FUZZY LOGIC METHODOLOGY FOR THE COMPARISON OF COSTRUCTION FIRMS

Amaury A. Caballero
Florida International University, USA
E-mail: amauryc@eng.fiu.edu

José D. Mitrani
Florida International University, USA
E-mail: mitrani@eng.fiu.edu

Abstract: General contractors, private owners, and public agencies are often faced with a problem; how to evaluate bids from competing construction organizations with respect to important, but difficult to qualify variables other than the lowest price. The paper presents a methodology for comparing the qualifications and work capacity of construction firms using a fuzzy logic model. The paper discusses the process of choosing an appropriate family of parametric membership functions by which to define qualifications and capacity. The model provides a means by which general contractors, private owners, or public agencies can rank competing construction organizations on criteria other than the bid price for the work.

Keywords: Construction Management, Fuzzy logic, Decision-making.

1. INTRODUCTION

In any decision-making process it is necessary to evaluate different alternatives and discard those that do not fit certain previously established criteria. If the criteria are mathematically quantifiable, a mathematical model may be created for the evaluation process. Development of such models has the advantage of generalizing a solution to typical problems, which solution may then be applied to other similar problems within or without the same area of endeavor. The use of these models, however, is not without problems. First, the results obtained by using the model are only as good as the methodology used by the model to perform the evaluation. Second, the problem is not only how good the selected methodology is but also, how to evaluate the different input parameters to be used by the model. Last, but not least, is the problem of how to accurately interpret the results obtained. If the selection is made using a computer, it will be necessary to look at some characteristic databases and assign a number to each of the selected parameters in the process of selecting alternatives., difficulties arise during the decision making process, especially when it becomes mandatory to move to the definition of practical indicators or categories and then to evaluate them according to certain practical assumptions.

As is well known, general contractors, private owners, and public agencies are often faced with a problem: how to evaluate the bids of competing construction organizations with respect to variables other than the lowest price. It is axiomatic that each of these constituencies wants to choose from amongst the competing firms the one that best suits their needs. However, most of the time the evaluation of the firms is made based exclusively on the proposed costs, with subsequent negative consequences when the chosen firm eventually does not perform. This problem may be solved using a more accurate procedure or model that may be used as a tool in the selection-making process and that guarantee a truthful final result. The fuzzy logic model that is presented in this paper allows the user to define preferences and concerns when ranking competing firms and in this way obtains better (or expected) results.

2. FUZZY LOGIC METHODOLOGY

There are three main tasks to be considered when defining a fuzzy model [1]:

- Selection of an appropriate family of parameterized membership functions.
- Interviewing of human experts familiar with the target system to determine the parameters of the membership functions used in the rule base.
- Refining the parameters of the membership functions using regression and optimization techniques.

The fuzzy models presented in this paper were developed using only the first task and partially the second one.

The three elements comprising the model are:

- Selected firm descriptors (parameters)
- Fuzzy set vocabulary
- The domain of each variable

2.1. Selected firm descriptors

In the present case, the desired outcome is a methodology that allows individuals, agencies, or general contractors rank the capability of competing construction organizations to perform a certain project.

The selection of descriptors for evaluating the competing firms is the mandatory starting point for the decision-making process. This question have been addressed by a group of authors on the common essential attributes of business organizations [2]. After reviewing several references, the following are the attributes selected for the comparison [3]:

- *Number of years in business*
- *Number of full time personnel*
- *Annual revenues*

2.2. Fuzzy set vocabulary and domain of each variable

The specifications of the fuzzy set vocabulary and variable domains are the foundation of the model. The model's correct behavior as well as its fitness for practical applications depend on well thought-out variable domains. Variable domains are established based on detailed studies of the particular characteristics of the application. Figure 1 shows a concrete example selected for demonstrating the methodology.

3. USE OF THE STANDARD ADDITIVE FUZZY MODEL (SAM)

An additive standard fuzzy model stores *n* fuzzy rules in the form "If Condition 1; and Condition 2; and …….; Condition *m*; Then Output X", and computes the output as the centroid of the "clipped" output membership functions obtained from the fired rules. A detailed analysis of SAM models is treated in [4]. As is well known, the number of rules grows exponentially with the number of input and output variables. Selecting the three parameters of Figure 1, with the defined vocabulary, the number of rules will be 5 x 4 x 4 = 80. For evaluating a firm in, for example: fair, good or excellent will be necessary to fire the correspondent rules and through the defuzzification process to obtain a number reflecting the "grade" obtained by this specific firm. The problem is more complicated than it looks at first glance. The first question to solve is how to relate different inputs to the outputs through the corresponding rules. Secondly, the project characteristics may drastically change from one to another, so trying to use always the same scale for the evaluation of competing firms is complicated and does not necessarily lead to the best results. For example for a small project a large company will not necessarily give better results than one smaller. Trying to use this form of evaluation force to the inclusion of several parameters defining also the projects characteristics, with the correspondent "rule explosion".

