DESIGN AND IMPLEMENTATION OF A FUZZY EXPERT DECISION SUPPORT SYSTEM FOR VENDOR SELECTION

Case Study in OIEC IRAN(Oil Industerial Engineering and Construction)

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Abstract: Supplier selection and evaluation is a complicated multi objective process with many uncertain factors. Sealed bid evaluation is the most common approach for supplier selection purpose in Iran. In this paper, a fuzzy expert decision support system is developed for solving the vendor selection problem with multiple objectives, in which some of the parameters are fuzzy in nature. Basic important factors considered for supplier selection are price, quality and delivery time. The designed system has been designed and implemented and evaluated in a lead famous company and the results are discussed.

1 INTRODUCTION

The explosive growth in business to business commerce is expected to revolutionize the transaction process between buyers and sellers. Effective purchasing and supply management can contribute significantly to the success of most organizations (Johnson, 2002). Procurement and supply management are one of the most significant parts in EPC (Engineering, Procurement, and Construction) contracts. When a supplier selection decision needs to be made, the buyer generally establishes a set of evaluation criteria that can be used to compare potential sources. The basic criteria typically utilized for this purpose are pricing structure, delivery (lead-time and reliability), product quality, and service (i.e., personnel, facilities, research and development, capability, etc.). Frequently, these evaluation criteria conflict with one another. In addition, the importance of each criterion varies from one purchase to the next. This situation can be more complicated further by the fact that some of the criteria are primarily quantitative (price, quality, etc.) and some are qualitative (service, etc.).(Garfamy, 2004) The literature on supplier selection spans over three decades and covers virtually all the aspects of business. Researchers have long sought to understand and model the relationships between suppliers and buyers (Bhutta, 2001). In this paper, vendor selection process is simulated by use of expert systems and fuzzy theory. The paper is organized as follows. In Section 2, we present the importance of the mentioned subject and a brief review of the literature on vendor selection process and the main approaches being executed in Iran. Section 3 gives an introduction to fuzzy and expert DSS system as well as fuzzy expert system architecture. Section 4 describes the design and development of the system. Section 5 describes the implementation of the system in one of the famous oil companies in Iran and finally Section 6 concludes the paper.

2 LITERATURE REVIEW

The source-selection decision is highly complex and purchaser's most difficult responsibility. First, such a decision involves more than one selection criterion when choosing among the available suppliers. Second, criteria included in the supplier selection process may frequently contradict each other (lowest price against a poor quality).

Third complication surrounding the supplier selection decision arises from internal policy constraints and externally imposed system constraints placed on the buying process. Fourth, as organizational requirements and market conditions change, the importance of the analysis of tradeoffs among the selection criteria may be increased (Weber, 2000; Weber,2000a). Garfamy classifies the main Supplier selection criteria as cost, quality, cycle time, service, relationship, organization (Garfamy, 2004) which every criterion is composed

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of different factors. For example cost factors are price , logistics costs (transportation, inventory, administration, customs, risk and damage, handling and packaging), operating costs, after sales service costs. (Bhutta, 2001) reviews the status of methodology literature in supplier selection, a total of 154 papers from 68 refereed journals are reviewed and classified into various categories such as Mathematical Models, Criteria, Case Study, Literature review, Conceptual. (Kumara, 2004) has formulated a vendor selection problem as a fuzzy mixed integer goal programming vendor selection problem that includes three primary goals: minimizing the net cost, minimizing the net rejections, and minimizing the net late deliveries. There are some restrictive assumptions in the aforementioned formulating; For example, only one item is supposed to be purchased from one vendor. Also, (Kumar a, 2005) formulated Vendor selection problem as a fuzzy Multi-objective Integer Programming incorporating three important goals: cost-minimization, quality-maximization and maximization of on-time-delivery-with the realistic constraints such as meeting the buyers' demand, vendors' capacity, vendors' quota flexibility, etc. In the proposed model, various input parameters have been treated as vague data with a linear membership function of fuzzy type with the same restriction pointed above. However, each company selects its own special criteria and a unique approach for vendor selection. In here some applicable common approaches in Iran will be described.

2.1 Common Vendor Selection Approaches in Iran

Sealed bid evaluation is most common approach for vendor selection in Iran. The common procedure is that first technical scoring will be done based on the technical or quality evaluation. In the quality evaluation Step vendor's capacity for performing the projects is estimated base on such factors as work experience, management staff, technical staff, manufacturing abilities, financial abilities, and good background in other projects, creativity and innovation, among others. Technical evaluation is based on such criteria as exact consideration of buyer or client technical request, complete vendor documents, consideration of international standards, quality of installation and supervision and other technical factors.

