Fuzzy Evaluation Method for Project Profitability

Rekik Ali, Gabsi Mounir, Valentina Emilia Balas and Masmoudi Nissen

Abstract The problem of the project management is performed with the optimization task under uncertainty and subject to real-world constraints. We use the probability theory and insufficiently proved methods, due to unavailable data indeed we need different methods for a best way to evaluate uncertainty. One of these approaches is based on the application of the fuzzy sets theory. Since its inception in 1965, the theory of fuzzy sets has advanced in a variety of ways and in many disciplines. Applications of this theory can be found, for example, in artificial intelligence, computer science, medicine, control engineering, decision theory, expert systems, logic, management science, operations research, pattern recognition, and robotics. This paper proposes a fuzzy decision making approach for project selection problem under uncertainty. An evaluation is provided as an illustration of the proposed approach. In the conclusion, we show how this method can help decision makers in the selection of appropriate project based on their profitability.

Keywords Fuzzy logic · Project management · Project selection · Uncertainty

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N. Shakhovska (ed.), *Advances in Intelligent Systems and Computing*,
Advances in Intelligent Systems and Computing 512,
DOI 10.1007/978-3-319-45991-2_2

1 Introduction

Project selection under uncertainty has become an important research topic in project management [1, 6]. In this context, Markowitz [10] based on the variance of project returns as a risk measure for the optimal project choice, introduced the so-called mean-variance model. Companies should be well advised to use the different management project concepts. Today, many organizations are faced with the problem of the project selection and the resources allocation in order to create an optimal decision during the project selection. Among the various models of project selection, we can mention those based on multicriteria decision support system, nonlinear, stochastic [18], linear, dynamic [12], fuzzy programming [14], and fuzzy decision trees [13].

Existing scientific and methodological approaches have the following disadvantages [15]:

- Absence of generic risk assessment model that is invariant to the input parameters;
- The results of mathematical modeling of the risk assessment require clearer graphical interpretation.

The known models that aid in determining the degrees of risk are based on the evaluation of a single parameter (criterion), which leads to the impossibility of comparing the relative risk estimations for two or more parameters simultaneously.

The fuzzy sets theory is used to handle uncertain information in multiple systems, such as planning support systems and the decision support in the project selection management systems. This theory offers an alternative framework for dealing with uncertainty of the selection project parameters. Approximations of these parameters can be estimated by experts based on their skills [5].

Buckley was one of the first authors who used the fuzzy sets in finance [2]. He used them to represent the fuzzy present value, the fuzzy future value, and the fuzzy internal rate of return.

Yu et al. have proposed a decision analysis tool based on several criteria for assessing credit risk from the theory of fuzzy sets [16]. Reveiz and Leon [11] have studied the operational risk in using the fuzzy inference system to take into account the complex interaction and the non-linearity of these elements. Moreover, Leon and Machado [7] have proposed an index established by using an inference system based on fuzzy logic and allowing to make a general assessment of the relative importance of a systematic financial institution.

The objective of this paper is to develop a fuzzy model in order to optimize the innovative project selection under risk. The fuzzy set theory is used with the aim to describe and reduce uncertainty in the information project [14].

Project selection problems have been discussed in a many management tasks such as R&D [8, 9], quality management and environmental management [4].

The objective of this paper is to develop a fuzzy model in order to optimize the project profitability under risk. The fuzzy set theory is used with the aim to describe and reduce uncertainty in the project selection.

The paper is organized as follow: Sect. 2 describes the basic concepts of the fuzzy sets, in this case we introduce the notion of membership functions, the different types of fuzzy numbers and the operations that we can apply on the fuzzy sets. Section 3 represents an application of fuzzy logic to solve a selection project problem by using the inference engine proposed by Mamdani. After that, we introduce the input and output parameters of the proposed approach as well as the membership functions for all model parameters, the simulating results obtained according the inference steps. We analyze the experimental results and discuss the parameters which have an impact on our approach in the Sect. 3.

2 The Basic Concepts of the Fuzzy Logic

The fundamental characteristic of a classical set is the abrupt boundary between two categories of elements: those that belong to the set and those that do not belong to it, since they belong to its complement. In this case, the membership relation is represented by a function which takes μ truth values in the pair $\{0, 1\}$ [17].

Hence, the membership function of a conventional set A is defined by:

$$\mu_A(x) = \begin{cases} 0, & if \quad x \notin A \\ 1, & if \quad x \in A \end{cases} \tag{1}$$

In contrast, a fuzzy set is any set which allows its elements to have different membership grades (membership function) in the interval [0,1]. For a classical set X, a fuzzy set is defined as follows:

$$A = \{(x,\ \mu(x)),\ x \in X\}. \tag{2}$$

The grade of the elements x in relation with the fundamental set X is defined by the membership function $\mu_A(x)$.

