DOI: https://doi.org/10.15276/hait.05.2022.24
UDC 519.68

Application of fuzzy evolutionary methods for the development of dual-education projects

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ABSTRACT

The article aims to present a method of specialties cases management based on models of system evolution within the framework of a pilot project in institutions of professional pre-higher and higher education of Ukraine for the training of specialists in the dual form of education. The obtained data allowed determining that the methodology of project management can be successfully implemented in Ukrainian dual education. However, the Ukrainian system of dual education still lacks many elements, and some of them cannot be reproduced in the national environment, because the student himself can choose a form of education. The article presents a simulation of the dual education system evolution in a specific specialty in the form of a multicriterial optimization problem. Well-known McKinsey model is adapted to determine the variant of the strategy for managing the dual education system. With the help of such model, the specialties of the educational institution were ranked as candidates for investment according to the criterion of future profit. The trajectory of the specialty evolution has been developed by means of the method for assessing of qualitative factors, such as the attractiveness of the labor market and the competitive status of the educational institution. The inclusion of the specialty evolution trajectory in the integral criteria of the McKinsey model, made it possible to not only establish a competitive status for the current period, but also extrapolate it without significant changes to the entire strategic period to predict the competitive status of a particular specialty. It is proposed to apply a decision support system based on the use of an apparatus of fuzzy sets and fuzzy logic to formalize decision-making in an intelligent system. The using of the fuzzy logic apparatus made it possible to adjust and clarify the strategic positions of each business unit of the dual education project portfolio. Thus, a significant practical effect was obtained, since the using of this fuzzy system allows to quickly assessing the forecast positions of dual education projects, to evaluate the future competitive status of the educational product and the management strategy of this project.

Keywords: Dual education, specialty trajectories; fuzzy evolutionary methods

For citation: Kozyr S. V., Molokanova V. M. "Application of fuzzy evolutionary methods for the development of dual education projects". ***Herald of Advanced Information Technology*****. 2022; Vol. 5 No. 4: 325–341. DOI: https://doi.org/10.15276/hait.05.2022.24**

INTRODUCTION, FORMULATION OF THE PROBLEM

In conditions of the rapid technological development and the transition to the knowledge economy there is a request to find effective forms of modern education. The dynamic external environment changes the trends of specialties and the trajectories of stakeholders in the educational space.

Now we need to reduce the gap between the special (professional) competencies of graduates of educational institutions and the requirements for the professional competencies of specialists in the labor market. This task becomes relevant to introducing of the education dual form (EDF) at the level of professional pre-higher and higher institutions. According to the Order of the Ministry of Education and Science of Ukraine dated 15.10.2019 No. 1296 "On the introduction of a pilot project in institutions of professional pre-higher and higher education for the training of specialists in the dual form of education", a large-scale experiment on the implementation of EDF in 44 educational institutions was launched, and it will last until 2023.

The state and direct participants are also interested in the implementation of this project: "for educational institutions, this form of organization of education will help attract the attention of a certain category of applicants, as well as actually update the content of educational programs, gain access to the material and technical base of employers for advanced training of scientific and pedagogical workers. In addition, it will contribute to increasing the competitiveness of graduates entering the labor market, their financial independence and gaining work experience during their studies. Employers, for their part, will receive specialists with solid theoretical knowledge and demanded competencies in the labor market, familiarization with the peculiarities of work in the company / at the enterprise, adaptation, etc." [1].Today's higher education institutions are opening new specialties in demand by the labor market, introducing a dual form of education, such as a new technology of education, in order to increase their competitive status. The need for colleges and universities to carry out a significant number of unique activities gives rise to the using of project management for their implementation. Thus, solving the problem of the development of dual education necessitates the methodology development for managing a portfolio of projects for dual education processes organizing.

The purpose of the article is to analyze and summarize the dynamics of project management of the dual form of education using a systematic approach and the expert systems based on the apparatus of fuzzy sets and fuzzy logic.

In accordance with the goal, the following research objectives are formed:

– to investigate the evolutionary methods of creating a system of education dual form for a particular specialty;

– to predict the evolution of dual education systems on the basis of expert opinions;

– determine the functions of belonging to the possible values of each of the internal parameters of the system, as well as the time values of structural changes and changes in the management strategy;

– to make modeling the management strategy of the dual form education system using the McKinsey model.

1. LITERATURE REVIEW

According to the Part 10 of Article 9 of the Law of Ukraine "About Education", the dual form of education is a way of obtaining education, which involves combining the training of persons in educational institutions (in other subjects of educational activity) with training in workplaces at enterprises, institutions and organizations to acquire a certain qualification, as a rule, on the basis of mutual agreement [2].

The concept of cooperation of educational institutions with government and business has arisen for a long time. Back in 1996, the first international conference devoted to this concept was held in Amsterdam, and in 2009, for the purpose of its further development, the International Association of the Triple Helix was established as an interaction of three components – science, business and the state [3]. The emergence of this concept of the triple helix is associated with certain socio-economic conditions. Since with the growing role of innovation in development, state institutions cannot constantly support the processes of such innovation. The high level of interactions uncertainty between the participants in the innovation process requires closer ties between science, business and the state. To solve this problem, it is proposed to build communication platforms in which all stakeholders are involved [4]. In addition to the cooperation of the three driving ones, the concept of the "Triple Helix" involves the creation of a space of knowledge and innovation [5, 6], [7, 8].

The emergence of firms focused on the capitalization of knowledge opens up new opportunities for scientists and qualified professionals. This circumstance has recently led to the active participation of universities in the creation of innovative firms [9], [10], [11], [12]. When analyzing the success stories of such knowledge-oriented organizations, the main reason of their success is university cooperation within the "Triple Helix" [13]. It is noted that the three spaces considered by the "Triple Helix" are nonlinear. Theoretically, they can be created in different ways, while it is allowed to use any direction as a basis for the development of the other two. The result of joint efforts may be some hybrid entity that combines resources, people and networks, crossing the entire "Triple Helix" [14], [15].

However, "at this stage of development, dual education is no longer limited to the cooperation of educational institutions and companies, but is based on complex network links between wide ranges of stakeholders. The formation, effectiveness of the functioning of dual education and the success of its implementation in different national contexts at the request of time depends on a number of factors – historical, cultural, social, and economic. This makes it necessary to consider dual education through the prism of process, project and system approaches"[16].

2. MODEL DEVELOPMENT AND MODELLING METHOD USING

The idea of replacing the paradigm of modeling systems with a paradigm of modeling their evolution is currently actively developing [17]. We will perform a formulation of the evolution modeling for a complex dual form education system (DFES) implementation in a particular specialty.

Each DFES dynamically goes through the stages of the life cycle: research, design, and implementation, provision of dual education services, modernization (niche search) or elimination. Only one of these stages is productive, it is the stage of providing dual education services. Therefore, first, at the initial stages of the life cycle, they solve the problem of maximizing the time of this stage of DFES. The time of other stages is minimized. At the same time, it is necessary to take into account the contradictions that are determined by the need to increase the number of applicants in the dual form of education, the growth of the quality of educational services, the advanced training of scientific and teaching staff, the structural and functional transformation and the educational institution and the enterprise management. It is obvious that the evolution of DFES is carried out in two directions: vertically (external) and horizontally (internal). The vertical evolution determined by the movement of DFES along the stages of its life cycle. The horizontal evolution dynamics determines by DFES state within each of its life cycle stages.

At the macro level, it is necessary to solve the problem of multicriterial optimization

$$T_f \to max, T_m \to min, E_f^t = (P_t, C_t, S_t) \to max, \quad (1)$$

where: T_f - time of the stage of DFES operation; T_m -time of modernization or adaptation of the system; E_f^t – system efficiency; P_t – set of tasks that are solved by the system at a time t; C_t – a set of corresponding possible structures; S_t – set of management strategies.

