ABSTRACT: After a short analysis of the procedures and criteria to use in contractors selection processes, this paper deals with a contractors’ selection system based in the fuzzy-logic technique called fuzzy control. A tool has been conceived for use in the private sector, in traditional design-bid-build projects. The system includes an assessment of several qualitative and quantitative issues, taking also into account the risk of not achieving the client’s objectives. The system allows using three different selection policies: when the essential objective for the client is, respectively, cost, time and quality.

1. INTRODUCTION

Fuzzy sets and fuzzy logic have been used in process and system fuzzy-control, and also to decision making. And also to project selection, the financial analysis of projects, generic project control using fuzzy-control systems, project time control, and project risk analysis. Nguyen (1985), for instance, applied fuzzy sets (but not fuzzy logic) to contractor’s bid assessment. Muralidharan et al (2002) cite the work of Li et al (1997), also using fuzzy sets for supplier rating. There are several authors working in the application of fuzzy-control techniques to decision making in the selection of contractors, using more or less adequate sets of selection criteria (Russel and Skibniewski, 1988; Pack et al, 1992; Rankin et al, 1996, among others). Frequently price has been the only criterion used in contractors’ selection. Its main advantage is a simple and fair awarding process. When the owner’s project management maturity increases, he / she normally tends to use a more complete set of selection criteria, since he / she realizes that the cheapest bid is not normally the most economical alternative. Using fuzzy controllers in this field can allow to manage different criteria in an effective way. When the client uses a wide set of selection criteria, the main problem is that the number of rules grows exponentially with the increase in the number of criteria, reaching the order of hundreds of rules. Additionally, the client could need a controller including various “policies”: a “policy” is each of the different modes of work that the decision support system will have; for instance, this systems should run in different ways depending on the priority objective for the owner (cost, time, quality). This paper presents a system based on the fuzzy control theory, to help a private sector decision maker in selecting contractors in the traditional procurement system (design-bid-build).
2. SELECTING A CONTRACTOR: CRITERIA

The authors have critically examined the main bibliography related to pre-selection and selection criteria (see references), and the main criteria for selection of traditional design-bid-build contractors, are concerned with:

- Experience in similar projects in recent years.
- Knowledge of the codes, as well as the local regulations and market.
- Quality of previous, similar works and other quality issues. Overall customer satisfaction.
- Sustainability criteria.
- Internal resources: equipment.
- Internal resources: own site supervisors skills and experience.
- Internal resources: skills and experience of the site manager and other responsible staff on site.
- Internal resources: other technical staff assigned to the contract (skills and experience).
- Personnel turnover in recent years.
- Organizational capacity: organizational structure.
- External resources: subcontracting.
- Understanding of the several project issues (design, client needs, …).
- Capacity to offer design; design alternatives proposed by the contractor.
- Adaptation of the construction methods and equipment to the specific work to undertake.
- Safety records.
- Insurance policy coverage.
- Proposed schedule.
- Performance records.
- Contracting and turnover records.
- Financial stability.
- Capital or facility life cycle cost.
- Interest shown by the contractor during the contracting process.
- After-sales service.

3. APPLYING FUZZY CONTROLLERS IN THIS FIELD

In multicriteria contractor pre-selection and selection, some of the selection criteria are qualitative. Reducing subjectivity in these kinds of assessments can be done through linguistic labels. With a fuzzy system, in general, the input and output variables take values on fuzzy sets. For each variable, the fuzzy sets are defined in a universe of discourse, which is generally a subset of the real line. In the case of fuzzy controllers, the fuzzy sets are fuzzy numbers, either triangular or in another shape. The reader can find different examples of fuzzy partitions and basic concepts of fuzzy numbers in Kaufmann and Gupta (1991) and Klir and Yuan (1995). A fuzzy system can simulate specific human thinking when making decisions.
This capacity is useful when trying to substitute human knowledge with an artificial system that carries out the same function simulating the reasoning process, after capturing the expert’s knowledge through the rule base. There is an added advantage in using fuzzy systems to help with decision making, probably the main one: all the decisions made by any member of the organization will respect the same criteria set and utilized in the same way, reducing bias and other problems (for instance, potential corruption).

The input variables to the fuzzy system are the first elements introduced into a fuzzy controller. The behaviour rules of the system will be deduced from those variables. Standard partitions of three elements have been used to implement the inputs of the application here presented, except for a price-related variable in which a four-elements partition has been used in order to perform a more precise assessment in cases where the other inputs are very similar. Triangular fuzzy numbers are useful in cases with numeric inputs, but on many occasions, the input variables that will be used are not numeric but linguistic (management capacity or competences, degree of commitment, etc.). Linguistic variables are useful to facilitate the assessment of these specific fuzzy criteria. Figure 1 includes the complete system diagram for the system here presented. As it can be seen in Figure 1 (center), the system has intermediate variables, to facilitate the reasoning process by concentrating the information provided by the input variables. The intermediate variables are distributed in layers of variables through which the information flows. Each one of the intermediate variables is generated by a set of fuzzy rules that will be referred to later on. All the intermediate variables are also defined as fuzzy. To aid the decision maker it is necessary to use a defuzzifier so that the values of the output fuzzy variable are translated to a crisp value that he or she can easily understand. The system here presented has only one output variable with the contractor assessment: a fuzzy variable with a partition of four elements. The system could show to the user a numeric or linguistic output for each contractor. When working with an entirely linguistic output, several contractors could have the same assessment (or label). Thus, the system shows a numeric (0 to 100) assessment, to provide the user with an easy classification of contractors. To run, the system needs an expert-knowledge base that will use the several previously referred to variables in order to infer (fuzzy inference) from them a global assessment for each contractor. This process tries to simulate the human thought process to provide a judgment or assessment based both on numeric values for certain parameters, and other qualitative concepts. This fuzzy inference process involves two essential sub-processes: the aggregation of premises and the aggregation of results. A rule will have the classical IF / THEN structure necessary for the "modus ponens" reasoning, but in the first part of the rule, there will be several antecedents: IF ... AND ... AND ... AND ... THEN ...

The aggregation of premises is the combination of all the inputs to a rule (located after the AND operators) to determine the membership degree of this rule. One way is to take, as the membership degree of the sentence located after THEN, the minimum of the membership degrees of the antecedent sentences.
The system here presented includes an interface screen where the user enters the data for a total of 22 input variables:

- Experience in similar projects in the last 10 years.
- Quality of previous, similar works.
- Contractor’s equipment.
- Own site supervisors skills and experience.
- Site manager and other responsible staff on site (skills and experience).
- Other technical staff assigned to the contract (skills and experience).
- Personnel turnover in the last 5 years.
- Organizational structure.
- Project understanding.
- Adaptation of the construction methods to the specific work to undertake.
- Safety records.
- Proposed schedule.
- Insurance policy coverage.
- Subcontracting assessment.
- Interest shown by the contractor during the contracting process.
- Failure in critical objectives in past projects.
- Failure in secondary objectives in past projects.
- Turnover records.
- Contracting records.
- Financial stability.
- Price: difference between proposal price and “homogenized” price.
- Price: difference between “homogenized” price and (realistic) price estimation.

The system outputs include:

- An assessment of the different intermediate variables for the contractor:
  - Overall managerial capacity
  - Overall technical capacity
  - Other risks: risk level
  - Time objective and risk of not achieving it
  - Cost objective and risk of not achieving it
  - Quality objective and risk of not achieving it
- And the final assessment including all the 22 variables, to be used in establishing a prioritized list of contractors.

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