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Selection of Vertical Formwork in Construction Project Using Fuzzy Logic

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Abstract: Vertical formwork system has a considerable share in total construction cost of a project. Selection of an appropriate vertical formwork system is important and challenging role in cost savings in a construction project. The aim of this paper is to propose a decision support tool to contractors and consultants while making the selection of a vertical formwork system using fuzzy logic incorporated with Relative Importance Index (RII). Eighteen major factors were identified and categorized into four groups. Importances of these factors were quantified by using Relative Importance Index method and ranking to these groups is given on the basis of their importance index. In this research paper a simple form of Mamdani type fuzzy rule is used. The results obtained from relative importance index are utilized as a fuzzy rule weights to construct a fuzzy assessment model for the selection of vertical formwork system.

Key words: Construction projects, Vertical formwork system, Relative Importance Index (RII), Fuzzy logic.

INTRODUCTION

Formwork system plays a major role in any construction project and selection of vertical formwork system is a very critical decision that is to be made at early stage of a construction project. Selection of vertical formwork system is a complex process since various perspectives have to be checked out before the selection to be made. There are several other factors that must have to be considered before the decision making process.

Many attempts have been made for the selection of appropriate vertical formwork system in the construction. Artificial neural networks, Knowledge base expert system, Value engineering and other attempts have been made for the selection of appropriate vertical formwork system. Some of the researchers [1] employed a neural based approach to anticipate the acceptability of new formwork system. Knowledge acquisition of an expert system was developed to assist the formwork designer in making the selection of the optimum formwork system [2, 3]. A computer system was developed to help contractors to select the optimum horizontal formwork [2, 3].

The attempt to use fuzzy logic incorporated with relative importance index has not been made for the selection of a vertical formwork system. However fuzzy logic used earlier in other construction applications such as, crane selection [2, 3] site layout planning [4, 5]. This paper mainly focuses on the analysis of importance of factors affecting the selection of vertical formwork systems.

METHODOLOGY

The following steps will be followed to quantify relative importance of schedule delay factors.

Step 1: An interview with field experts to evaluate the factors affecting the selection of a vertical formwork system according to their relative importance.

Step 2: Use of Relative Importance Index (RII) used as data analysis method to assess the importance's of factors affecting the selection of a vertical formwork system.

Step 3: Analysis to identify the most and the least significant factors affecting the selection of a vertical formwork system in construction projects.

Step 4: The index obtained for each factor from RII method is used as a fuzzy weight for the fuzzy rules.

Step 5: Fuzzy probability assessment model was developed in order to evaluate the factors affecting selection of vertical formwork system using Fuzzy Logic Toolbox of the MATLAB.

Step 6: Conclusion and recommendations.

QUESTIONNAIRE DESIGN AND DATA COLLECTION

The questionnaire is designed to determine the importance of the factors affecting selection of vertical formwork system. A scale between 0 to 10 is used to reflect the importance of the factor, where 0 means very low important and 10 means very high important. Questionnaire was prepared by using Google forms and response of 44 experts from the construction industry is recorded to identify the importance of the factors affecting the selection of vertical formwork system.

FACTORS AFFECTING SELECTION OF VERTICAL FORMWORK SYSTEM

While making the selection it was found that there are so many factors that affect the selection of vertical formwork system. Factors affecting the selection of vertical formwork system were classified by the earlier researchers [2, 3]. These factors are classified into four major groups as job

specifications, supporting organization, local conditions, and building design.

To determine the most important factors affecting the selection of vertical formwork system semi-structured interviews were conducted with experts working with reputed construction organizations. The purpose of these interviews was to determine the most important factors which are encountered during the construction projects. Factors affecting selection of vertical formwork system are enlisted in Table 1.

Table 1. Factors affecting selection of vertical formwork system

Building design	Lateral support system	Rigid frame system
		Shear walls
		Framed shear walls
		Framed tube
		Tube in tube
	Building height	
	Building shape	Irregular
		Uniform
	Openings/inserts	
Job specification	Concrete finish	As cast concrete finish
		Exposed concrete finish
		Architecture concrete finish
	Construction sequence	
	Cycle time	
Supporting organization	Stripping cost	
	Reuse cost	
	Location of adjacent buildings and obstruction	
	Crane time	
	Operating system	
	Safety management	
	Yard facility	
Local conditions	Area practice	Labor quality
		Labor cost
	Weather	Hot weather
		Cold weather
	Access to site	
	Site size	

DATA ANALYSIS

Relative Importance Index (RII) method is used to determine the relative importance of the various causes of delays. The same method was adopted in this study. The ten-point scale ranged from 1 (very low important) to 10 (very high important) was adopted and transformed to relative importance indices (RII) for each factor as follows:

Relative Importance Index (RII) = $(\sum W)/(A*N)$ … (1)

Where W is the weighting given to each factor by the respondents (ranging from 1 to 10), 'A' is the highest weight (i.e. 10 in this case), and N is the total number of respondents. The RII value had a range from 0 to 1 (0 not inclusive), higher the value of RII, more important was the factor affecting the selection of vertical formwork system.