Note that the efficiency of a system is a function of its state q, which is defined as a set of values of internal and external parameters of its functioning. The system designated by the external environment and its evolution. Formally, such an impact is carried out through the function of external conditions *φ(t)*. On the other hand, the need for dynamic development of the system is determined by internal factors, their influence is carried out through the implementation of the function $\phi(q, t)$. In [18], the process of functioning of a complex system, together with modernization procedures, was divided into time intervals, i.e.

$$T_f + T_m = \{t_0 < t_1 < \cdots < t_n < \cdots\} . \quad (2)$$

We believe that at times it there is a modernization or adaptation of the DFES, which consists a number of tasks, structures or management strategies. Such changes are the result of the analysis and implementation of decision-making procedures. In the intervals between moments of time t_i the functioning of the system is performed.

So, the problem (1) will be rewritten as follows:

$$E_f^{[t_k, t_{k+1}]} = F_k(p_k^i, c_k^j, s_k^l) \to max, \quad (3)$$

$$p_k^i \in P_k, c_k^j \in C_k, s_k^l \in S_k, k = \overline{0, n-1},$$

$$\begin{aligned} P_{k+1} &= f_{k+1}(P_k, \varphi(t_k), \phi(q_k, t_k)), \\ C_{k+1} &= g_{k+1}(C_k, \varphi(t_k), \phi(q_k, t_k)), \\ S_{k+1} &= h_{k+1}(S_k, \varphi(t_k), \phi(q_k, t_k)), \end{aligned} \quad (4)$$

where P_{k+1} is denote problems solved by the system at time t_{k+1}; C_{k+1} is corresponding version of the system structure; S_{k+1} is management strategy; φ(t_k) is value of the external conditions at time t_k; ϕ(q, t) ϕ(q_k, t_k) is value of the internal state function q_k at time t_k.

Problems (3) and (4) have a solution when performing at each time interval a set of constraints R_k, the presence of source data A_k, sets of models Mo_k, methods Me_k and means V_k. The tasks (3) and (4) reflect the need to change the structure and organization of DFES for a particular specialty, as a result of the evolution of the external environment and internal needs.

Thus, the paper presents the modeling of the evolution of introducing dual education complex system in a particular specialty in the form of a multi-criteria optimization problem. To solve the problems of optimization of complex systems of different origin, evolutionary algorithms [19], [20], [21] are widely used, which are part of a broader technology of so-called Soft Computing, including neural networks, fuzzy logic, probabilistic reasoning and trust networks [22], [23]. These technologies complement each other and are used in various combinations or independently to create Intelligent Systems (IS). The development of the decision-making subsystem of an intelligent system requires the formalization of product rules.

2.1. Forecasting the evolution of dual education systems based on expert opinions

Formally, the experts' conclusions will be presented in the form of the product composition rules [24], [25]. Their basic elements are fuzzy sets, for which it is necessary to determine the functions of belonging to the possible values of each of the internal parameters of the system, as well as the time values of structural changes and changes in the management strategy. Thus, we will formally present expert opinions with rules like “if..., then...” (5):

$$\begin{aligned} &If\ t \in T_1^{11} \& q_1 \in Q_1^{11} \& \dots \& q_n \in Q_n^{11}, or \\ &t \in T_1^{21} \& q_1 \in Q_1^{21} \& \dots \& q_n \in Q_n^{21}, or \\ &\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots\dots, or \\ &t \in T_1^{d1} \& q_1 \in Q_1^{d1} \& \dots \& q_n \in Q_n^{d1}, \\ &then\ s \in S_1, \\ &else\ if \end{aligned} \quad (5)$$

$$t \in T_1^{12} \& \, q_1 \in Q_1^{12} \& \dots \& \, q_n \in Q_n^{11}, or$$
$$t \in T_1^{22} \& \, q_1 \in Q_1^{22} \& \dots \& \, q_n \in Q_n^{22}, or$$
$$\dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots, or$$
$$t \in T_1^{d2} \& \, q_1 \in Q_1^{d2} \& \dots \& \, q_n \in Q_n^{d2},$$
$$then \; s \in S_2,$$
$$\dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots,$$
$$else \; if$$
$$t \in T_1^{1r} \& \, q_1 \in Q_1^{1r} \& \dots \& \, q_n \in Q_n^{1r}, or$$
$$t \in T_1^{2r} \& \, q_1 \in Q_1^{2r} \& \dots \& \, q_n \in Q_n^{2r}, or$$
$$\dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots \dots, or$$
$$t \in T_1^{dr} \& \, q_1 \in Q_1^{dr} \& \dots \& \, q_n \in Q_n^{dr},$$
$$then \; s \in S_r.$$

At (5) a fuzzy set with the corresponding belonging function, by means of which the confidence of the k-th expert in the time value of T_k^{ij} the *j*-th structural adjustment for the i-th assumption is determined, where Q_k^{ij} *is* the fuzzy set of values k –th internal parameter, S_k is a fuzzy set of values k-th variant of the structural elements composition.

To determine the variant of the management strategy of the DFES, we can use a system of production rules similar to (5). It will have the same form and, in order not to repeat, we denote it as 5*. The system of production rules (5*), which corresponds to the task of determining the set of tasks, is formed with some differences.

The system (5*) takes into account the assumptions of experts about environmental conditions. At the same time, it is impossible to ignore internal parameters, the values of which change over time, and also exert their influence on the resulting characteristic. Therefore, in (5*) there are functions of belonging, but not for all internal parameters, but only for significant parameters. Similar (5*) systems occur when predicting structural and organizational changes.

Note that the systems (5) and (5*) reflect the conclusions of only one expert and are based on experience, knowledge, intuition and, which is the main thing, on the results of designing systems or elements-analogues [26], [27], [28], [29]. Such conclusions reflect the possible various options for the evolution of the system and form the elemental basis of a fuzzy knowledge base.

2.2. Justification of the complex systems evolution modeling result adequacy for the introduction of dual education

The process of systems evolution modeling is a rather complex poorly structured problem, since there is no clearly defined procedure, method, algorithm for solving it, as well as determining the levels of hierarchy. Such systems are the subject of study in artificial intelligence [30].

Since the evolution of the system is the process of transition from state to state depending on internal necessity and external conditions, the organization of information includes the initial data, constraints, models, methods, means, criteria for evaluating the decisions obtained, forms the basis for analyzing the effectiveness of each stage of the system life cycle, forecasting future processes and making decisions. Thus, modeling systems evolution is a more informative process than modeling only systems structure.

It is important to note that systems evolution modeling in the overwhelming majority of cases must be carried out at the initial stages of life cycle such as the stage of scientific research and design. However, at this time there is no initial data that could be obtained in the later stages, so a significant part of them is predicted, which in turn leads to a shift in the results. We propose to carry out their verification and optimization using evolutionary modeling [31], [32].

Let us give some arguments in favor of the fact that the evolutionary paradigm has methodological and substantive aspects. Note that it is based on ideas that are expressed by a certain axiomatic. According to her, the course of evolution is determined by hereditary variability, which is a prerequisite for evolution; the struggle for existence as a controlling and guiding factor; natural selection as a factor transforming evolution.

Adapting these axioms to the problem of the evolution of DFESs, we note that evolutionary modeling in this case is fully justified, since:

1. Hereditary variability indicates the possibility for DFES to reorient to the specialty that should be developed, which determines the environment and evolution. The innovative potential of dual education projects can be interpreted as a prerequisite for the evolution of the system.

2. The market of labor determines the guiding factor in the evolution of the system, and is regulated by the law of equality of supply and demand, that determines the need to solve problems and (1)-(4)

3. Natural selection in this case is determined by the effectiveness of the result of solving the problem (1)-(4). The state in which the dual education system is located for a certain moment of time is an indicator of its effectiveness (Fig. 1).