The technical and commercial committee estimates the technical score of each vendor based on the abovementioned criteria. Vendors obtaining higher technical score than a specific threshold are approved technically and their commercial quotation will be unsealed. In this Step, all quotations will be apple to apple based on special declared conditions. One of the common approaches for sake of making the quotations apple to apple is that the offered price will be divided by the technical score. Another approach is to consider a ratio for technical and commercial, for example 30 for commercial and 70 for technical score. Obviously, the ratio can be different depending on the conditions of each project.

The above-mentioned approaches are popular methods in the governmental companies. In many private ones which do not allow this status, such other methods are used that in many cases, technical evaluation is done by accept or reject and no scoring methods are done. In this way, the lowest price is the winner although the difference in price may be much less valuable than the difference in quality. Thus, decision making for selecting the right vendor is complicated and time consuming job which needs a committee of technical and commercial experts. Decision making in these committees are based on linguistic criteria. As an illustration, the price of a proposal is "high" and the other is "very high".

3 FUZZY EXPERT SYSTEM

An expert system is a computing system capable of representing and reasoning about some knowledge-rich domain with a view to solving problems and giving advice(Jackson, 1990).

Fuzzy set theory provides a framework for handling the uncertainties. (Zadeh, 1965) initiated the fuzzy set theory.(Bellman, 1970) presented some applications of fuzzy theories to the various decision-making processes in a fuzzy environment. In fuzzy sets every object is to some extent member of a set and to some extent it is member of another set. Thus, unlike the crisp sets membership is a continuous concept in fuzzy sets. Fuzzy is used in cases which the variables are linguistic and there is uncertainness in the problem. Fuzzy expert decision support system is an expert system that uses fuzzy logic instead of Boolean logic. It can be seen as special rule-based systems that use fuzzy logic in their knowledge base and derive conclusions from user inputs and fuzzy inference process (Kandel A, 1992) while fuzzy rules and the membership functions make up the knowledge base of the system. In other words a "fuzzy if-then" rule is a "if-then" rule which some of the terms are given with continuous functions.(Li-Xin,Wang 1994)

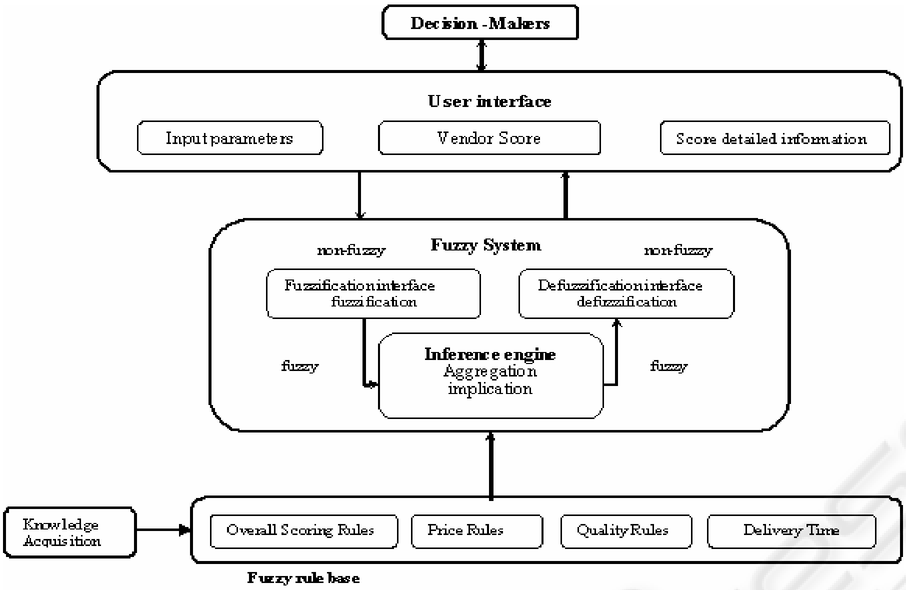

Figure 1: Architecture of Fuzzy Expert Decision Support System for Vendor Selection.

Most common fuzzy systems are: pure fuzzy systems, Takagi-Sugeno-Kang (TSK) and fuzzy system with fuzzifying and defuzzifying parts(Li-Xin Wang, 1994) .Since in the system developed in this paper the input and output are real numbers, the last kind is used. This system has a fuzzifier module in the input that changes the real numbers to fuzzy sets and a defuzzifier module in the output that changes the fuzzy sets to real numbers. The architecture of the system is composed of three main blocks as shown in figure 1.

A-Fuzzy inference engine: A program which analyzes the rules and knowledge aggregated in the database and finds the logical result. There are different selection for the fuzzy inference engine depending on the aggregation, implication and operators used for s-norm and t-norms (Li-Xin Wang, 1994)

B- User Interface: Users of this system are organizational decision makers that enter the real number of all variables via user interface. Also, user interface shows the result scoring. **C-Fuzzy rule base:** Experts' experience is used to build up the fuzzy rules. These rules are conditional statements and can be represented as "IF x is Xi and y is Yi and … THEN o is Oi" Where x and y are linguistic input variables. Xi and Yi are possible linguistic values for x and y; respectively.

