The Task of Assessing the Effectiveness of University Employees in Fuzzy Decisions*

Natalia V. Apatova [1[0000-0003-4066-3821]], Irina N. Ostapenko [1[0000-0003-1946-7586]] and Roman S. Usenko [1[0000-0003-0095-1183]]

[1]V.I. Vernadsky Crimean Federal University
Russian Federation, Republic of Crimea, Simferopol
i.n.ostapenko@mail.ru

Abstract. Talented employees, their intelligence, creativity, and ability to create something new are some of the main competitive advantages that determine the success of an organization's development. Due to dynamic changes in the labor market, the expectations and requirements of companies for employees are changing. Human skills and abilities have come to the fore in social production. Any manager, based on certain indicators, can evaluate his subordinates and their ability to quickly and efficiently complete the task. Quite often, qualitative indicators assessed by experts are used to assess the effectiveness of activities. The article discusses the possibilities of using the apparatus of fuzzy mathematics to assess the effectiveness of university employees. The study describes a method of a quantitative assessment of their effectiveness, which allows for competent management of the university. The main advantage of fuzzy models, in comparison with mathematical models based on classical mathematical tools, is associated with the possibility of using significantly smaller amounts of input data about the system for their development. In this case, the input data can be approximate, indistinct. The theory of fuzzy sets allows you to formally describe non-strict fuzzy concepts and provides an opportunity to understand the processes occurring in conditions of a high degree of uncertainty.

Keywords: Educational Organization of Higher Education, Employee Performance Evaluation, Fuzzy Mathematics, Membership Function.

1 Introduction

The modern economy is characterized by an extremely fast pace of changes in the business environment caused by technological innovations, the intensive development of new industries and activities, changes in consumer needs, and increased competition. In these conditions, the role of personnel increases, their ability to develop their

* Copyright 2021 for this paper by its authors. Use permitted under Creative Commons License Attribution 4.0 International (CC BY 4.0).

CEUR-WS.org/Vol-2914/paper2.pdf

labor potential, and use potential opportunities in the world of work to achieve the goals of the enterprise.

Talented employees, their intelligence, creativity, and ability to create something new are some of the main competitive advantages that determine the success of an organization's development. Due to the dynamic changes in the labor market, the expectations and requirements of companies for employees are changing. Human skills and abilities came to the fore in social production.

Any manager, based on certain indicators, can evaluate his subordinates and their ability to quickly and efficiently perform the assigned task. Quite often, to assess the effectiveness of activities, qualitative indicators are used, which are expert assessments.

The purpose of the article is to consider the methodology for the quantitative assessment of the effectiveness of university employees, based on the use of the apparatus of fuzzy mathematics.

2 Main part

The problems of human capital development and the assessment of the effectiveness of investments in human capital, in particular in education, were studied by such scientists: G.S. Becker [1], I. Šlaus and G. Jacobs [2], J. Mincer [3], R.J. Barro [4], V.M. Porokhnya [5], N.R. Kelchevskaya, E.V. Shirinkina [6], and others.

Recently, fuzzy logic methods have been widely used to assess the effectiveness of employees [7-11]. The methodology proposed in the article helps to assess the effectiveness of employees using these methods. The main advantage of fuzzy models proposed for use, in comparison with traditional mathematical models, is associated with the possibility of using much smaller amounts of input data about the system for their development. In this case, the input data can be approximate, indistinct. The theory of fuzzy makes it possible to formally describe non-strict fuzzy concepts and provides an opportunity to understand the processes taking place in conditions of a high degree of uncertainty.

A fuzzy set is a set of elements of an arbitrary nature, concerning which it is impossible to assert with complete certainty whether this or that element of the set under consideration belongs to this set or not. Fuzzy models are based on a system of rules, which is usually formed based on expert knowledge about the object of research. This approach is called knowledge acquisition and is effective if the expert has full knowledge of the system and can express this knowledge in verbal form and convey it.

The ability to draw on expert knowledge in this procedure is critical to success. However, in the case of measuring the level of creativity, the expert's knowledge is often incomplete, inaccurate, poorly formulated, and may even contain contradictions. Also, this knowledge is subjective, that is, the opinions of individual people about the functioning of the same information system may differ. Following the methodology for assessing the indicator of interest to us, using fuzzy modeling, it is possible to develop an expert system. At the output of the expert system, according to the input

data, an estimate of the indicator of interest to us will be obtained based on the criteria that determine it.