Fulfillment of the above three conditions indicates the existence of a model of evolution.

ISSN 2663-0176 (Print)
ISSN 2663-7731 (Online)

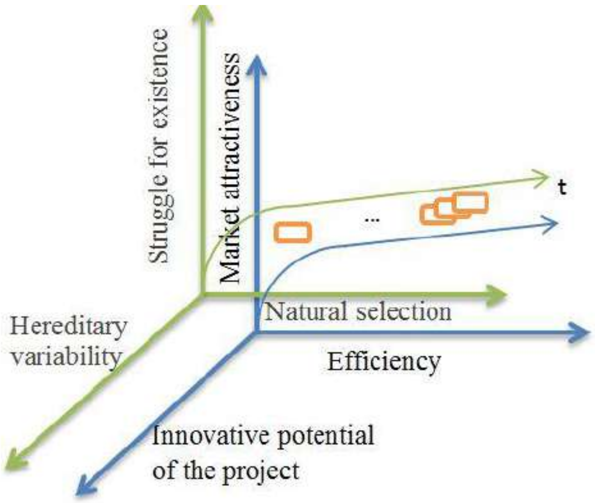


Fig. 1. **Model of dual education system evolution**
Source: **compiled by the authors**

The object that evolves is the dual education system. The space in which evolution is performed, the space of four dimensions: time, tasks, structures (structural and functional – transformation and management of higher education institutions and enterprises) and types of training organization, determined by algorithms for the allocation of resources.The criterion of evolution is the effectiveness of DFES, the structural element (solution) is its state. Thus, three components of evolutionary modeling are the model of evolution, the object of evolution, and the criterion of evolution. Their definition is a prerequisite for modeling the evolution of complex systems and indicates the validity of the application of evolutionary technologies to the processes of their creation.

However, the heuristic nature of evolutionary computations does not guarantee the optimality of the resulting solution [33]. However, the initial data when selecting projects for the dual education development portfolio are dynamically changing, characterized by inaccuracy and incompleteness. Therefore, it is important to obtain several suboptimal alternative solutions. Let us move on to the implementation of forecasting the evolution of dual education systems based on expert assessments using models of the multifactorial strategic analysis methodology and the apparatus of fuzzy sets and fuzzy logic.

2.3. Modeling the management strategy of the dual education system using the McKinsey model and the apparatus of fuzzy sets and fuzzy logic

Since “the management system of dual higher education is a complex of organizational and managerial coordination mechanisms (built in Ukraine according to the project approach) of complex network relations between stakeholders” [16], we will also select projects for the dual education development portfolio using approaches and methods inherent in project management.

Each educational product is a “commodity” sold in the market of educational services. A set of products forms a “product portfolio” [34]. The system of higher education should be adapted to market self-regulation.

To determine the variant of the DFES management strategy, we will use the well-known McKinsey model [35], [36]. This model is an example of a multivariate strategic analysis technique. With its help, all specialties of the educational institution are ranked as candidates for investment according to the criterion of future profit in a given strategic perspective. Accordingly, these specialties will be candidates for the portfolio of projects of the DFES. In the matrix along the *Y*-axis, we have those parameters of the educational services market that organizations are practically uncontrolled (that is, in fact, these are significant factors of its external environment), and on the *X*-axis we evaluate those parameters that depend from the organization.

The position (state) of a particular specialty is reflected in the coordinate and grid these matrices by points with coordinates corresponding to the level of competitive status of an educational institution in a particular specialty and its attractiveness in the market of educational services.(Fig. 2).

Attractiveness of the market				
	High	Specialty ‘System Analysis’ is Interim 1	Specialty ‘System Analysis’ is Leading 2	Specialty ‘System Analysis’ is Leading 1
	Average	Specialty ‘System Analysis’ is Losing 1	Specialty ‘System Analysis’ is Interim 2	Specialty ‘System Analysis’ is Leading 3
	Low	Specialty ‘System Analysis’ is Losing 3	Specialty ‘System Analysis’ is Losing 2	Specialty ‘System Analysis’ is Interim 3
		Low	Average	High
		Competitive advantages		

Fig. 2. **McKinsey matrix model of system dual education**
Source: **compiled by the authors**

The McKinsey model identifies three types of strategic positions (“Losing”, “Interim”, “Leading”), each of which includes three business positions. In accordance with the model of the first type of business, a high priority is established for investment, the second type is medium, and the third is low.

With proper positioning, it is possible to make an accurate forecast of the situation and make successful strategic decisions.

However, the McKinsey model as a strategic marketing tool taking into account a number of limitations:

1. In accordance with the methodology of the model, the competitive status is set for the current period of time, and then it is extrapolated without significant changes to the entire strategic period. However, in practice, significant changes can occur during this period.

2. The process of strategic choice according to the model is passive (the organization assumes a future that should take place as without its participation). In fact, one cannot limit oneself to passive observations, it is necessary to actively shape the future. Therefore, the model is correct only in the short term.

3. Qualitative indicators that form integral criteria are extremely difficult to unambiguously assess (large variation, excessive subjectivity of expert assessments, a large amount of material and, consequently, restrictions on the time factor). All this reduces the accuracy of estimates and makes the model not very successful.

In order to reduce the flow of these restrictions and to obtain a forecast of the educational institution competitive status in a particular field of knowledge, we propose to include the trajectory of evolution or the trend of specific specialties with the indicators that form integral criteria.

The content of the problem that needs to be solved by the decision maker person (DMP) is to determine the possibility of the composition of quantitative and qualitative, objective and subjective factors, and to develop a method for evaluating such a composition. It is necessary to base it on a measure, since the measure is an essential unity of quantitative and qualitative factors. The object and process have its own measure, that is, qualitative and quantitative certainty.

Analytical methods to determine the impact of such reasons on the final choice of a design solution is impossible. At the same time, using mathematical modeling, which includes the apparatus of artificial neural networks (ANN) using and methods of fuzzy set theory (FST)), such uncertainty can be reduced, which will allow DMP to correct and clarify expert conclusions [17], [31], [37], [38].

Fuzzy logic systems are used in fuzzy expert systems [30], [31], [33]. They are based on constructions of logical rules such as “if ..., then ...”, where the condition and conclusion (consequence) are expressed by a set of verbal characteristics described using fuzzy sets [39].

It is precisely for the formalization of the process of human thinking in the course of decision-making, on which intellectual, in particular, expert systems are based, since the early 1970s, the American scientist L. Zade has been asked to use fuzzy logic. Later, this direction became widespread and gave rise to the creation of a separate branch of artificial intelligence, called “soft computing”.

Let the expert define the linguistic variable. “Competitive advantages” using the following concepts: “low”, “average” and “high”. This description can be formalized using the linguistic variable, where β is the $\langle \beta, T, X, G, M \rangle$ name of the linguistic variable “Competitive advantages”. The mark T is the set of its values {“low”, “average” “high”}. The note X is the set that is the domain of each of the fuzzy variables. The note G is formation of new terms using bonds “and”, “or” and modifiers such as “very”, “not”, “slightly” and others, for example, “very low”, etc.; M is a semantic procedure that allows us to convert each new value of a linguistic variable created through the G procedure into a fuzzy variable, that is, to form a corresponding fuzzy set.

In Fig. 3 shows the possible form of functions belonging to N fuzzy sets “low with competitive advantages", “average with competitive advantages” and “high competitive advantages”.

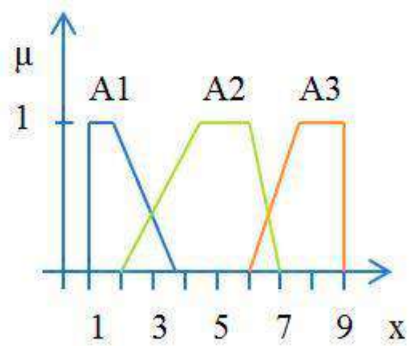


Fig. 3. **Membership functions of fuzzy sets: “low competitive advantages” = A1; “average competitive advantages” = A2; “high competitive advantages”= A3**

Source: compiled by the authors

The previous sections show that it has been successfully used to perform tasks and solve problems in which the initial data is unreliable and poorly formalized.