4 DESIGN OF THE FUZZY EXPERT SYSTEM

The goal of a fuzzy expert DSS is to take in subjective, partially true facts randomly distributed over a sample space, and build a knowledge-based expert system to produce useful decisions(Vadiee N, 1994). The overview of the framework is shown in Fig 2.There are 7 fundamental Steps in the development of a fuzzy expert DSS. Details of these Steps are as follows:

4.1 Identification and Analysis of the Problem

As mentioned above, in many bids in different organizations the winner is selected just by the price factor and other important factors such as 'quality' and 'delivery time' are not considered.

4.2 Identification of Critical Factors and Membership Functions

This Step involves the compilation of a list of critical factors based on a literature review and in depth interviews with expert people who are involved in the procurement and bid evaluation process. This survey shows that there are three importance factors for vendor selection which are of great customer consideration. They are price, quality and delivery time.

4.3 Fuzzy Rules Construction

Fuzzy expert DSS makes decisions and generate output values based on knowledge provided by the designer in the form of IF _condition_ THEN _action_ rules. The rule base specifies qualitatively how the output parameter "overall rating" of the vendor proposal is determined for various instances of the input parameters of "price", "quality" and "delivery time".There will be nine rules out of our depth interviews as below:

Rule 1: IF "Wanted Price" is cheap AND "Vendor Price" is cheap THEN "Price Matching" is high.

Rule 2: IF "Wanted Price" is cheap AND "Vendor Price" is moderate THEN "Price matching" is medium.

Rule 3: IF "Wanted Price" is cheap AND "Vendor Price" is high THEN "Price matching" is low.

Rule 4: IF "Wanted Price" is moderate AND "Vendor Price" is cheap THEN "Price matching" is medium.

Rule 5: IF "Wanted Price" is moderate AND "Vendor Price" is moderate THEN "Price matching" is high.

Rule 6: IF "Wanted Price" is moderate AND "Vendor Price" is expensive THEN "Price matching" is medium.

Rule 7: IF "Wanted Price" is expensive AND "Vendor Price" is low THEN "Price matching" is low.

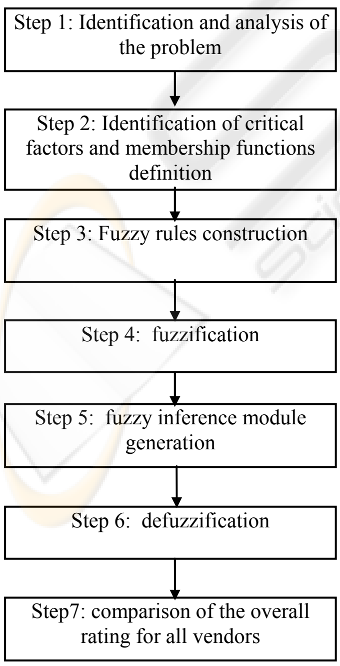

Figure 2: Fuzzy Inference Process for vendor selection.

Rule 8: IF "Wanted Price" is expensive AND "Vendor Price" is moderate THEN "Price matching" is medium.

Rule 9: IF "Wanted Price" is expensive AND "Vendor Price" is expensive THEN "Price Matching" is high.

We will have the same inference for "quality" and "delivery time".

4.4 Fuzzification

Fuzzification refers to the process of taking a crisp input value and transforming it into the degree required by the terms(E.W.T. Ngai., 2003). The "fuzzified" values are determined by intersecting the input value to the fuzzy membership function. In the present study triangular membership functions have been used to define the fuzzy sets for the linguistic values of "price", "quality" and "delivery time". The same triangular membership functions have been defined for "wanted Price", "wanted quality" and "wanted delivery time". The membership function of "price matching" indicates the degree of matching in price between "price" and the customer's "wanted Price". It takes "low", "medium" and "expensive" as its linguistic terms. The same approach is used to define "quality matching" and "delivery time matching". Due to the fact that all input values are normalized, fuzzification input will be between 0 and 1. For instance, an input value of "price" .4 results in a degree of membership in the set labeled "cheap" of 0.25 and a degree of membership in the set labeled "medium" of 0.75 (see Fig. 3)

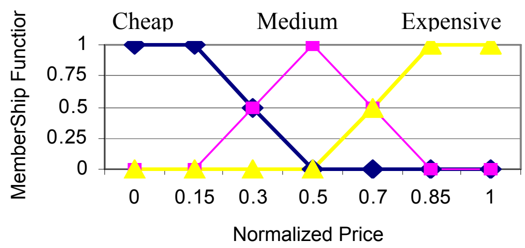

Figure 3: Fuzzy Membership Function for Price.