For each element having a value of 0 means that the member is not included in the given set, on the contrary if the value is 1 means full member included. Values in the range from 0 to 1 characterize the fuzzy members.

We suppose that, A and B are two fuzzy sets, then we define the membership function as follow:

$$\mu_{A \cup B}(x) = \max(\mu_A, \mu_B) \tag{3}$$

$$\mu_{A \cap B}(x) = \min(\mu_A, \mu_B) \tag{4}$$

$$\mu_{\overline{A}}(x) = 1 - \mu_A(x). \tag{5}$$

when $X = R$ is a set of real numbers, we talk about fuzzy numbers. In the practical field, it is more convenient to work with fuzzy numbers of a special type: triangular and trapezoidal.

The trapezoidal membership function is given by the formula:

$$\mu_A(x) = \begin{cases} 0, & for \quad x < a_1 \quad or \quad x > a_4 \\ \frac{x-a_1}{a_2-a_1}, & for \quad a_1 \le x < a_2 \\ 1, & for \quad a_2 \le x \le a_3 \\ \frac{a_4-x}{a_4-a_3}, & for \quad a_3 < x \le a_4, \end{cases} \tag{6}$$

where $a_1 \le a_2 \le a_3 \le a_4$.

For trapezoidal membership functions, we use the notation: $A = (a_1, a_2, a_3, a_4)$. In the case where $a_2 = a_3$, we obtain a triangular membership function. Let us notice that for triangular membership functions, we use the notation: $A = (a_1, a_2, a_3)$ (Fig. 1).

Let us notice that fuzzy numbers can be added, subtracted, multiplied and divided, as well as ordinary numbers. Moreover, the operations on fuzzy numbers are determined by the following expansion principle.

Let $c = f(a, b)$ be an arbitrary numerical function. For example, concerning the addition operation, $f(a, b) = a + b$. Then, the value of $C = f(A, B)$ of this function with the fuzzy numbers A and B has a membership function which is calculated by the following formula:

$$\mu_C(x) = \sup \min(\mu_A(x), \mu_B(y)), \tag{7}$$

And their α—cuts are deduced according to the following formula:

$$C^\alpha = \{c = f(a, b) | a \in A^\alpha, b \in B^\alpha\}. \tag{8}$$

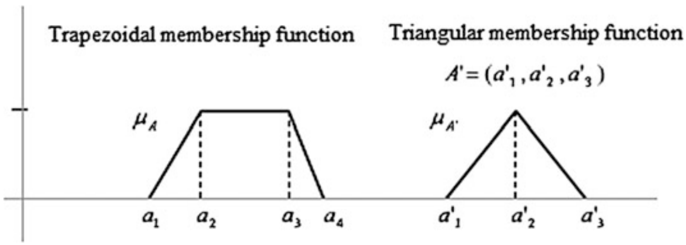


Fig. 1 Trapezoidal and triangular membership functions

3 Application of Fuzzy Logic to the Project Selection

Based on the inference engine proposed by Mamdani, our method represents the certainty degree about the coincidence of metadata elements and user's preferences. The typical structure of our method contains the following units: fuzzification, defuzzification, and an interface system (Fig. 2).

- *Fuzzification interface*: simplify modifies the inputs so that they can interpreted and compared to the rules on the rule base. The fuzzifier determines the degree to which they belong of each input values to each of the fuzzy sets based on the membership functions.
- *Rule base*: holds the knowledge, in the form of a set of rules, of how best to control the system.
- *An inference system*: Inference mechanism allows mapping given input to an output using fuzzy logic. It uses all pieces described in previous sections: membership functions, logical operations and rules. They vary in ways of determining outputs. Each rule is represented in the following form:

$$if\ X_1\ is\ A_1\ and \ldots and\ X_n\ is\ A_n\ then\ Y\ is\ B$$

  with X_i being input and Y output linguistic variables, and with A_i and B being linguistic labels with fuzzy sets associated defining their meaning.
- *A defuzzification interface*: is allowed to find one single crisp value that summarises the fuzzy set. There are several methods to solve this machanizm, and the centroid method is considered as one among them. The centroid method simply the weighted average of the output membership function.
  It can be determined by the following formula:

$$\bar{X}(centroid) = \frac{\int_b^a x\mu(x)dx}{\int_b^a \mu(x)dx}$$

  where [a, b] is the interval of the aggregated membership function.