Advantages of such approach in expert systems based on the using of a fuzzy set apparatus and fuzzy logic are follows:

– to describe the conditions and method of solving the problem, we can use a language that is close to natural;

– universality (according to the theorem of B. Cosco [31], any mathematical system can be approximated by a system built on fuzzy logic);

– efficiency (associated with universality), which is confirmed by a number of theorems similar to theorems on the completeness of artificial neural networks.

At the same time, fuzzy decision-making systems have certain disadvantages:

– the initial set of fuzzy rules is formulated by a human expert and may be incomplete or contradictory;

– the appearance and parameters of the functions of belonging, describing the input and output variables of the system, are chosen subjectively and may turn out to be such that they do not fully reflect reality.

To eliminate, at least in part, these shortcomings, it was proposed to create fuzzy systems adaptive, adjusting the rules and parameters of the functions of belonging in the course of their work. One of the most successful among such systems is fuzzy neural networks.

A fuzzy neural network is a combination of an artificial neural network with a mechanism of fuzzy logical inference that is a computational system that contains several layers of artificial neurons, at least one of which corresponds to a system of rules (knowledge base).

Among the integrated neuro-fuzzy models ANFIS (Adaptive Network-Based Fuzzy Inference System) has the highest accuracy.

This is due to the fact that the Takagi-Sugeno rules are implemented in ANFIS:

$$if\ x_1 \in A_1 \& \ x_2 \in A_2 \& \dots \& \ x_n \in A_n$$
$$then\ y = f(x_1, x_{2,} \dots x_n).$$

In the rules of such a system, $\{x_i\}$ are input variables; y is the output variable; $\{A_i\}$ are fuzzy terms defined on the $\{x_i\}$; $f(x_1, x_{2,} \dots x_n)$ is a linear function that depends on the input variables. This system can be successfully used to set up the membership function as well as the rule base in a fuzzy expert system [30], [33].

The structure of the ANFIS neural network for the case when it is necessary to set three input variables (x_1 – is "Competitive advantages"; x_2 – is "Attractiveness of the market"; x_3 – "The evolution trajectory of the education system") is shown in Fig. 4. X_1 and x_2 are defined by three fuzzy terms, x_3 – by two (increasing and decreasing trajectories).

Each of the layers performs the following functions:

– the 1th layer is the phasor. Network inputs x_1, x_2,...x_n are connected only with their terms. The number of neurons in the first layer is equal to the sum of the powers of the term sets of the input variables. Each neuron of this layer converts the input signal xi into a fuzzy set using the membership function $\mu_{A_i}(x_i)$ (see Fig. 3);

– the 2th layer is the the rule activator. Each neuron in this layer is denoted as Π_j ($j = \overline{1,m}$), and performs logical multiplication of the input signals, simulating the logical AND operation and sending the signal to the output, namely:

$$\omega_j = \mu_{A_i}(x_1) \wedge \mu_{A_i}(x_2) \wedge \mu_{A_i}(x_3),$$

where: A_i – is the number of terms for each input variable. In fact, each neuron of the second layer implements the activity of one rule. In the specific case, m = 18;

– the 3th layer is the normalization. Here each neuron calculates the normalized strength of the rule, i.e.

$$\overline{\omega_j} = \frac{\omega_j}{\sum \omega_j}\ , j = \overline{1,m};$$

– the 4th layer is the inference of the rules. The number of nodes of the fourth layer is also equal to t. Each neuron is connected to one neuron of the third layer as well as to all inputs of the network.

The neuron of the fourth layer calculates the contribution of one fuzzy rule to the network output:

$$y_j = \overline{\omega_j}(b_{0,j} + b_{1,j}x_1 + \dots + b_{n,j}x_n), j = \overline{1,m}.$$

– the 5th layer is the defuzzifier. It is the final one, where the output signal of the neural network is received and the results are reduced to clarity for defuzzification using a simple convolution of the original variables, which is equivalent to the center of mass method, namely:

$$y = \frac{\overline{\omega_j}}{\bar{j}}, j = \overline{1,m}.$$

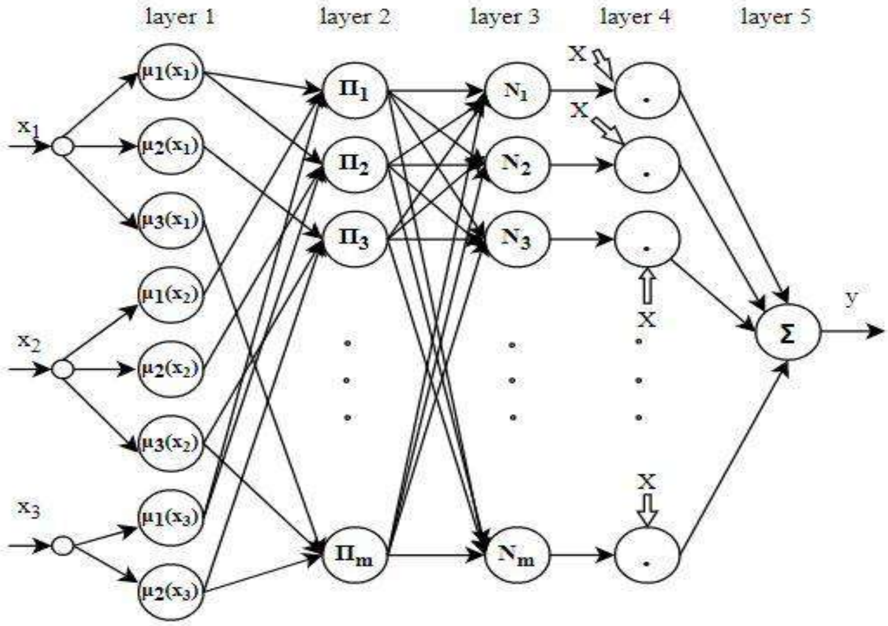


Fig. 4. **Structure of the ANFIS neural network for the formation of a portfolio of projects of the dual education system**
Source: **compiled by the authors**

Typical neural network training procedures can be applied to train an ANFIS network because it uses differentiable functions. Usually, a combination of gradient descent in the form of back propagation algorithm and least squares method is applied. The backward error propagation algorithm adjusts the parameters of the rule antecedents, i.e. membership functions. The least squares method estimates the inference coefficients of the rules, since they are linearly related to the network output. In addition to the back propagation method, other optimization algorithms (Levenberg-Marquardt method and others) can be used to adjust the membership functions [33].

Thus, the using of the fuzzy neural networks (FNN) apparatus will allow the expert to adjust and clarify their conclusions, determine the strategic and positions of each business unit of the dual education project portfolio.

The problem that needs to be solved by the decision maker person (DMP) is determination of the quantitative and qualitative composition, objective and subjective factors, to develop a method for evaluating such a composition.

So, the steps of such method for assessing the composition of quantitative and qualitative, objective and subjective factors are follows:

1. Selection of quantitative indicators that affect the efficiency of the system.
2. Determination of qualitative indicators of impact.
3. Inclusion in the indicators the evolution trajectory of the education system.
4. Determination of the composition of quantitative and qualitative, objective and subjective factors, that is necessary to serve as a base on a measuring, since the measuring is an essential unity of quantitative and qualitative factors.
5. The using of the fuzzy neural networks (FNN) apparatus, which will allow the expert to adjust and clarify his conclusions. Thus, on the basis of a systematic approach, a technology has been developed to find a criterion for the effectiveness of the dual education system at the stage of project initiation and during all its life cycle depending on tasks, structures and management strategies. The main components of the technology are the neural networks models of efficiency criterion and evolutionary algorithms as methods for its optimization.