4.5 Fuzzy Inference Generation

Fuzzy inference is guided by the fuzzy rules. The standard max–min inference algorithm was used in the fuzzy inference process, as it is a commonly used fuzzy inference strategy (E.W.T.Ngai., 2003).Mamdani inference is used as equation 1:

$$\mu_B = \underset{i=1}{\overset{M}{Max}} \left[\underset{x \in U}{Sup} \min \left[\mu_A(x), \mu_A(x_1), \ldots \mu_A(x_n), \mu_B(y) \right] \right] \quad (1)$$

In the max–min composition fuzzy inference method, the min operator is used for the AND conjunction (set intersection) and the max operator is used for the OR disjunction (set union) in order to evaluate the grade of membership of the antecedent clause in each rule.

4.6 Defuzzification

When the inference process is complete, the resulting data for each output of the fuzzy classification system are a collection of fuzzy sets or a single, aggregate fuzzy set. The process of computing a single number that best represents the outcome of the fuzzy set evaluation is called defuzzification (E.W.T. Ngai., 2003). There are several existing methods that can be used for defuzzification. These include the methods of maximum or the average heights methods, and others. These methods tend to jump erratically on widely non-contiguous and non-monotonic input values(Diego, 1999). We chose the centroid method, also referred to as the “center-of-gravity (COG)” method, as it is frequently used and appears to provide a consistent and well-balanced approach. (Klir ,G.j.T.A ,1998).
For each output using this defuzzification method, the resultant fuzzy sets are merged into a final aggregate shape and the centroid of the aggregate shape computed.

4.7 Comparison of the Overall Rating for All Vendors

The overall ratings for all vendors are obtained by passing measures of their initial factors and weightings through the proposed fuzzy logic model. The final score is calculated via defuzzification. The system finally ranks all vendors according to their final scores and displays them in descending order.

5 IMPLEMENTATION AND EVALUATION OF THE FUZZY EXPERT DSS FOR VENDOR SELECTION

Considering the fact that the system should be capable of evaluating all bids whether big or small, the ‘highest price’, ’highest quality’ and ‘longest delivery time’ are used for normalizing inputs. Thus, the designed fuzzy system will have inputs between 0 and 1. For using the same system for all bids in all projects we define a weigh for each of the factors price, quality and delivery time and the final score that is a number between 0 and 1 will be the average of the system outputs considering the factors.

A prototype system is designed by use of Matlab fuzzy toolbox. Once the prototype system is built, testing and evaluation of the prototype system can be performed. The designed system was tested for 10 bids in OIEC for different bids. An example is shown in table 1 for a bid evaluation. In this example vendor3 has the most score and will be the winner of the bid. In this example as it is clear although vendor2 has less offered price, considering the whole factors together vendor3 will be the best selection.
Comparison of outcome with the decision of transaction committee shows that the system works properly and can be used instead of the transaction committee. Evaluation is achieved through interviews with the experts and users. We particularly asked the potential users about the effectiveness and the usability of the prototype system. Also we asked them to tell us what they considered to be the strengths and weaknesses of the prototype system, and how it should be improved. From fifteen interviews, 12 agreed that the proposed expert system is seen to be a promising system for supporting the selection of right vendor based on the positive results of its evaluation and three of them needed more time for more careful evaluations.

Table 1: An Example of the bid evaluation in the fuzzy expert decision support system.

Bid Evaluation		Price(q_i =7)	Delivery (q_i =4)	Quality (q_i =5)	Price Match	Delivery Match	Quality Match	Overall Score
Vendor1	Offered	145,555,050	14 weeks	6	.71	.564	.837	.7131
	Normalize	.7661	.56	.8571				
Vendor2	Offered	131,211,253	25 weeks	5	.91	.439	.595	.6938
	Normalize	.6906	1	.7143				
Vendor3	Offered	141,022,800	7 weeks	5.5	.76	.781	.686	.799
	Normalize	.7422	.28	.7857				
Vendor4	Offered	190,000,000	10 weeks	7	.51	.623	1	.6913
	Normalize	1	.4	1				
Wanted	Wanted	130,000,000	8 weeks	7	---	---	---	---
	Normalize	.6842	.32	1				

6 CONCLUSIONS

This paper has described a new method for design of a fuzzy expert DSS, which is used to assist companies by facilitating vendor selection. Three critical factors for vendor selection which are above all considerable for the customer are price, quality and delivery time. The designed system evaluates the degree of match between vendor offer and customer need and considering the importance of each factor in each bid the final score of each vendor is determined. Comparing this system with the conventional one, the new system is much less time consuming and the need to have different transaction committee meetings for decision making is omitted. Performance evaluation is done in a case study in a lead oil company (OIEC) in Iran using expert validation and prototype testing. The results of the prototype evaluation are satisfactory and support the view that the system has performed its functions as expected.

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