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SUSTAINABLE DEVELOPMENT OF ORGANIZATIONS BASED ON THE COMBINATORIAL MODEL OF ARTIFICIAL INTELLIGENCE

Aleksandra Kuzior[1], Aleksy Kwilinski[2], Volodymyr Tkachenko[3]

[1]Silesian University of Technology, 26 Roosevelta Street, Zabrze, 41-800, Poland
[2,3] The London Academy of Science and Business, 3rd Floor, 120, Baker Street, London, W1U 6TU, England*
[3]Kyiv National University of Construction and Architecture, 31, Povitroflotsky Avenue, 03680, Kyiv, Ukraine

E-mail: [2] koaduep@gmail.com (corresponding author)*

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Abstract. The article specifies the organizational capabilities of application of artificial intelligence technologies in the model of sustainable development of the organization. Also, the article provided the theoretical and methodological background of the organizational changes and development, as well as determined the possibilities of application of artificial intelligence technologies in the functionality of the organization. It was proposed to use the methodological approach to application of neural networks in maintaining of the intelligent management of organizational development. There was developed the combinatorial model of artificial intelligence for decision making about the organizational development.

Keywords: artificial intelligence; sustainable development; organization; neural networks; fuzzy sets; real parameters; expert surveys

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JEL Classification: M21, O16

1. Introduction

The relevance of the study on organization development, the principles and methods of managing the process of changes in organizations is determined by their critical significance for achievement of the goals of social and economic development, ensuring the strategy of modernization of the economy, and increasing of the gross domestic product of the country. For several recent years, the practical aspects of economic management in the world faced the major changes, enterprises and organizations started

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operating in new economic conditions, due to the increased competition rates, and the continually changing external environment. The global competition and the need for efficient use of such key success factors as innovativeness, expenses, product quality, require all organizations to increase the organizational flexibility and adaptive capacities (Repenning, 2002). The latter feature is mainly provided at the expense of the tools of artificial intelligence, organizational changes and development. At the same time, in many similar studies the methods of organizational changes based on artificial intelligence are considered without regard for their integrated impact and relationship with the organization's strategy.

The great variety of available approaches to the problem of formation and realization of the direction of stable development in general and organizational changes in particular, conditioned the need for conducting the study on examination and generalization of research and methodological tools for the usage of artificial intelligence, in order to receive the sustainable dynamics of the organization development.

2. Literature Survey

The research methodology of organizational development and changes, based on artificial intelligence technologies and the intelligent assistance systems, are presented in the following forms: intelligent expert systems; inductive systems; semantic networks, neural networks, genetic algorithms.

1) The intelligent expert systems contain the knowledge database and inference engine. Some researchers (Brynjolfsson, McAfee, 2012; Carley and Gasser, 2000; Sampson et. al. 2002) demonstrated that the user interface, which is required for the correct transmission of user responses to the knowledge base, is the important component of the expert system. Also, the other researchers (Fuchs et. al. 2016; Bilan, Y., Lyeonov, S., Luylyov, O., Pimonenko T., 2019) noted that the ability of the system to explain on demand the train of its thought, providing comments to various stages of its intelligent decisions, is the important characteristic of expert systems.

2) Inductive systems. The inductive systems in the development process of organizations allow passing many difficulties in acquiring of knowledges from the source data, as well as reduce the time and computing costs, due to the fact that the reporting systems are able to manipulate the crude model of the knowledge area (see Jarrahi, 2018; Lucas et. al. 1990; Schmidhuber, 2015; Tsang & Kwan, 1999). The expert has to provide the learning inductive system with the examples of observable signs and the corresponding diagnoses. The inductive systems use artificial intelligence predicates for testing the membership of some pattern to the certain category or class. The conceptual language includes the rules, predicate formulas, automata (accepting or rejecting the decisions).

3) The semantic networks are the system of knowledge, which have the certain sense in view of the holistic image of the network. In particular, the nodes of such system correspond to the concepts and objects, and arcs — object relationships. Usually, the semantic network interpretation is realized through the procedures using the method. There are several types of semantic network processing procedures; the most typical of them is matching of parts of the network architecture, depth and width search procedures, which interpret the semantic network as the weighted graph, as well as subnetworks

construction and matching them to the network database (Moody et. al. 2003; Nagar & Malone 2011; Wang, 2016; Vasylieva, T., Lyeonov, S., Lyulyov, O., & Kyrychenko, K., 2018).

