a 5-point Likert scale where 1 =Very Low, 2 = Low, 3 = average, 4 = High and 5 =Very High. The respondents were also allowed to add other criteria not covered by the questionnaire. The five-point scale was transformed to fuzzy number for each criterion, using the fuzzy method to obtain the ranks of the different criteria. The questionnaire was sent to a sample of 52 experts associated with contractor selection and tender in the field of construction projects. Out of the 52 distributed questionnaires, 39 completed questionnaires were received from the targeted sample, which represents 75% of the total sample The respondents' occupation varied between organization manager, project manager, construction manager, and others, with an experience level of 4 years to more than 40 years. Out of the 52 questionnaire distributed to various construction companies 39 responses were obtained. That means the percentage of response is 75%.

Table1 below shows the proportion the present designation of respondent in their respective companies. It shows that Project Managers have the highest proportion (41.03%) while site engineers (5.13%) have the lowest proportion. Having project managers as respondents from the organizations would help to validate the findings of this paper because they are usually given the task to evaluate and select main contractors to execute the projects.

Table 1: Respondant's percentage

Present designation in the company	No. of respondent	%
General manager	5	12.82
Project manager	16	41.03
Assistant engineer	6	15.38
Site engineer	2	5.13
other	10	25.64
Total	39	100

Table2 below shows the proportion of respondent's experience in construction. Over 70% of the respondents have the requisite construction experience of over 10 years. Having respondents with such an impressive working experience in construction indicates that the respondents are well conversant with selecting suitable contractors to implement projects. This really adds validity to the findings of this study.

Table 2: Respondant's experience in construction

Respondent's experience in construction(yrs)	No. of respondent	Respondent %
< 5	3	7.69
5 to 10	9	23.08
10-15	9	23.08
15-20	5	12.82
>20	13	33.33
Total	39	100%

2.2 Ranking the factors

Ranking of the factors are done by using uzzy.The fuzzy weightage is calculated by using the equation (1) given below.

W= (F X R)/N…….. (1)

Where-W-weight age of each factor, W-Fuzzy rule matrix, R-Respondents matrix, and N-Total number of respondents.

It is observed that the main factors to be considered for the selection of construction contractor are completion within the scheduled duration, quality assurance in accordance with standards for design and construction, quality achieved in the previous project, quoted bid price, equipment and human resources available, past experience with similar type of project and number of years in similar project qualification &engineering skill of contractor, subcontractor and key personnel etc. The fuzzy weightage of these factors are more than 90%.The ranking of the various factors is as shown in the table3 below.

Table 3: Ranking of factors

Sl. No	Factor	Weightage in %	Rank
1	Completion of project within the scheduled duration	97.44	1
2	Quality assurance in accordance with standards for design and construction	96.15	2
3	Quality achieved in the previous project	95.51	3
4	Quoted bid price is in consistent with the owner estimate &planning report	95.00	4
5	Equipment and human resources available	94.87	5
6	Qualification &engg. skill of contractor ,subcontractor and key personnel	94.23	6
7	past experience with similar type of project and number of years in similar project	93.59	7
8	Time and cost over run in the previous project	89.10	8
9	License and insurance of the contractor	88.46	9
10	Failure of a contract in the past	87.82	10
11	Type and size of project completed	86.54	11

12	Current work load and working capital.	85.89	12
13	Last 5-Years turn over history	84.62	13
14	NEBOSH certified officers for the occupational safety &health requirement of the work	84.62	14
15	Retaining 5% of the amount certified, by the client as retention money	81.41	15

3. Modelling in Fuzzy MATLAB

The assessment model for the construction contractor selection factors is developed using fuzzy logic as per procedure explained here. There are five primary graphical user interface tools for building, editing, and observing in the fuzzy inference systems toolbox. The most important factors identified from the questionnaire were used as input variable for the development of model. Since each criterion is represented in five different forms, there are five membership function associated with each criterion. The fuzzy weightage obtained from the analysis of the questionnaire is used for the rule weight. With the membership functions and fuzzy rules formulated, it is possible to use them with specific values of the input variables (numeric not linguistic) to compute a numeric value of the output variable. This process is known as the fuzzy rule-based inference. In the inference process, the firing strength of each fuzzy rule is calculated. This is based on the degree to which the input elements meet the preconditions of a rule, which is measured by the fetched membership values from the fuzzy set concerned. The firing strength of a rule determines how much its consequence can be applied to the output value.