3. EXPERIMENTAL RESULTS

The experimental basis of the study was chosen to form a portfolio of dual education projects based on the State Vocational Institution “Dnipro Center for Vocational Education”. To determine the projected versions of the portfolio management strategy of dual education projects, the McKinsey model is adapted (see Table 1). In addition to qualitative factors, such as the attractiveness of the labor market and the competitive status of the educational institution, the trajectories of the evolution for the specialties are also included.

ISSN 2663-0176 (Print)
ISSN 2663-7731 (Online)

Table 1. **Adapted McKinsey matrix model with the competitive status rating scores of the project educational product and the management strategy**

Attractiveness of the market	High	5.Support of the marginal position; stabilization; search for personnel	6. Selective growth; maintaining the position	7. Growth; finding ways to lead; maximizing educational services
	Average	2. Reduction of the area; planned exit	4. Stabilization; identification of growing segments; investing in very profitable professions	6. Selective growth; assessing the potential for leadership by segmentation
	Low	1. Liquidation; quick way out	2. Search for partners; development of promising specialties; consideration of exit from the local market	3. Stabilization; search for niches; short-term investments (courses); planned reduction
		Low	Average	High
		Competitive advantages		

Source: **compiled by the authors**

Recall that the projected value of the educational institution competitive status in a particular industry is an indicator of its effectiveness in the future. The result of solving the problem (1)-(4) determines the state of the portfolio of dual education projects in a particular specialty. The position of this status is a certain sector of the McKinsey matrix, which shows both the competitiveness of the educational product and the strategy for managing this project.

Phasing process of input and output variables will be follows:

1) The set *T1* = {"low", "medium", "high"} is used as the term set of the first input of variable "Relative competitive advantages of higher education institutions in the specialty" (IRCA).

2) For the second input variable, the set *T2* = {"low", "average", "high"} is used as the term set "Market attractiveness".

3) The project of dual education in a particular specialty is not a stable system. Therefore, to assess the effectiveness of projects in a changing environment, the third change in the specialty trend was used.

4) The specialty rating will be evaluated in points from 1 to 9. As a term-set of the original linguistic variable "Rating" we will use the set *T3* = {"very low", "low", "below average", "average", "above average", "high", "very high"}.

An example of constructing a fuzzy model of a system of dual education projects for several specific special activities was carried out using the MATLAB environment and it's Fuzzy Logic Toolbox. The purpose of creating this model is to determine the states in which each business unit is located at a certain point in time, and acts as an indicator of its effectiveness. The development of a fuzzy model (its conventional name dual education) was carried out in the FIS editor, where initially 3 input variables (advantages, attractiveness, trend) and the output variable, which determines the case rating by specialty, are given. To solve the problem of fuzzy modeling, a fuzzy inference system based on the Mamdani algorithm was used [30], [33].

The parameters of the fuzzy model proposed by the MATLAB system by default are left unchanged. They include logical operations (min – for fuzzy logical I, max – for fuzzy logical OR), implication method (min), aggregation method (max) and defuzzification method (centroid).

The view of the interface of the FIS editor is presented in Fig. 5.

For beginning, the behavior of the model was investigated with only two input variables. "Relative competitive advantages of higher education institutions (IRCA) in the specialty" and "Market attractiveness", which adequately reflected McKinsey matrix model of system dual education (Fig. 6). When constructing a fuzzy model for evaluating the performance indicator for the variables, the functions of belonging are given, which are measured in the range of real numbers from 0 to 10. In this case, the lowest estimate value of each of the variables is 0, and the highest is 10.

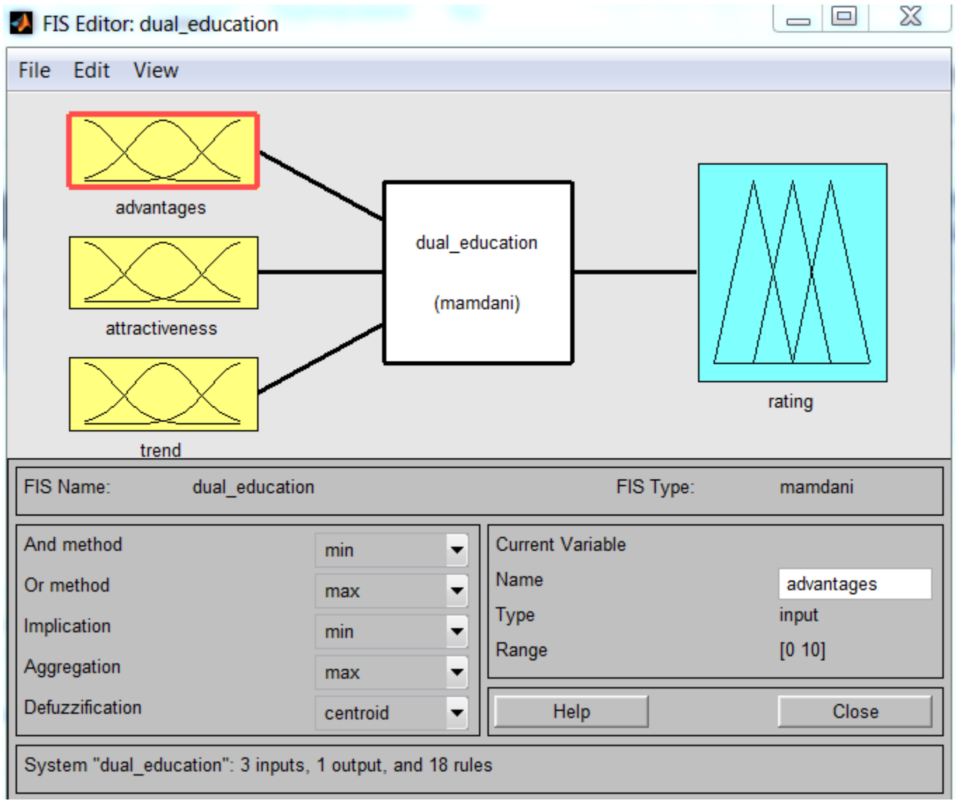


Fig. 5. **Graphical interface of the FIS editor for the proposed task**
Source: **compiled by the authors**