4) Neural networks. The systems, which have the neural networks (neuronets) for solution of a problem(s), are called the neural network systems. The set of neurons connected by axons is called the neural network. The neuron shall be understood to mean rather conditional neuron model of the artificial intelligence model, which performs a number of transformations over the input signals (Ramchurn et. al. (2012). In the certain scientific works (Dirican, 2015; Gibson et. al. 2015; Lin, 2002), it is stressed that the independence of approximation accuracy from the dimensions of inputs serves as the significant advantage of neural network approximation in comparison with the traditional approximation methods. Therewith, the problem of the maximum acceptable dimension and the largest number of independent variables is completely compensated, which makes the traditional methods of approximation as unusable. The reporting factors make the neural network approach as universal and indispensable for representing the complicated Boolean and other functions from a large number of arguments. To date, there are actively developed new methods to estimate the approximation accuracy depending on the number of neurons, and neural networks construction with the specified approximation accuracy, in terms of the additional conditions and constraint on the learning rates of the neural network, the neural network layout and topology, the type of neuron activation function.

5) Genetic algorithms and evolutionary modeling. The evolutionary design of the artificial (technical) system shall be understood to mean the goal-directed development of its development processes, and changes, based on the analogies with models of natural evolution. The evolutionary design is located at the intersection of the theory and methodology of computer-aided designing, development of the theoretical foundations of information science and biological sciences on evolution (Etzioni & Etzioni 2017; Tkachenko, V., Kwilinski, A., Klymchuk, M., & Tkachenko, I., 2019). The evolutionary design is suggested to use the lines of computer evolution models (in particular, genetic and evolutionary algorithms) and building of hybrid evolutionary models (Gonzalez et. al. 2016; Grossmann, 2007), in terms of solution of the design problems and system optimization. Thus, we generate the concept that sustainable development of the organization can be represented in the complex of elements of the application methodologies of artificial intelligence, and the advantages of those ones, which form the organizational development based on the current economic situation.

3. Methods

Various concepts and models of organizational development are realized into practice through the methods of organizational changes. To date, there is no generally recognized definition of the organizational development methods. First of all, they have the practice-oriented focus, and the authors usually developed them, based on their ideas about realization of the effective changes. The system research considers the analysis of the system and environment interaction.

4. Results

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4.1. Theoretical and methodological background of the organizational changes and development

Within frames of the study, the borderlines between the system and environment can significantly change. It appears that the organization (enterprise) is often considered as the system consisting of two main subsystems – the management and managed subsystems (Fig. 1).

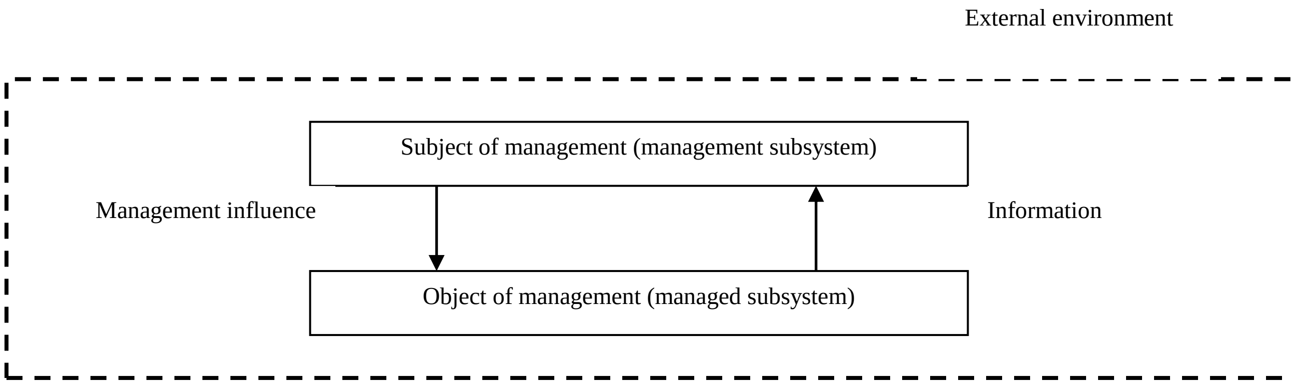

Figure 1. Cybernetic representation of the system within frames of organizational development (see Sastry, 1997)

The reporting classification allows diversifying the methods of organizational development, and provides guidance on the relationship between them. At the same time, it does not provide any answers on the issue of cause-and-effect communication between the methods. These aspects indicate the complexity of usage of the traditional technologies of economic development and econometric modeling, and put the issue of moving to the artificial intelligence technology in formation of the model of sustainable development of the organization. In the middle of modern thinking on the management of the organization development, there is the issue of adaptability and intellectualization to the constant changes of the external environment, which form the vector of sustainable development of the organization (Figure 2).