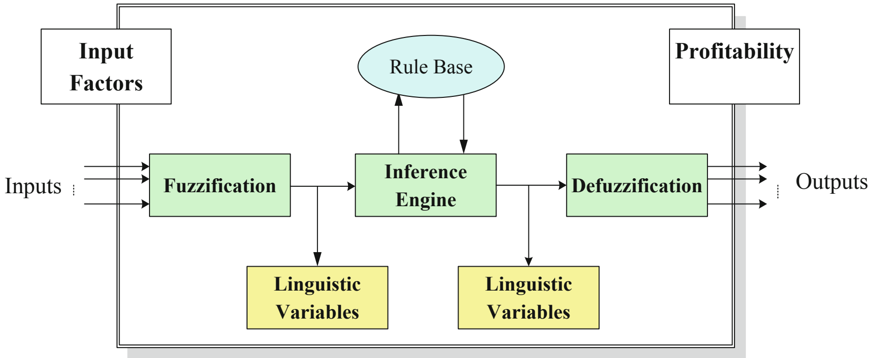


Fig. 2 A typical structure of a fuzzy inference system

3.1 The Proposed Approach

As an uncertainty assessment of the project selection it is advisable to take a parameter of profitability P_{Prof} [3]. The input parameters in this case are obtained by statistical analysis of the average value Q_{RR} (rate of return by introducing an innovative project), economic effects expected using more productive technologies T, for example, the performance degree in the existing equipments, which would produce a greater effect, and as output parameter we have the estimated value of the project's profitability P_{Prof}.

We present the membership functions of the triangular fuzzy numbers $Q_{RR} = [Q_{\min}, Q_0, Q_{\max}]$ and $T = [T_{\min}, T_0, T_{\max}]$ as follow:

$$\mu_Q(x) = \begin{cases} \frac{1}{Q_0 - Q_{\min}} x + \frac{Q_{\min}}{Q_{\min} - Q_0}, & Q_{\min} < x < Q_0; \\ \frac{1}{Q_0 - Q_{\max}} x + \frac{Q_{\max}}{Q_{\max} - Q_0}, & Q_0 < x < Q_{\max}; \\ 0, & (x < Q_{\min}) \vee (x > Q_{\max}). \end{cases} \quad (9)$$

$$\mu_T(x) = \begin{cases} \frac{1}{T_0 - T_{\min}} x + \frac{T_{\min}}{T_{\min} - T_0}, & T_{\min} < x < T_0; \\ \frac{1}{T_0 - T_{\max}} x + \frac{T_{\max}}{T_{\max} - T_0}, & T_0 < x < T_{\max}; \\ 0, & (x < T_{\min}) \vee (x > T_{\max}). \end{cases} \quad (10)$$

The first input indicate the rate of return by introducing an innovative project (Q), his universe of discourse be [0–100]. The second indicate the economic effects expected using more productive technologies (T), its universe of discourse be [0–100]. Both two fuzzy numbers are expressed by a set of terms {low, medium, high}. As result, the output variable characterizes the project profitability (P).

Graphically, the membership functions for each input variable are shown in Figs. 3, 4 and output variable in Fig. 5.

Before the creation of the rule databases, the number of linguistic terms can be changed.

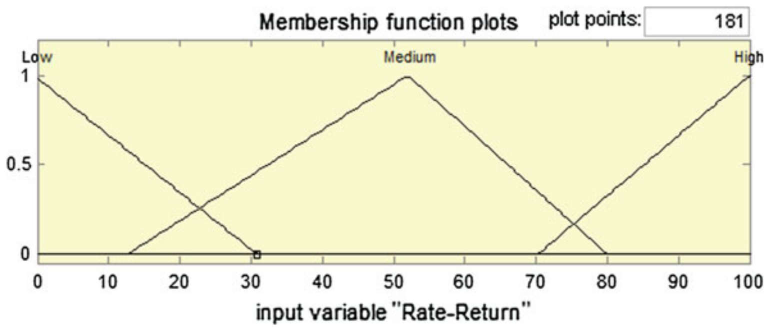


Fig. 3 Membership functions for the rate of return by introducing of an innovative project