Let us consider the issue of modeling the effectiveness of an employee's activity, more precisely, the effectiveness of the employee's return, to the educational organization of higher education using an expert system developed using the software tools of the MATLAB package. By the described approach, it is necessary to develop an expert system, which will have to make it possible to assess the effectiveness of an employee of the university based on the given input variables and their subjective assessments.

Following this approach to assessing the effectiveness of an employee using fuzzy modeling, it will be necessary to develop an expert system. It will have to allow evaluating the employee's performance based on the given input variables and their subjective assessments.

When assessing the effectiveness of an employee, the following factors can be determined that affect the parameter being assessed:

- Professional competence level (F1)
- Self-education (F2)
- Employee age (F3)

These factors can be used as input variables, and their level can be set expertly based on the results of testing according to the method presented in Table 1.

Table 1. Levels of input variables and types of term sets.

Input variables	Type of term set
Professional competence level (F1)	Very low (VL)
	Low (L)
	Medium (M)
	Above average (AA)
	High (H))
Self-education (F2)	Occasionally (OS)
	Regularly (R)
Employee age (F3)	Young (YN)
	Medium (M)
	Mature (F)

The input variable "Professional competence level (F1)" should be presented in points on a scale from 0 to 100 and can be represented as 5 term sets with the following gradation:

- Very low (0-20);
- Low (20-40);
- Medium (40-60);
- Above average (60-80);
- High (80-100).

For the problem being solved, for the input variable "The level of professional competencies (F1)", it is necessary to choose a trapezoidal membership function, which is a generalization of the triangular one and allows you to determine the kernel of a fuzzy set in the form of an interval. The specified parameters of the input variable "Level of professional competence (F1)" in the editor of membership functions are shown in Figure 1.

The input variable "Self-education (F2)" (which includes work on their level of scientific and educational qualifications, including official refresher courses) should be represented as 2 term sets with the following gradation:

– Episodic (1)
– Regular (2).

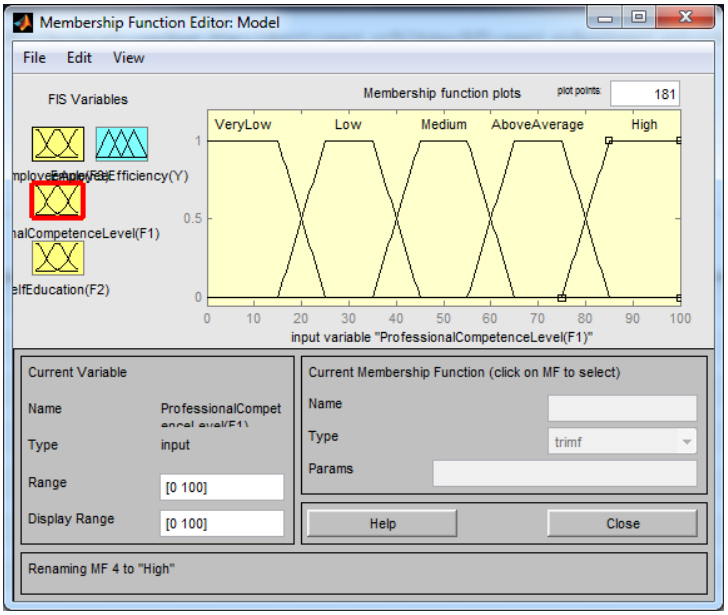

Fig. 1. Parameters of the input variable "Level of professional competence (F1)" in the editor of membership functions.

For the problem being solved for the input variable "Self-formation (F2)" it is possible to choose a sigmoid membership function. This type of function allows you to form membership functions for which the values starting from some value of the argument and up to + (-) infinity are equal to 1.

These functions are useful for specifying linguistic terms such as “low” or “high”. The specified parameters of the input variable "Ca-formation (F2)" in the editor of membership functions are shown in Figure 2.

And, finally, for the problem to be solved for the input variable "Employee age (F3)", it is also necessary to choose a trapezoidal membership function with 3 term sets:

– Young (25-35);
– Medium (35-50);
– Mature (over 50; for example, 50-80).