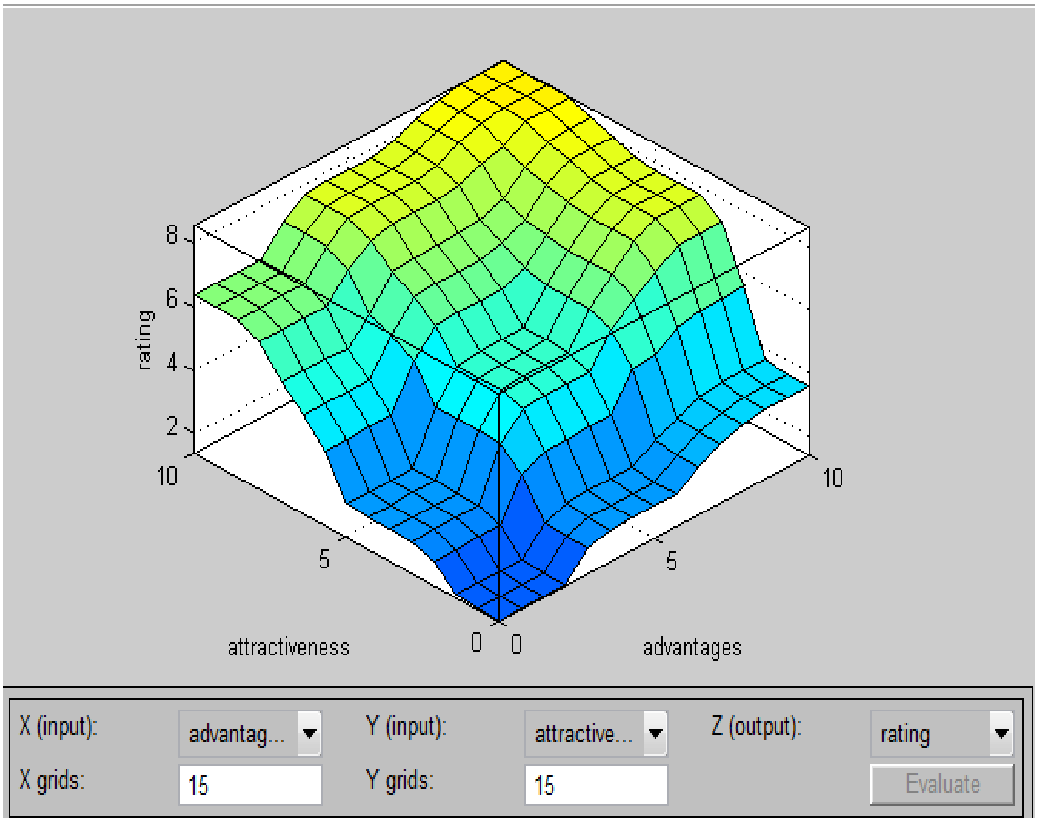
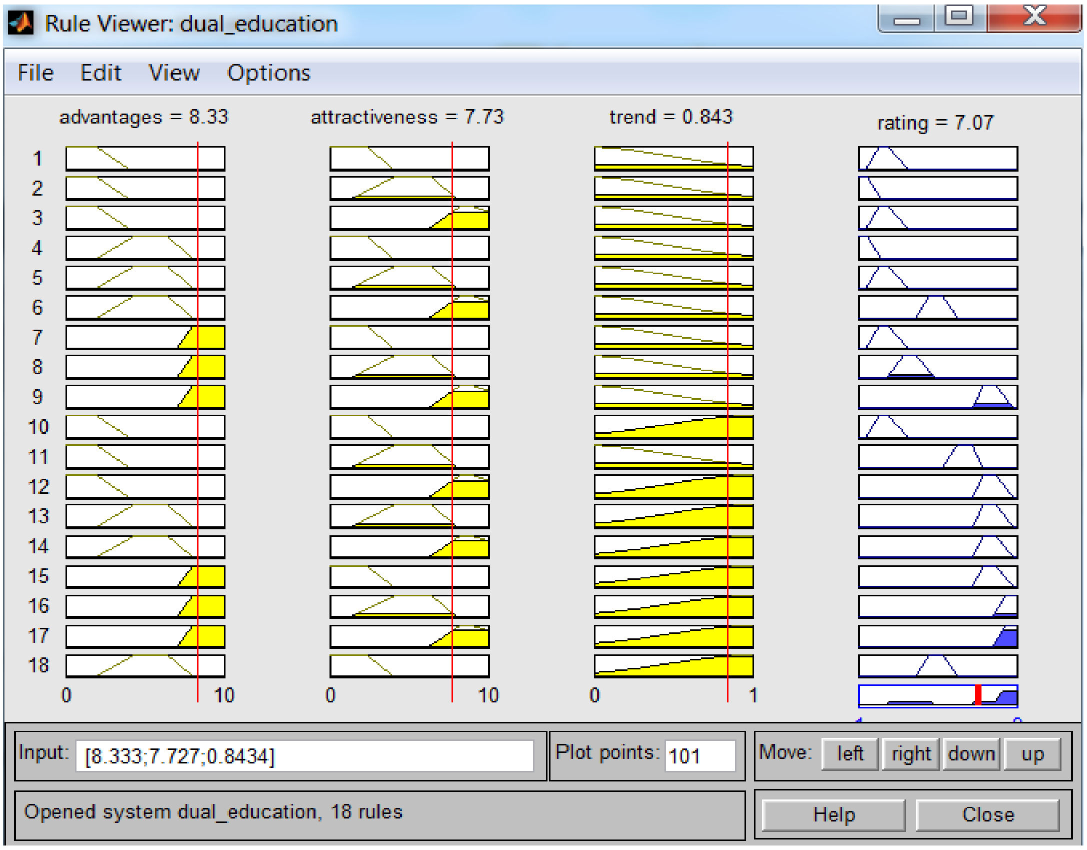


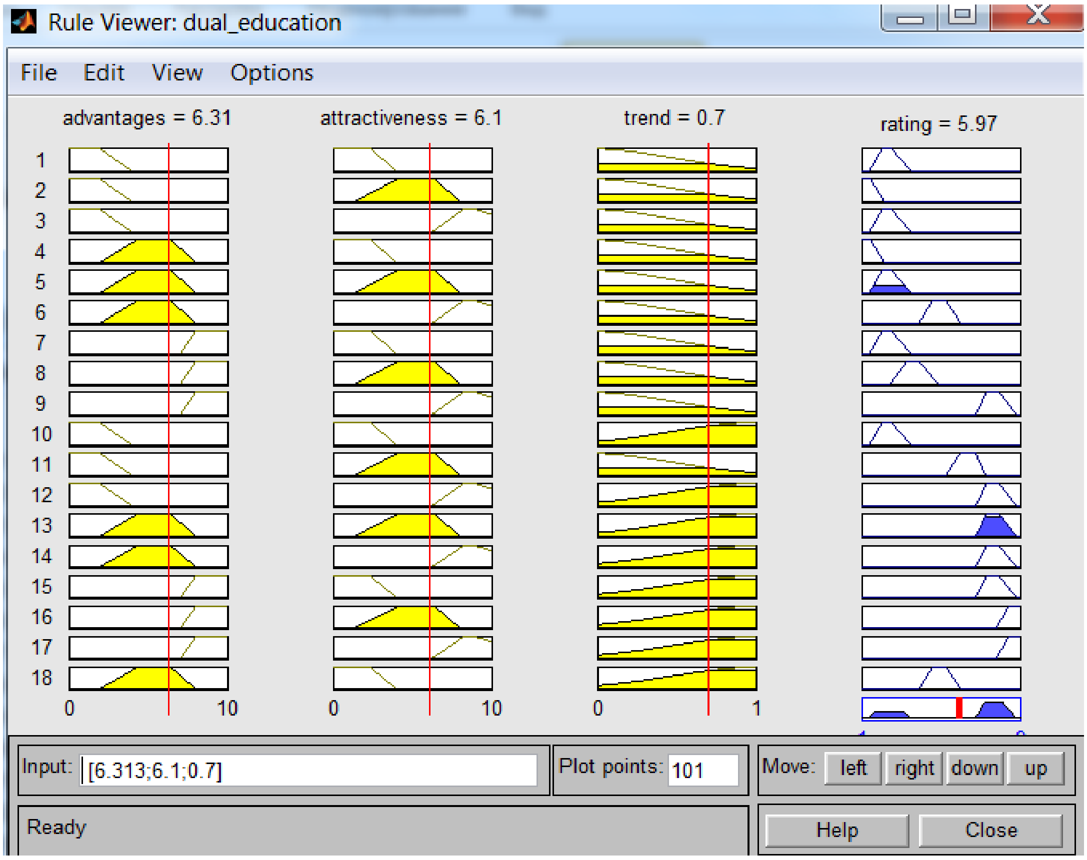
Fig. 6. **Behavior of the adapted McKinsey matrix model of dual education system with two input variables “Relative competitive advantages of the educational institution by specialty” and “Market attractiveness”**
Source: **compiled by the authors**

ISSN 2663-0176 (Print)
ISSN 2663-7731 (Online)