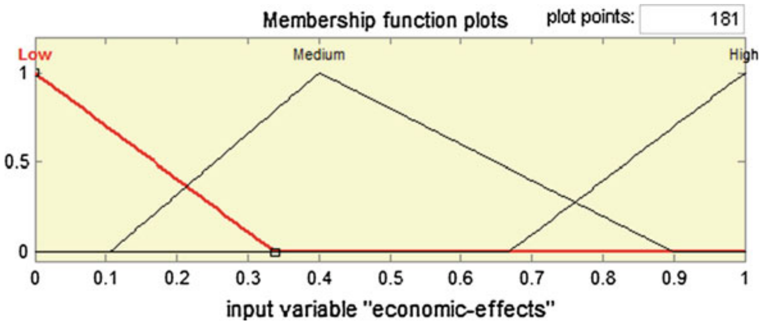


Fig. 4 Membership functions for the economic effects expected using more productive technologies

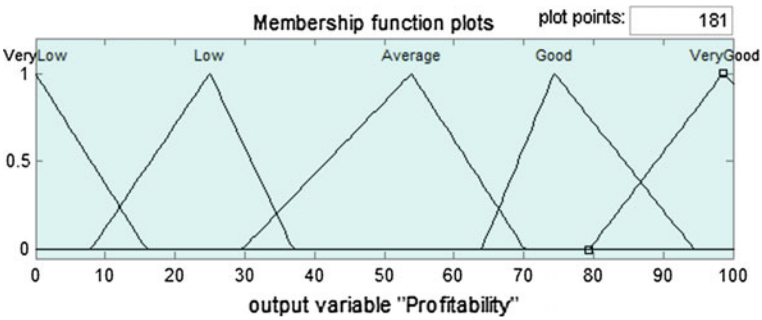


Fig. 5 Fuzzy membership functions for the project profitability

To simulate consolidated factors, the expert must establish a fuzzy knowledge base of Mamdani type. Antecedents may be joined by OR; AND operators (Fig. 6).

In our method we consider the classical engine developed by Mamdani based on the minimum t-norm as conjunctive and implication operators, the defuzzification method is the centroid. The inference engine taking into account the membership functions obtained according the inference steps (Fig. 7).

1. If (Rate-Return is Low) and (economic-effects is Low) then (output1 is VeryLow) (1)
2. If (Rate-Return is Low) and (economic-effects is Medium) then (output1 is VeryLow) (1)
3. If (Rate-Return is Low) and (economic-effects is High) then (output1 is Low) (1)
4. If (Rate-Return is Medium) and (economic-effects is Low) then (output1 is Low) (1)
5. If (Rate-Return is Medium) and (economic-effects is Medium) then (output1 is Average) (1)
6. If (Rate-Return is Medium) and (economic-effects is High) then (output1 is Average) (1)
7. If (Rate-Return is High) and (economic-effects is Low) then (output1 is Average) (1)
8. If (Rate-Return is High) and (economic-effects is Medium) then (output1 is Good) (1)
9. If (Rate-Return is High) and (economic-effects is High) then (output1 is VeryGood) (1)

Fig. 6 Examples of rules

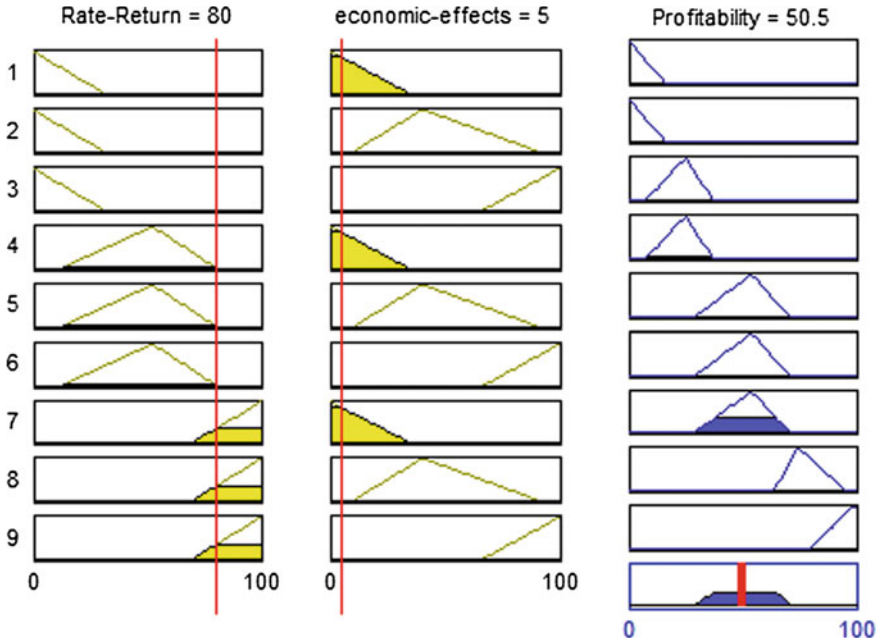
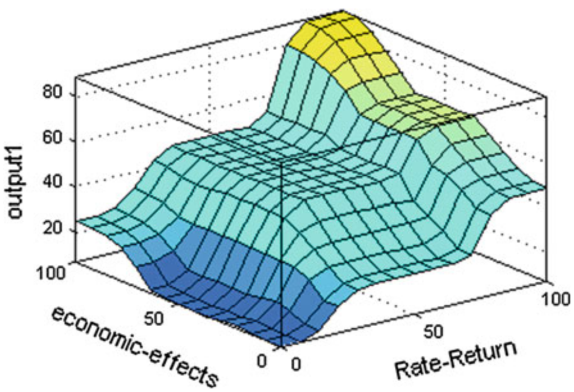