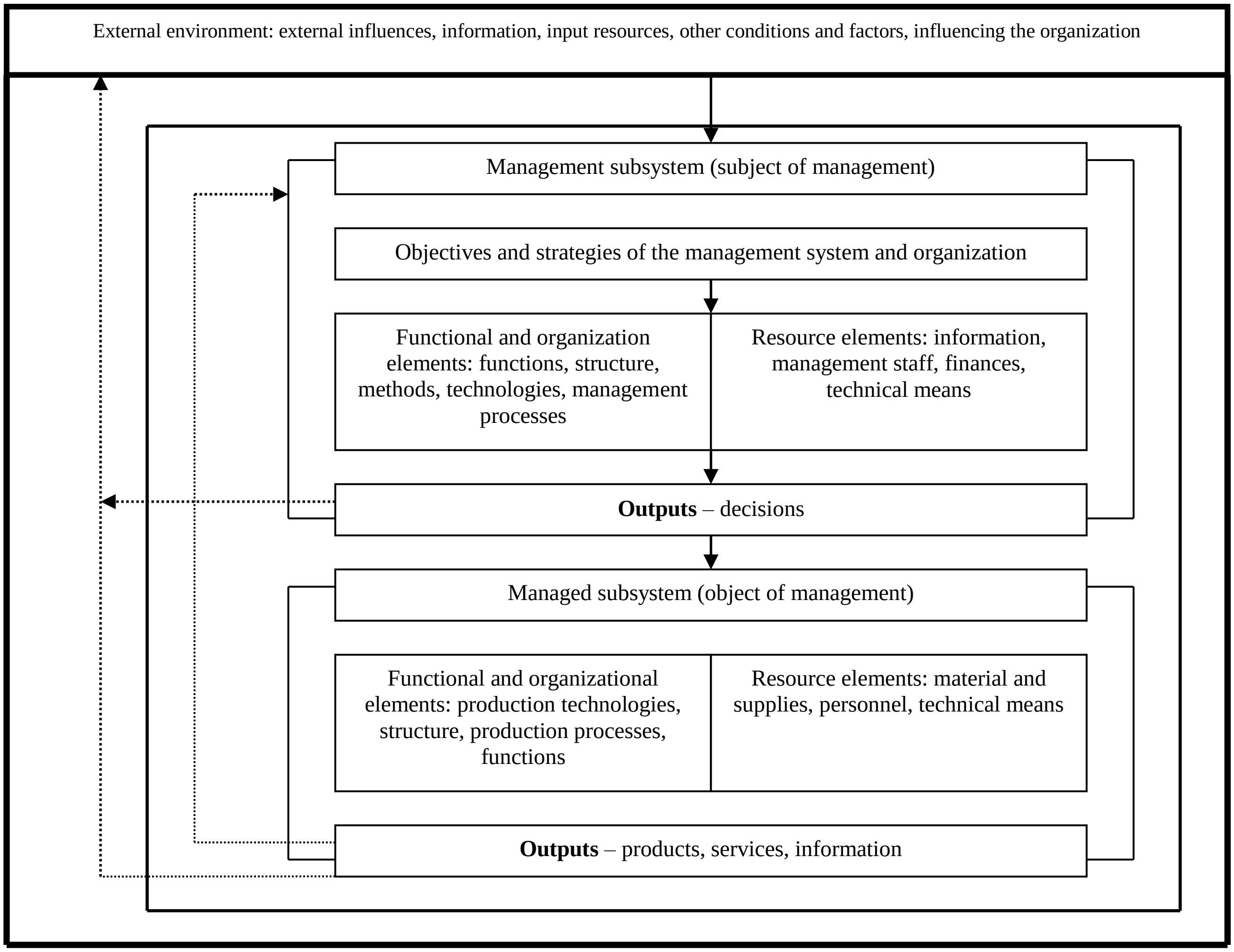

Figure 2. System view on the components of the organization development

Therefore, we shall define the method of organizational development as the set of different methodologies with the uniform nature, which application has impact on one or more subsystems of the organization, as well as changes its qualitative characteristics. All measures, taken to ensure the further achieving of the outlined objectives, are interrelated. Thus, in terms of making a decision to change the form of the organization existence, it always ultimately leads to changes in the management system - structure, processes, methods, etc. Technology variations certainly lead to formation of a new production and labour management, and contribute to provide the appropriate measures for the human resource management (Saunders et. al. 2006; Kwilinski, A. 2019).