The RII was used to rank (R) the different factors. These rankings made it possible to cross- compare the relative importance of the factors as perceived by the respondents (i.e. consultants and contractors). Each individual factor's RII perceived by all respondents were used to assess the general and overall rankings in order to give an overall picture of the factor for the selection of vertical formwork system.

The ten-point scale is used for the analysis of factors affecting selection of vertical formwork system. The scale is an ordered, one-dimensional scale from which respondents choose one option that best aligns with their view. There are typically between four and seven options. Five is very common. All options usually have labels, although sometimes only a few are offered and the others are implied. A common form is an assertion, with which the person may agree or disagree to varying degrees. In scoring, numbers are usually assigned to each option (such as 1 to 10). A benefit is that questions used are usually easy to understand and so lead to consistent answers. A disadvantage is that only a few options are offered, with which respondents may not fully agree. As with any other measurement, the options should be a carefully selected from set of questions or statements that act together to give a useful and coherent picture.

A ten-point scale, ranged from 1 (very low important) to 10 (very high important) was adopted by the author in this thesis as shown in Table 2 and Table 3, 4 and 5 shows the scale used, RII, group of factors, most important factors and ranks.

ANALYSIS OF FACTORS AFFECTING SELECTION OF VERTICAL FORMWORK SYSTEM BY USING FUZZY LOGIC

Fuzzy logic [6, 7] based systems can handle linguistic inputs called variables and processes these inputs into crisp output so that it can be very easy to make the decision. Fuzzy linguistic variable are the variables which can be defined by words, phrases, or sentences in given language. For Example consider a factor concrete finish as a linguistic variable it can be defined as 'very low important', 'low important', 'moderately important', 'high important' and 'very high important'.

The words are usually less precise than the numerical values, linguistic variables are used for the evaluation of complex systems that cannot be defined by using numbers or quantitative terms [6, 7] and fuzzy logic is used to analyze the importance of the factors affecting the selection of vertical formwork system.

FUZZY INPUT VARIABLES

Five input variables (Fig. 1) were identified to define the importance of these factors for selection of vertical formwork system. Five membership functions were expressed as very low (VL), low (L), moderate (M), high (H), very high (VH). The shape and range of these membership functions were determined by having discussion with the experts from the construction industry.

Table 2. Ten point scale

Scale Point	Description
1	Very low important
2	Very low important
3	Low important
4	Low important
5	Medium important
6	Medium important
7	High important
8	High important
9	Very high important
10	Very high important

Table 3. Results obtained using RII

Sr.	Group of factors	No.	Factors	1	2	3	4	5	6	7	8	9	10	RII	Rank
A	Building design	1	Lateral support system	0	0	0	0	0	0	3	17	22	2	0.7875	3
		2	Building height	0	0	0	0	1	1	4	10	24	4	0.8523	4
		3	Building shape	0	0	1	4	3	7	22	7	0	0	0.6500	14
		4	Openings/inserts	0	0	0	0	2	0	7	24	11	0	0.7954	7
B	Job specification	1	Concrete finish	0	0	0	7	8	1	1	11	13	3	0.7181	9
		2	Construction sequence	0	0	0	1	0	3	21	10	6	3	0.7568	8
		3	Cycle time	0	0	0	0	0	2	4	3	17	18	0.9023	2
C	Supporting organization	1	Stripping cost	0	0	0	0	17	23	3	0	0	1	0.5773	16
		2	Reuse cost	0	0	0	0	0	3	4	12	22	3	0.8409	5
		3	Location of adjacent building and obstruction	0	0	0	1	0	11	13	18	1	0	0.7136	10
		4	Crane time	0	2	12	19	6	3	2	0	0	0	0.4045	18
		5	Operating system	0	0	0	1	3	11	21	7	1	0	0.6750	13
		6	Safety management	0	0	0	0	0	0	2	3	21	18	0.9250	1
		7	Yard facility	0	0	0	0	0	1	13	13	15	2	0.8091	6
D	Local conditions	1	Area practice	0	0	0	0	3	10	20	10	1	0	0.6909	12
		2	Weather	0	0	0	0	1	7	25	7	4	0	0.7136	11
		3	Access to site	0	0	0	1	5	20	15	2	1	0	0.6341	15
		4	Site size	0	0	2	14	14	10	0	3	1	0	0.5113	17