3.1 Analysis steps for the model development

(i)**Defining input and output variables** The identified contractor selection factors are considered as input variable for the assessment model and the output variable is taken as the "contractor selection probability Constructed a twenty input, one output system in the FIS editor. The most important factors for the selection of construction contractor identified from the questionnaire survey were entered as input members and "contractor selection" as output member. These are shown in the Figure 1 below

(ii) **Defining membership functions for variables:** The membership function represents the fuzziness degree of linguistic variables. Membership functions give a numerical meaning for each linguistic variable. There are different shapes of membership functions, viz, triangular, trapezoidal, Gaussian, bell-shaped, piecewise-linear etc. Triangular fuzzy membership functions are used in this study. A triangular fuzzy number 'x' with membership function μ(x) is defined by

$$\mu(x) = \begin{cases} (x-a)/(b-a) & \text{if } a \le x \le b \\ (x-c)/(b-c) & \text{if } b \le x \le c \\ 0 & \text{Otherwise} \end{cases}$$

Membership functions associated with all of the input and output variables are defined in membership function editor. An example of membership function of completion within the schedule is shown in Figure 2 below

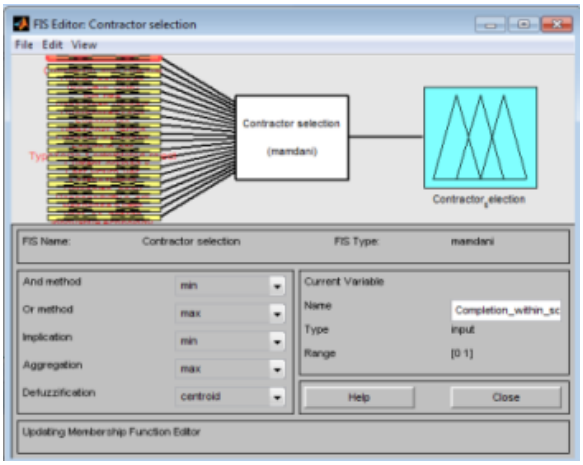

Figure 1: Input variables

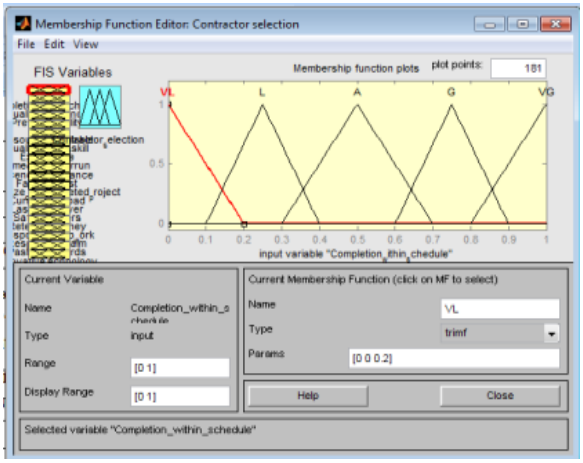

Figure 2: Membership functions

(iii) **Defining rules:** In order to perform fuzzy inference, rules which connect input variables to output variables are defined. For the present model 100 rules are constructed in the form of IF-THEN as shown in Figure 3.

(iv) **Defuzzification:** Defuzzification is the process in which outcomes of control models in the form of fuzzy numbers can be converted to precise output numbers. Finally, the input-output mappings are obtained by choosing view menu and under it view surface. Figure 4 below shows completion of project within the scheduled and the bid price with respect to contractor selection. Similarly, contractor selection for different combination of input variables can be obtained. This helps to view the dependency of output to any two of the input. That is it generated and plots an output surface map of the system.