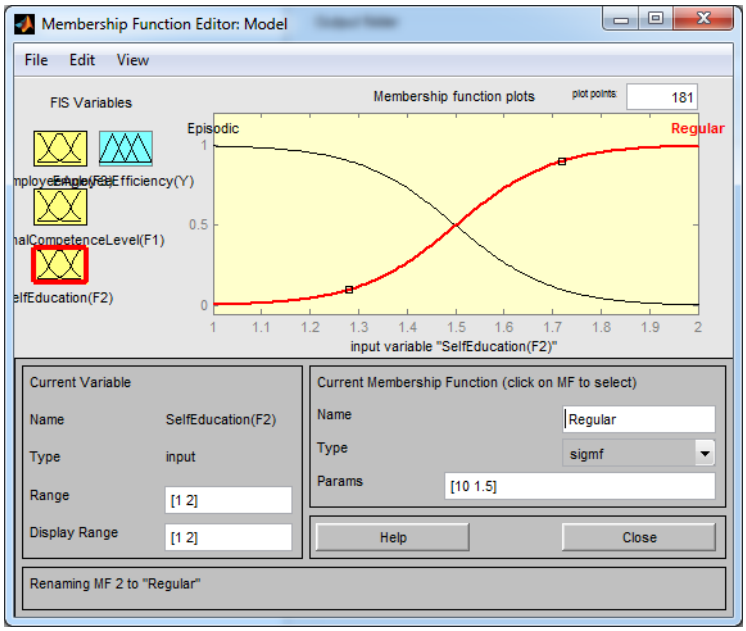

Fig. 2. Parameters of the input variable "Self-formation (F2)" in the editor of membership functions.

The specified parameters of the input variable "Employee age (F3)" in the editor of membership functions are shown in Figure 3. At the output of the expert system, based on the input data, one can obtain, for example, an assessment of the employer's investment in an employee in terms of efficiency. In our case, we will choose Y - the level of "efficiency of return" of the employee from 0 to 1, so that in the future it will be convenient to compare with the result of logistic regression (Table 2).

Table 2. Output variable levels and types of term sets.

Output variable	Term set type
Efficiency performance (Y)	Very low (VL)
	Low (L)
	Average (AV)
	Above average (AA)
	High (H)
	Very high (VH)

The specified parameters of the output variable "Employee efficiency (Y)" in the editor of membership functions are shown in Figure 4.

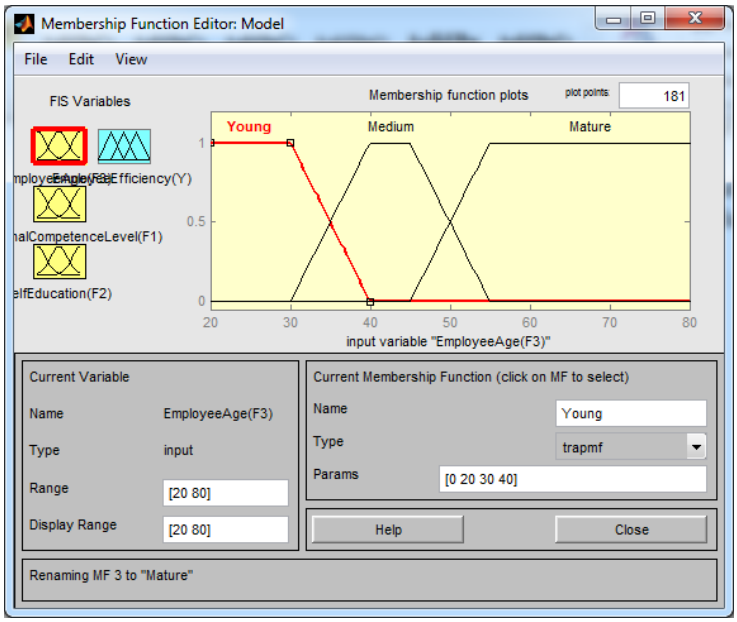

Fig. 3. Parameters of the input variable "Employee age (F3)" in the editor of membership functions.

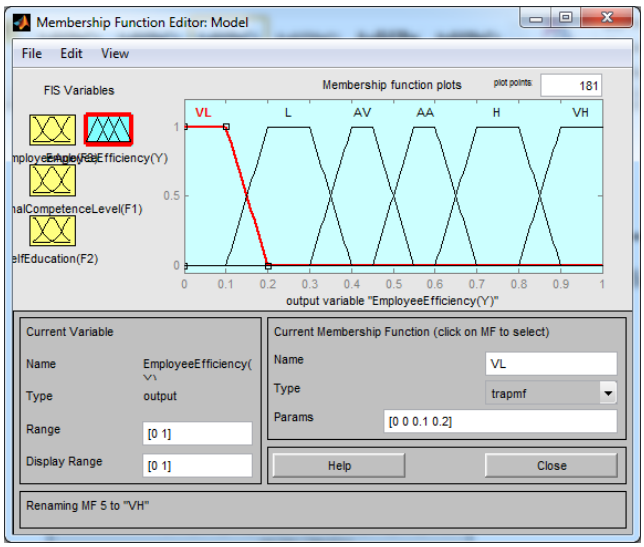

Fig. 4. Parameters of the output variable "Employee efficiency (Y)" in the editor of membership functions.