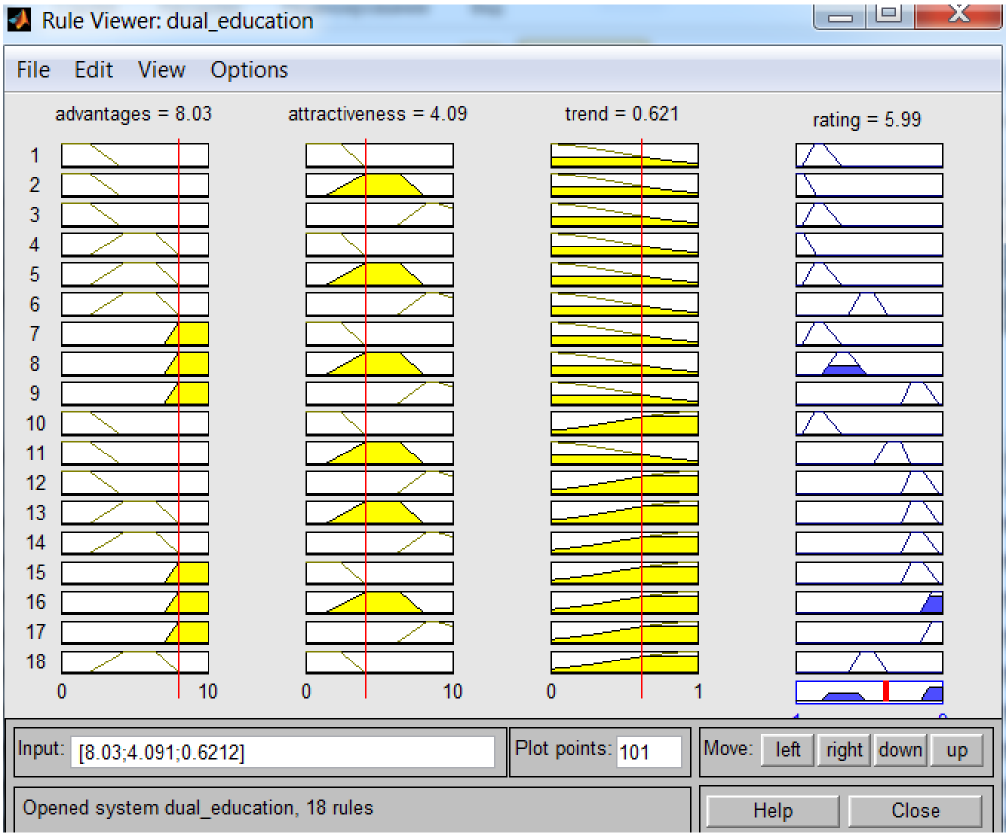
a


Rule Viewer: dual_education
File Edit View Options
advantages = 8.33
attractiveness = 7.73
trend = 0.843
rating = 7.07
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
10
0
10
0
1
Input: [8.333;7.727;0.8434]
Plot points: 101
Move: left right down up
Opened system dual_education, 18 rules
Help
Close

b


Rule Viewer: dual_education
File Edit View Options
advantages = 6.31
attractiveness = 6.1
trend = 0.7
rating = 5.97
1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
0
10
0
10
0
1
Input: [6.313;6.1;0.7]
Plot points: 101
Move: left right down up
Ready
Help
Close

c



d

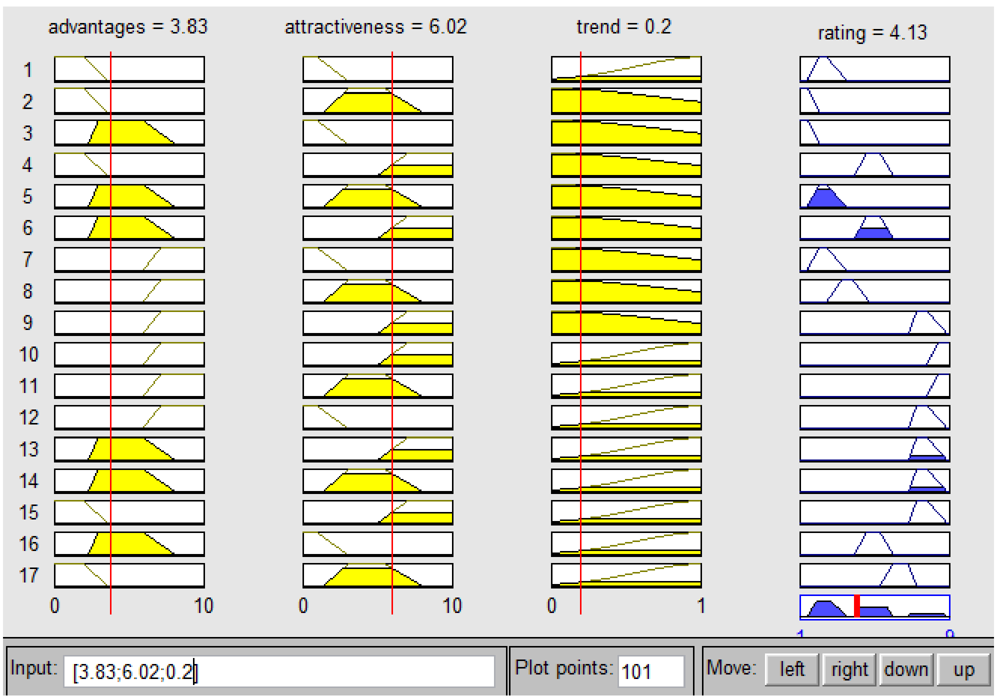


Fig. 7. **Graphical interface of the rule editor for specialties:**
a – "Installation and maintenance of renewable energy systems";
b – "Electrician for repair and maintenance of electrical equipment";
c – "Operator of machine tools with program control;
d – "Emergency medical technician"
Source: **compiled by the authors**

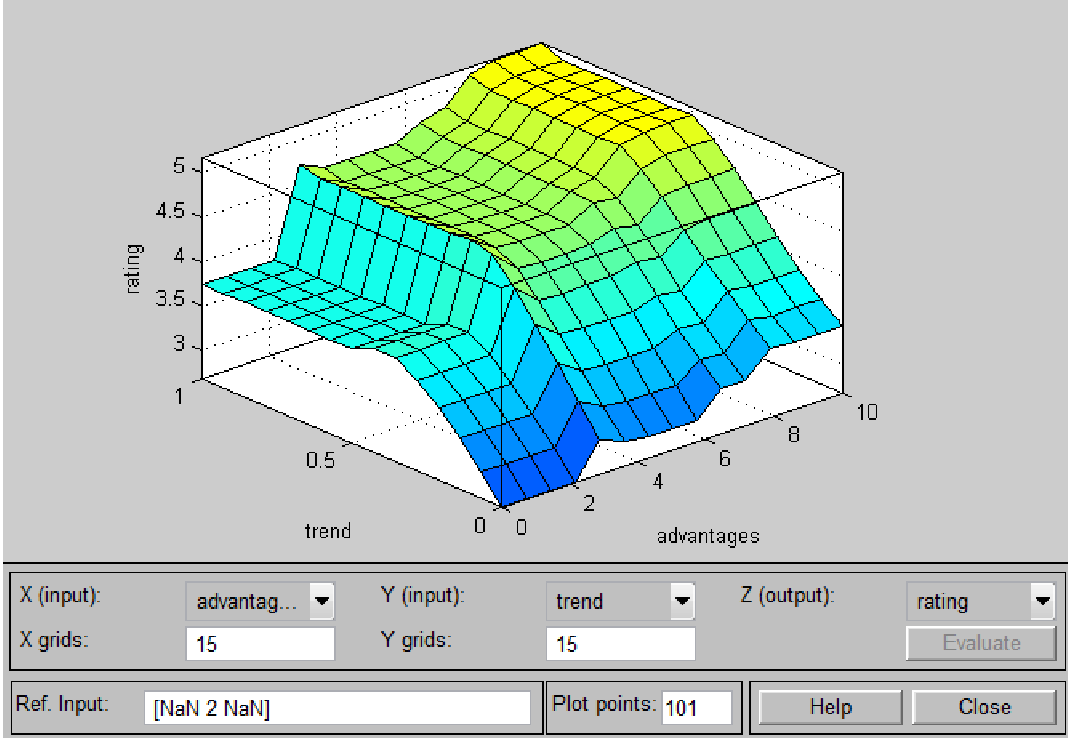


Fig. 8. **The fuzzy inference surface for the variables "advantages" and "trend"**
Source: **compiled by the authors**