Another way of solving the problem is to look for the firm that better fits some pre-established conditions. For each project, the experts will decide the requirements, and the selection is not made based on the firm that obtained the best grades, but the one that best fits the defined conditions for that specific project.

4. COMPARISON OF CONSTRUCTION FIRMS FOR SELECTING THE MOST SUITABLE FIRM IN A BIDDING PROCESS.

The method of composition to be used is presented in "*Fuzzy Logic for Business and industry*" [5]. The average of the degrees of membership (μ) is calculated by means of the compatibility index (CI) for each analyzed alternative with respect to some specified situation, from the equation:

$$CI = [\sum^{N} \mu_i (x)]/N \qquad (1)$$

$i=1$

Where $\mu_i(x)$ is the degree of membership for the parameter i in the firm, and N is the number of parameters. Logically, one has to ensure that the same parameters are used for all firms and that the number of parameters N is constant throughout the computations.

The individual distributions were generated by software [6], and no representation is made at this time that these are the actual distributions. The descriptors of the particular parameters are as indicated on the individual figures. The actual descriptors need not be the same for different organizations using the model. All that is required is that the definition be understood and agreed to. Given that one of the essential features of fuzzy logic is that there are ranges of possibilities, the descriptors generally will have overlapping ranges.

It is easy to see that organizations may fall within two distributions. The assumed fuzzy sets shown in Figure 1 can be used to demonstrate this fact. If one has an organization that has 9 full time employees it falls within both the small ($\mu = 0.2$) and moderate ($\mu = 0.55$) distributions. If the standard being evaluated is, say, moderate, then only the membership function for the moderate range is of interest.

If it is considered that the different attributes are not of equal importance, then relative weights must be calculated. One simple method for determining such weights is the technique of successive comparisons. As an example, if a particular user of the model outlined above feels that **P** (personnel factors) should be 1.5 times as important as **B** (business experience factors), then the weights assigned would be 1.0 for **B** and 1.5 for **P**. Putting this aside, but considering that **P** is the most important factor thus far, the user would next rank **P** and **F** (financial). If the relative weight obtained as a result of this pair wise comparison is 2.0, then the relative weights for all three criteria will be:

B	1.0
P	1.5
F	1.5 x 2.0 = 3.0
Total	5.5

If these are normalized the resulting weights are as follow:

BUSINESS EXPERIENCE: 1.0/(1.0 +1.5+3.0) = 0.182
PERSONNEL: 1.5/(1.0 +1.5+3.0) = 0.273
FINANCIAL: 3.0/(1.0 +1.5+3.0) = 0.545

Having the relative weights, the modified formula for the compatibility index calculation becomes:

$$CI = \sum_{i=1}^{N} \omega_i \mu_i(x) \qquad (2)$$

where ω_i is the weight of attribute and the other terms are as defined in equation (1).

As a demonstration of the utility of the use of fuzzy logic in the selection of construction organizations using other than cost factors, the authors designed 6 hypothetical firms as indicated in Table 3. Only the three attributes shown in Figure 1 were utilized. The standards against which the firms are being evaluated are:

- Number of Personnel: **Medium**
- Business Experience: **Young**
- Financial Situation: **Medium**

The calculations for the Compatibility Index were performed utilizing the same software that generated the fuzzy sets, based on equations (1) and (2), and the results are shown in table 4.

Table 3. Firms and Attributes

Firm	**Full time employees**	**Annual revenues (millions of $)**	**Business experience (years)**
A	10	5	5
B	23	12	14
C	30	25	10
D	37	31	16
E	16	27	8
F	25	18	6

Table 4. Fuzzy Set Calculations

Firm	Equation (1)	Equation (1) rank	Equation (2)	Equation (2) rank
A	0.018	4	0.054	4
B	0.563	1	0.763	1
C	0		0	
D	0		0	
E	0.128	3	0.055	3
F	0.206	2	0.327	2