After determining the types of membership functions for input and output variables and their terms for the developed expert system, it is necessary to set the rules of fuzzy inference.

The level of influence of input variables on the output is described in Table 3.

Table 3. Level of Influence of input variables.

Input Variables	Y
Professional competence level (F1)	High
Self-education (F2)	Medium
Employee age (F3)	Low

To understand how the input variables affect the output, a matrix of fuzzy inference rules should be drawn up. Since we have three input variables with different numbers of gradations, the number of fuzzy inference rules determine by multiplying the number of gradations of input variables, which in our case will be 5 * 2 * 3 = 30. The compilation of fuzzy inference rules by the developed rule base is shown in Figure 5.

As a result of processing the values of the input variables, after the formation of the output fuzzy set and its subsequent defuzzification, a clear value of the output variable will be found.

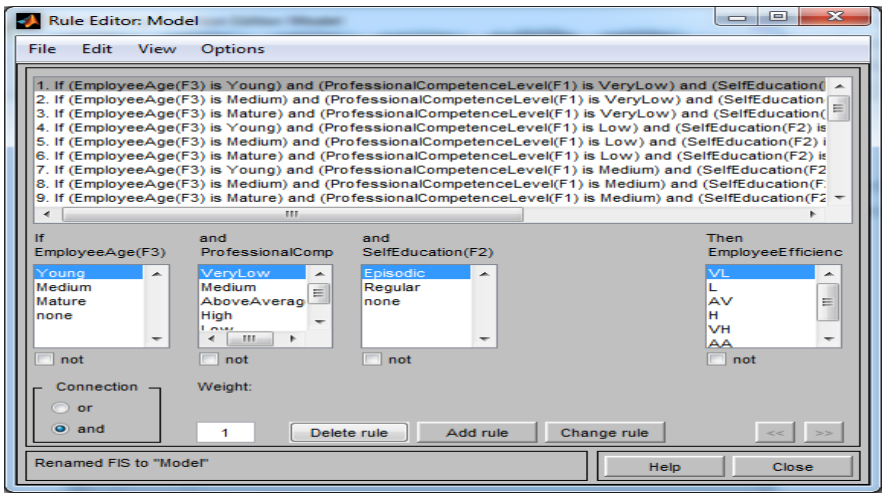

Fig. 5. Drawing up rules for fuzzy inference.

So, suppose that in the course of the expert assessment, the values of three input variables were obtained. These values of the input variables can be set in the Rule Viewer window, and at the same time, the value of the output variable can be obtained at the output. In Figure 6, as an example, the value of the output variable "Employee efficiency (Y)" is found for the following initial values of the input variables:

– The level of professional competencies (F1) - 45;

– Self-education (F2) - 1;
– The employee's age (F3) is 52.

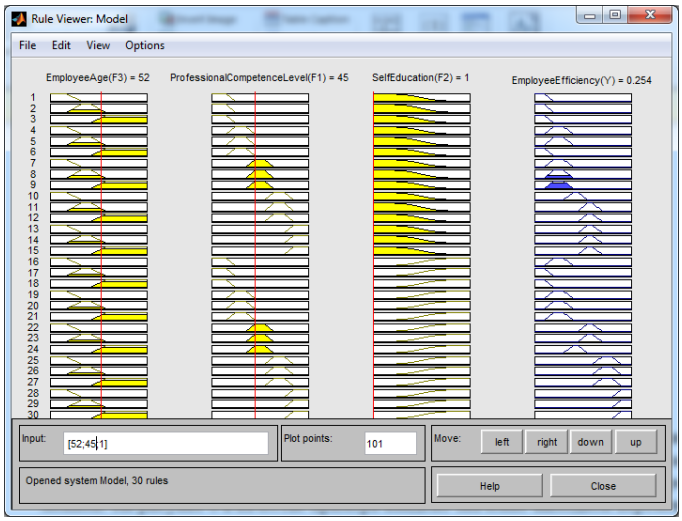

Fig. 6. The result of modeling a fuzzy inference system for given values of input variables

For the given values of the input variables, the expert system evaluates the employee at 0.254 points out of 1.