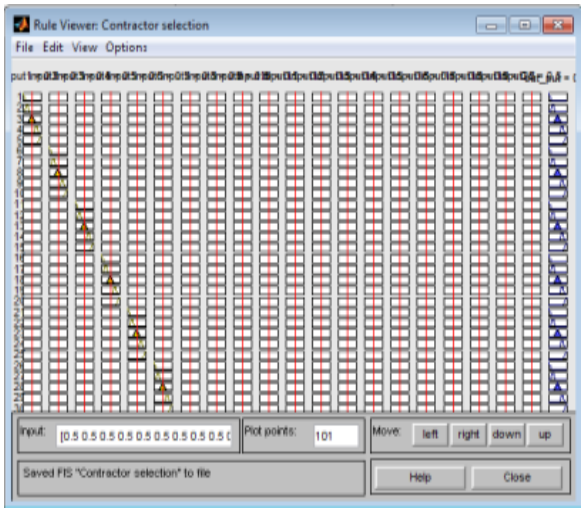

Figure 3: Rule viewer

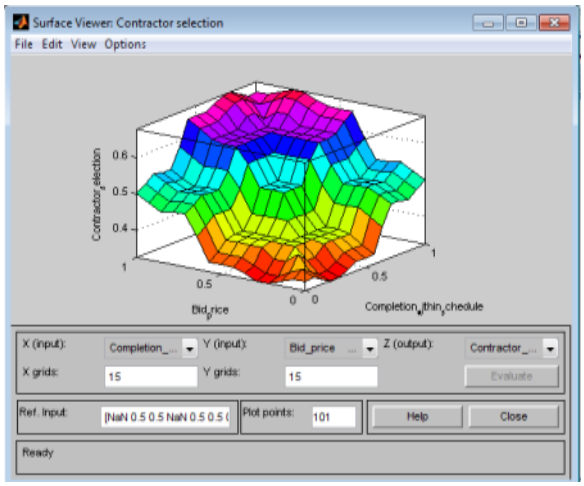

Figure 4: Surface viewer

3.2 Model validation

A real construction project cases was used to test the developed model's applicability and highlight its benefits. It was a ten storied apartment having 1, 19,185squre meter area. Total five contractors submitted the bid. Five contractors anonymously named 1, 2, 3, 4 and 5 had been subjected to a detailed prequalification by investigating their completion of the project within the scheduled time, past performance, past experience in similar project, safety record, current work load etc.Fuzzy rules define the value or level of a decision maker in controlling a system using fuzzy control. Since each of fuzzy variables has five membership functions there could be a total of five different combination of precondition that affect the selection of a contractor.

Table 4: Assessment of contractor by decision makers

Sl no	criteria	Linguistic assessment of criteria for contractor				
		1	2	3	4	5
1	Completion Within the Scheduled duration	L	H	VH	H	VH
2	Quality assurance	VL	M	H	H	H
3	Consistent bid price	VL	M	H	L	L
4	Available resources	L	M	VH	VH	VH
5	Qualification &skill okey personnel	L	H	VH	VH	VH
6	Experience in similar project	L	L	VH	VH	VH
7	Current work-load	L	M	M	M	M
	output from model	**0.35**	**0.43**	**0.56**	**0.5**	**0.5**

The linguistic assessment given by the decision makers for the candidate contractor for their performance is as shown table 4 above. The linguistic assessment is put in the form of different rules to get the output from the model. The corresponding output value represents the defuzzified score obtained for each candidate contractor. It is also shown in table 4 above.In this study in order to compose the fuzzy rule the fuzzy rule matrix as shown in table6 below is used. It represents the criteria weight assessment corresponding to the input very low, low, medium, high, and very high respectively.

Table 5: Linguistic scale for criteria weight assessment

Linguistic set	Fuzzy set		
Very low	[0	0	0.2]
Low	[0.1	0.25	0.4]
Average	[0.3	0.5	0.7]
High	[0.6	0.75	0.9]
Very high	[0.8	1.0	1.0]

Each criteria is represented in forms 'verylow', 'low', 'medium', 'high', 'very high'. Therefore it is essential to present those five forms foreach criterion and figure out in each case the corresponding output suitability. In this study in order to compose the fuzzy rule a score of 0,0.25,0.5,0.75,1 is given to the input'very low','low','medium','high','very high' respectively. The total score obtained for contractor 1, 2, 3, 4&5 are 0.35, 0.43, 0.56, 0.50, and 0.50 respectively. So it is preferred to select contractor 3.

4. Conclusions

Selection of an appropriate contractor to deliver the project under consideration as per requirements is the most crucial challenge faced by any construction client. The most important factors to be considered for the construction contractor selection were identified based on questionnaire survey. Out of the 52 questionnaire distributed to various companies 39 responses were obtained, that represents that the percentage of response was 75% The analysis was done manually by using fuzzy. From the analysis the most important factors to be considered for the selection of construction contractor are the completion of the project within the scheduled duration, consistent bid price and quality of construction etc. It is recommended to consider the identified factors for the prequalification of the construction contractor for the selection of the appropriate contractor for the project to avoid the failure due to inefficient contractor. It is recommended to apply the developed model for prequalification of any type of construction project. Then the prequalification can be done in more realistic and systematic way and thus to avoid the failure of the project due to in efficient contractor.

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