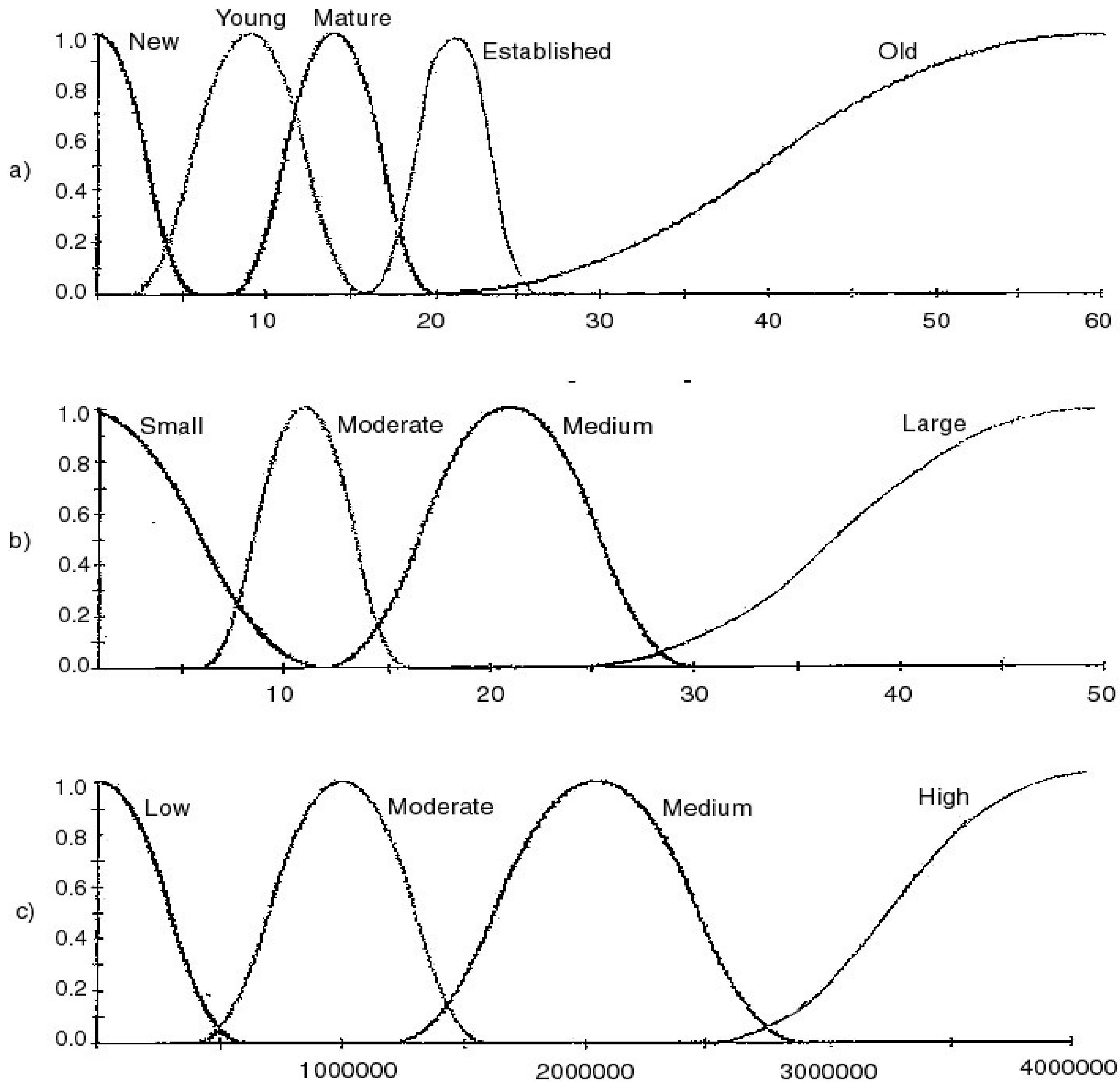

Figure 1. Fuzzy Sets: a) Business Experience b) Number of Employees c) Annual Revenue

5. CONCLUSIONS

The extension of the model previously presented provides a refinement that allows the user of the basic model to more completely reflect their concerns in the ranking of competing firms. The power of the fuzzy logic model is that it uses imprecise terms to arrive at 'crisp' values. Modifying these 'crisp' values by establishing weights, reflecting the importance of various attributes, is a logical next step.

The use of software to both generate the fuzzy sets and perform calculations provides the necessary link between theory and practice. The number of manual calculations that would be required to examine several competitors and more than a small number of attributes is excessive, time consuming, and would surely discourage any practical application of the work.

An additional effort is required to demonstrate the usefulness of the model. In particular, it is necessary to move to the practitioners to:

- Develop the parameters that are of concern.
- Develop the distributions for the descriptors.
- Develop the weights and see if these can be generalized throughout the construction industry.

The presented methodology possesses the flexibility and possibility of knowledge representation that characterizes the fuzzy models. These models are adequate for solving difficult, computational complex and imprecise situations, as they exist in many practical cases of decision-making.

6. REFERENCES

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