Similarly, it is possible to obtain the numerical characteristics of the efficiency for all employees, which are presented in Table 4. As can be seen from Table 5, the developed expert system characterizes the employee's efficiency in the range from 0 to 1, while the minimum value is 0.185 and the maximum value is 0.921.

The graphical interface of the MATLAB package allows you to get a graph of the dependence of the output variable on the values of any of the input variables. Figure 7 shows the dependence of the output variable "Employee efficiency (Y)" on the input variable "Level of professional competencies (F1)".

Also, the graphical interface of the MATLAB package allows you to get the surface of the dependence of the output variable when changing two input variables with a fixed value of the third variable. Figure 8 shows the dependence of the output variable "Employee efficiency (Y)" on the level of professional competencies and self-education, at a fixed age of the employee.

Table 4. Assessment of employee performance

№	F1	F2	F3	Y
1	45	1	52	0,254
2	62	2	32	0,699
3	52	2	36	0,570
4	92	2	34	0,912
5	78	2	41	0,784
6	30	1	50	0,185
7	48	1	60	0,251
8	74	2	67	0,749
9	64	1	38	0,507
10	56	2	56	0,478
11	75	1	57	0,577
12	36	1	48	0,218
13	45	2	28	0,571
14	98	2	37	0,914
15	42	1	36	0,254
16	30	2	44	0,250
17	58	2	46	0,620
18	86	2	62	0,921
19	35	2	42	0,250
20	54	1	47	0,253

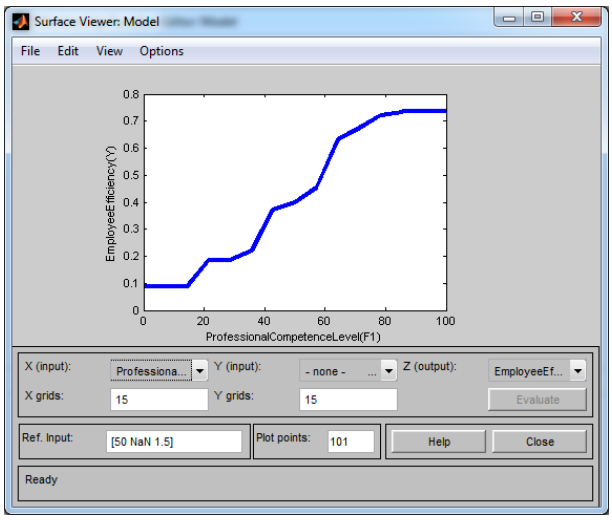

Fig. 7. Dependence of the output variable "Employee efficiency (Y)" on the input variable "Level of professional competencies (F1)".

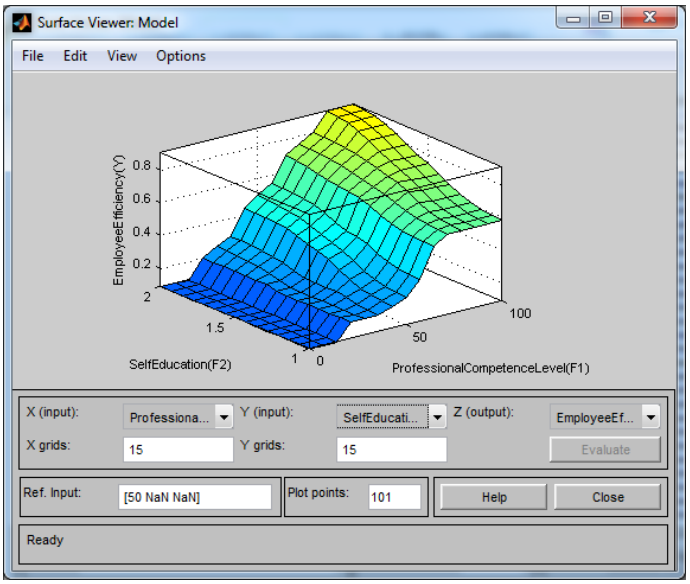

Fig. 8. The surface of the dependence of an output variable on two input variables.

The presented graphs allow us to say that the dependence of the employee's efficiency on the factors determining it, following the compiled rules of fuzzy inference, can be both linear and non-linear.

Having considered the results of Table 4, we can conclude that the effectiveness of an employee from the factors determining it can be obtained numerically using an expert system built on fuzzy logic. However, the described approach can be rather complicated for specialists who do not know how to use fuzzy logic tools.

The simplest way to assess the effectiveness of an employee from the factors that determine it can be the use of a linear regression equation.