Fig. 7 Operation mode the inference system

Fig. 8 Characteristic surface of the system



In Fig. 8 there is shown a characteristic surface for the rules database of the fuzzy system that characterize the project profitability.

Many tools are used to develop applications based on the fuzzy logic principle. We can mention the MATLAB software package, which is considered the most famous. Also there is a FUZZY-TECH software not yet become frequently used as MATLAB [7].

4 Modeling Results

To estimate the project profitability at different values of the input data we represent the various results in the Table 1.

As modeling results, we received the following values of project profitability:

- For alternative variant 1: 5.18 balls;
- For alternative variant 2: 23.2 balls;
- For alternative variant 3: 19.3 balls;
- For alternative variant 4: 23.3 balls;
- For alternative variant 5: 50.5 balls;
- For alternative variant 6: 51.2 balls;
- For alternative variant 7: 5.99 balls;
- For alternative variant 8: 32.5 balls;
- For alternative variant 9: 35.4 balls;
- For alternative variant 10: 48.6 balls;
- For alternative variant 11: 51 balls;
- For alternative variant 12: 51.1 balls;
- For alternative variant 13: 78.4 balls;
- For alternative variant 14: 84.4 balls;
- For alternative variant 15: 91.2 balls;
- For alternative variant 16: 92.8 balls.

Table 1 Simulating results

Alternative variants	Rate of return by introducing an innovative project (Q_{RR})	Economic effects expected using more productive technologies (T)	Project profitability (P_{Prof})
1	5	5	5.18
2	5	90	23.2
3	25	5	19.3
4	50	5	23.3
5	80	5	50.5
6	100	5	51.2
7	5	25	5.99
8	20	50	32.5
9	20	90	35.4
10	30	70	48.6
11	40	50	51
12	50	50	51.1
13	80	50	78.4
14	80	80	84.8
15	80	90	91.2
16	100	90	92.8

According to the obtained results we can see that the estimation value of project profitability 92.8 balls (the better variant) is the 16-th alternative variant, and the worst one is the first alternative variant: 5.18 balls. And we can conclude that if the value of Q is low and the value of T is good, the result value P is low, when we increase the value of Q, the result P increases. The values of P in this case are strongly related to that of Q compared to T, and we can see the different results in the following alternative variants:

- In the alternative variant 2 we have as project profitability result $P_{Prof} = 23.2$ taking into consideration $Q_{RR} = 5$ and $T = 90$.
- In the alternative variant 6 we have as project profitability result $P_{Prof} = 51.2$ taking into consideration $Q_{RR} = 100$ and $T = 5$.

5 Conclusion

The application of the fuzzy set theory provides a new method for the evaluation and the project selection based on their profitability. In this paper, we have developed a fuzzy model to solve a project selection task and we have determined the influent factor that maximizes the project profitability value based on the rate of return by introducing an innovative project and the performance degree in the existing equipments in order to achieve the strategic objective. As a result, the decision makers have now a better possibility for describing the information uncertainty in the project, by applying the fuzzy set theory. We used the fuzzy sets to determine the project qualitative characteristics, and to transform them into a mathematical model. In conclusion, our proposed model can provide an optimal project selection for decision makers in an uncertain environment. In the future research we could incorporate some criteria in order to make more accurate analysis.

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http://www.springer.com/978-3-319-45990-5

Advances in Intelligent Systems and Computing
Selected Papers from the International Conference on
Computer Science and Information Technologies, CSIT
2016, September 6-10 Lviv, Ukraine
Shakhovska, N. (Ed.)
2017, VII, 325 p. 111 illus., 47 illus. in color., Softcover
ISBN: 978-3-319-45990-5