Table 4. Ranking of the group of factors affecting selection of vertical formwork system

Group of factor	RII	Rank
Job specification	0.7924	1
Building design	0.7825	2
Supporting organization	0.7064	3
Local conditions	0.6374	4

Table 5. Most important factors affecting selection of vertical formwork system

Factor	RII	Rank
Safety management	0.9250	1
Cycle time	0.9023	2
Lateral support system	0.8523	3
Building height	0.8523	4
Reuse cost	0.8409	5

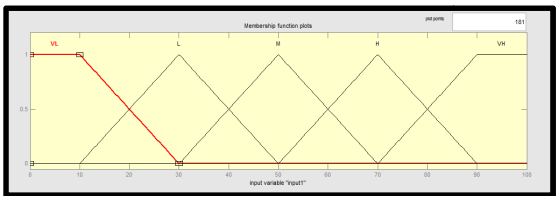
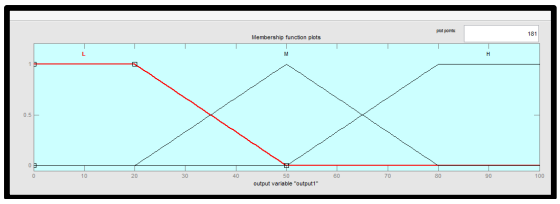


Fig. 1 Fuzzy input variables

FUZZY OUTPUT VARIABLES

Three membership functions were expressed as low (L), moderate (M), high (H) to represent the importance of the factor. The range of each membership function has been defined on the basis of discussion with the experts from construction industry and scores given by them (Fig. 2).



FUZZY DECISION RULES

Fuzzy rules are nothing but the preconditions that are applied to each factor before the analysis. Every rule has been given a rule weight calculated as shown in Table 6 and 7.

Table 6. Results obtained using Fuzzy Logic

Factor	Crisp value	Rank
Lateral support system	80.6	4
Building height	80.9	3
Building shape	79.7	12
Openings/inserts	80.6	5
Concrete finish	80.2	8
Construction sequence	80.4	7
Cycle time	81.2	2
Stripping cost	78.2	16
Reuse cost	80	10
Location of adjacent building and obstruction	78.1	17
Crane time	76.8	18
Operating system	79.8	11
Safety management	81.3	1
Yard facility	78.6	15
Area practice	80.5	6
Weather	80.1	9
Access to site	79.3	13
Site size	78.7	14

Table 7. Ranking of the group of factors affecting selection of vertical formwork system

Group of factor	Crisp value	Rank
Building design group	80.9	3
Job specification group	81.2	2
Support organization group	81.3	1
Local conditions group	80.1	4

CONCLUSION

The factors affecting vertical formwork selection were first identified and discussion with the experts from the construction industry. Eighteen factors were identified as the important factors while making the selection of vertical formwork system. Questionnaire was prepared and knowledge based system was developed. The data received from these experts is analyzed by the relative importance index method. A Fuzzy Logic system was used to identify the uncertainty and ambiguity in the selection of vertical formwork system.

REFERENCES

[1] Elazouni, Ashraf M., Amal E. Ali, and Refaat H. Abdel-Razek., "Estimating the acceptability of new formwork systems using neural networks." Journal of construction engineering and management 131.1 (2005): 33-41.

[2] Hanna, Awad S., Jack H. Willenbrock, and Victor E. Sanvido., "Knowledge acquisition and development for formwork selection system." Journal of Construction Engineering and management 118.1 (1992): 179-198.

[3] Hanna, Awad S., "Concrete formwork systems", CRC Press, 1998.

[4] Elbeltagi, Emad, et al., "Selection of slab formwork system using fuzzy logic", Construction Management and Economics 29.7 (2011): 659-670.

[5] Elbeltagi, Emad E., et al. "Fuzzy Logic Model for Selection of Vertical Formwork Systems." Journal of Construction Engineering and Management138.7 (2012): 832-840.

[6] Lotfi A. Zadeh, "Fuzzy sets., Information and Control", 1965; 8: 338–353.

[7] Lotfi A. Zadeh , "Fuzzy sets and systems". In: Fox J, editor. System Theory. Brooklyn, NY: Polytechnic Press, 1965: 29–39.