For the employee efficiency and input variables calculated using an expert system based on fuzzy logic, the following multiple regression equation can be obtained:

$$Y = -0.2876 + 0.0101F_1 + 0.1769F_2 - 0.0015F_3$$

The resulting equation allows you to calculate the employee's efficiency by specifying the values of the input variables (see Table 5).

Table 5 Regression statistics equation

Feature	Value
Multiple R	0,972
R-square	0,945
Normalized R-square	0,935
Standard error	0,066
Observations	20

Table 5 ("Regression statistics") and table 6 ("Analysis of variance") suggest that the obtained regression equation has fairly high accuracy (R2 = 0.94) and is statistically significant.

Table 6. ANOVA table

	df	SS	MS	F	Significance F
Regression	3	1,20714	0,40238	92,3174	2,58E-10
The remainder	16	0,069739	0,004359		
Total	19	1,276879			

To obtain more accurate results, you can use nonlinear modeling methods based, for example, on the use of neural networks [12].

3 Conclusion

In the context of informatization and digitalization, the value of human capital has increased as a factor in the company's success. The development of new knowledge and the adoption of managerial decisions for business success is the merit of the person. Today, the latest technologies provide a competitive advantage for the organization, but under equal technological conditions, talented employees, their potential, and knowledge are the key to the competitive advantages of the organization.

The approach using the apparatus of fuzzy mathematics in situations of a high degree of uncertainty allows you to operate with high-quality input data. A quantitative assessment of the personality quality under consideration can be useful in assessing the talent, creativity of an individual, and the creative potential of an organization. Assessment of the level of creativity of an individual is the most important stage in assessing the level of talent, the usefulness of an employee for the organization.

The proposed assessment cannot very accurately reflect the phenomenon so difficult to quantify, but it can be useful for monitoring the development of the creative component of intellectual capital. The presented results allow us to say that the dependence of the employee's efficiency on the factors determining it can be obtained numerically using an expert system built on fuzzy logic.

References

1. Becker, G.S.: Human Capital. A Theoretical and Empirical Analysis, with Special Reference to Education. Chicago, University of Chicago Press, 1993.
2. Šlaus, I. and Jacobs, G.: Human Capital and Sustainability. Sustainability, 3(1), 2011, pp. 97–154
3. Mincer, J.: Human Capital and the Labor Market. A Review of Current Research. Educational Researcher, 1989, vol. 18, no.4, pp.27–34.
4. Barro, R.J.: Education and Economic Growth. Annals of Economics and Finance, 2013, vol. 14, P. no.2, pp. 301–328.

5. Porokhnya, V.M.: Intelektual′nyy kapital ekonomichnoho zrostannya: navch. posibn. [Intellectual Capital of Economic Growth: textbook.]. Zaporizhzhya: KPU, 2012. (in Ukrainian)
6. Kelchevskaya, N. R. and Shirinkina, E. V.: Regional Determinants of Effective Use of Human Capital in the Digital Economy. Ekonomika regiona [Economy of Region]. 2019, no.15(2), pp. 465-482 (in Russian)
7. Ostapenko, I.N., Usenko, R.S.: Modelirovaniye pokazatelya urovnya tvorcheskogo razvitiya lichnosti [Modeling an Indicator of the Level of Creative Development of a Person]. Digital economy: information technology and models: monograph. 2018, pp.258-282. (in Russian)
8. Jevšček, M.: Competencies Assessment Using Fuzzy Logic. Journal of Universal Excellence. 2016, no.2, p. 187-202.
9. Houe, R., Grabot, B., Tchuente, G.: Fuzzy Logic In Competence Management. European Society for Fuzzy Logic and Technology: 7th conference. 2011, p.651-656.
10. Macwan, N., Srinivas, S.: Performance Appraisal Using Fuzzy Evaluation Methodology. International Journal of Engineering and Innovative Technology. 2013, no.3, p. 324-329.
11. Krichevskiy, M.L., Martynova, Yu.A.: Instrumenty iskusstvennogo intellekta pri otsenke effektivnosti investitsionnogo proekta [Instruments of Artificial Intelligence in Assessment of Effectiveness of Investment Project]. Kreativnaya ekonomika. 2018, no.12, pp.1105-1118. doi: 10.18334/ce.12.8.39265. (in Russian)
12. Apatova, N.V., Ostapenko, I.N., Usenko, R.S.: Decision-Making on Human Individual Capital Investment. CEUR Workshop Proceedings. 2020.