Table 2. **Comparative analysis of ratings of the competitive status of dual education projects by specialties**

No.	Speciality	advantages	attractiveness	trend	rating
1	Installation and maintenance of renewable energy systems	8.33	7.73	0.843	7.07
2	Electrician for repair and maintenance of electrical equipment	6.31	6.1	0.7	5.97
3	Operator of machine tools with program control	8.03	4.09	0.621	5.99
4	Emergency Medical Technician	3.83	6.02	0.2	4.13

Source: **compiled by the authors**

The dimensionality of the scale does not matter, and the scale from 0 to 10 is taken as the most intuitive for expert assessments. For variable "trend" – from 0 to 1, it takes into account the tendency to increase or decrease in demand for specialists in a particular specialty. After determining the affiliation functions of each variable based on the rules of positioning, the McKinsey matrix model and taking into account the trend of specialists' demands, the rules of fuzzy inference were introduced into the editor of the rule base. The procedure for aggregating conditions into rules is performed using fuzzy logical operations, such as fuzzy conjunction, fuzzy disjunction, and fuzzy failure.

The graphical interface of the editor after setting all 18-the rules of fuzzy inference for four specialties are shown in Fig.7a, Fig.7b, Fig.7c and Fig.7d.

The dependence of the specialty rating for the input variables "advantages" and "trend" and the surface that the system offers as a result of its work can be viewed in the corresponding window (Fig. 8).

The inclusion of the evolution trajectory for the specialty in the integral criteria of the McKinsey model made it possible not only to establish a competitive status for the current period. The model helps extrapolate state of DFES to the entire strategic period, to predict the competitive status by taking into account the influence of the trend of evolution of a particular specialty.

Because of the study, the predicted values of the competitive statuses of dual education projects in the following specialties were determined (see Table 2). The position on this status is a certain sector of the McKinsey matrix, which shows both the rating of the competitive status of the educational product (in points from 1 to 8) and the strategy for managing this project (Table 1). Thus, we have a competitive position in the educational product (rating) for the following specialty: "Installation and maintenance of renewable energy systems" – 7.07 and, accordingly, the Growth strategy- finding ways to lead;

Different strategies are determined because the first specialty has attractiveness of the market as "high", and the second specialty has "Average" rank and their positions in the matrix of the McKinsey model are different (Table 1). For "Emergency Medical Technician" specialty the rating is 4.13 and is proposed the "Stabilization strategy"; identification of growing segments; investing in very profitable professions.

According to the McKinsey adapted model matrix (see Table 1), the first three products fell into the high-priority group for investing in personnel, resources, material and technical values, and the fourth with an average priority.

Given the somewhat simplified nature, the application of this fuzzy system gives a significant practical effect, since it allows us to quickly assess the predictive positions of dual education projects, by which the future competitive status of the educational product and the management strategies of this project are evaluated.

The experiment of managing dual education projects allowed us to draw conclusions that the application of the theory of fuzzy sets opens up new opportunities for solving the problems of forming an organization's development portfolio in conditions of incomplete information. Since fuzzy neural networks are able to learn in the process of using, their application to assess the competitive status of the educational product and the strategy of managing this project allows us to approach solving one of the most complex problems of project management.

CONCLUSIONS

Evolutionary methods of creating a system of a dual form of education of a separate specialty are investigated in the article based on a systemic approach. The technology of finding the criterion for maximizing educational service. Ratings for the specialties "Electrician for repair and maintenance of electrical equipment" and "Operator of machine tools with program control" are 5,97 and 5,99, respectively. However, for the first of the comparable specialty ratings, is proposed "Selective growth strategy' maintaining the position, and for the second – "Selective growth" assessing the potential for leadership by segmentation.

the effectiveness of the dual education system at the stage of initiating the project, during its life cycle, as a dependence on tasks, structures and management strategies, is proposed. The main components of the technology are the use of fuzzy neural networks as efficiency criterion models and evolutionary algorithms as methods of its optimization.

Forecasting of the evolution of dual education systems was carried out on the basis of expert conclusions. To formalize decision-making in an intelligent system, it is proposed to apply a decision-making support system based on the use of a fuzzy set and fuzzy logic.

A methodology for evaluating the composition of qualitative factors, such as the attractiveness of the labor market and the competitive status of the educational institution and the trajectory of the evolution of the specialty, has been developed. The connection of the trajectory of the evolution of the specialty with the integral criteria of the McKinsey matrix model helps not only to establish the competitive status for the current period. The proposed model helps to then extrapolate it without significant changes for the entire strategic period, as well as predict the competitive status of an educational institution, taking into account the influence of the trend of the evolution of a particular specialty.

The use of the fuzzy logic apparatus made it possible to adjust and clarify the strategic positions of each business unit of the portfolio of dual education projects. Thus, a significant practical effect was obtained, since the use of this fuzzy system allows evaluating the forecast positions of dual education projects, which are used to evaluate the future competitive status of the educational product and the management strategy of this project.

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Conflicts of Interest: the authors declare no conflict of interest

Received 23.11.2022
Received after revision 15.12.2022
Accepted 22.12.2022

DOI: https://doi.org/10.15276/hait.05.2022.24
УДК 519.68

Застосування нечітких еволюційних методів для розвитку проєктів дуальної освіти

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АНОТАЦІЯ

Стаття має на меті представити метод управління кейсами спеціальностей на основі моделей еволюції систем в рамках запровадження пілотного проєкту у закладах фахової передвищої та вищої освіти України з підготовки фахівців за дуальною формою здобуття освіти. Отримані дані дозволили визначити, що методологія проектного управління може бути успішно впроваджена в українській дуальній освіті. Проте українській системі дуальної освіти поки ще бракує багато елементів, а деякі не можна відтворити в національному середовищі, адже це форма навчання, яку може обирати сам студент. У статті представлено моделювання еволюції складної системи запровадження дуальної освіти за конкретною спеціальністю у вигляді задачі багатокритеріальної оптимізації. Для визначення варіанта стратегії управління системою дуальної освіти адаптовано модель McKinsey. За її допомогою здійснено ранжування спеціальностей закладу освіти як кандидатів на отримання інвестицій за критерієм майбутнього прибутку. Розроблено метод оцінки композиції якісних чинників, як-то привабливість ринку праці і конкурентного статусу закладу освіти та траєкторії еволюції спеціальності. Включення траєкторії еволюції спеціальності до інтегральних критеріїв моделі McKinsey, дозволило не тільки, як прийнято до її методики конкурентний статус встановити на поточний період часу, а потім його без істотних змін екстраполювати на весь стратегічний період, а й спрогнозувати конкурентний статус за рахунок врахування впливу тренду еволюції конкретної спеціальності. Для формалізації прийняття рішень в інтелектуальній системі запропоновано застосувати систему підтримки прийняття рішень, засновану на використанні апарату нечітких множин і нечіткої логіки. Застосування апарату нечіткої логіки надало змогу коригувати й уточнювати стратегічні позиції кожної бізнес-одиниці портфелю проектів дуальної освіти. Таким чином, отримано значний практичний ефект, оскільки застосування даної нечіткої системи дозволяє швидко оцінити прогнозні позиції проектів дуальної освіти, за якими оцінюються і майбутній конкурентний статус освітнього продукту і стратегії управління цим проєктом.

Keywords: Дуальна освіта, траєкторії спеціальності, нечіткі еволюційні методи

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