We can maintain that application of the system approach in management issues facilitates the task of considering the organizations as open-ended systems in the unity of their components and inextricable connection with the outside world. The following definition accepted in Cybernetics serves as the generalization of ideas about management: the management shall be understood to mean the processes of information perception, processing, storage and transmission.

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Thus, any organization, which plans to develop or survive in the dynamic environment, has to work in the process of persistent changes, because its capacities of continued functioning are endangered. In such cases, the current economic environment for most organizations has such format that introduction of changes turned from emergency situation into the usual systematic process. The enterprises are forced to become flexible, constantly respond to changes in the external environment, develop and realize various local and global projects of changes in their business activities, which should develop without loss of control.

4.2. Usage of artificial intelligence technologies in the functionality of the organization

For realization of the effective performance of support systems of sustainable development of the organizations, it makes sense to apply the systems with artificial intelligence elements. It will allow making decisions based on the work of artificial intelligence models, which describe the processes of functioning at the level of qualitative concepts in formal manner. Application of artificial intelligence does not mean refusal of the traditional recommendations, methods based on the probability-theoretic view of the managerial processes of economic activities of the certain organization. Artificial intelligence models complement the traditional approaches to modeling and allow the creating of hybrid intelligence models (Staub et. al. (2015). The reporting approach somewhat simplifies decision-making and simultaneously reduces the risks.

Application of the artificial intelligence models requires the corresponding collection and processing of expert information: definition of the linguistic variables, characterizing the parameters of the management system of economic activities; formalization of decision-making rules. Expert estimations allow combining the experience and knowledge of specialists with statistical estimations, therefore they give more realistic figures. Also, the benefit of the reporting approach to modeling is that it allows estimating those situations, which would not appear in the commercial activities of the organization yet, therefore they have not been formalized at all.

In the information systems based on expert knowledge, the rules (or heuristics), which are used to make decisions in the certain subject areas, are stored in the knowledge database. The artificial intelligence system receives the tasks in the form of a set of facts, covering the certain situation, and the system uses the facts and draws the reporting conclusion aided by the knowledge database (Wixom & Todd 2005). The general structure of the artificial intelligence system based on information management is presented in the Figure 3.

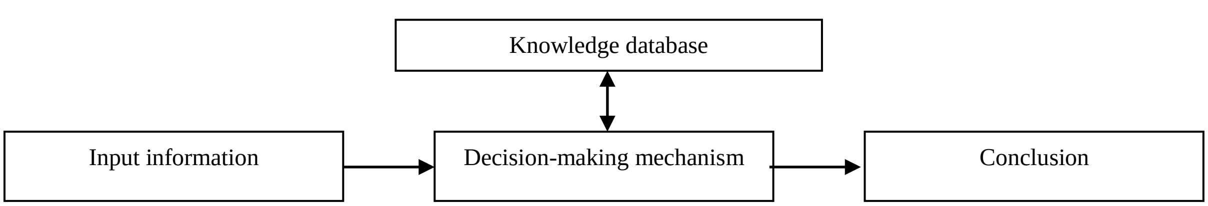

Figure 3. Model of knowledge representation, inference engine, and decision-making rules in the intelligent system

The provided model of knowledge representation, inference mechanism and decision-making rules defines the quality of expert estimations. The sizes and quality of the knowledge database (rules or heuristics) establish the following quality of expert estimations. The system operates in the following repetitive mode: selection (request) of data or research results, monitoring, interpretation of the results, uptake of new information, formation of temporal hypotheses by means of the rules, and then selection of the next amount of data or research results. The reporting process continues developing until coming of the information sufficient for providing the final conclusion on the vector of organizational development.

In the knowledge database of the intelligent system of information management, there are three types of knowledge:

1. structured knowledge – static knowledge about the subject area (once the knowledge is revealed, it does not change);
2. structured dynamic knowledge – changeable knowledge about the subject area (they start updating after new information becomes available);
3. working knowledge – knowledge applied for solution of the specific task or making consultations (Barro and Sala-i-Martin 2004).

Building of the knowledge database requires interviewing of specialists, who are the experts in sustainable development, and then systematizing, organizing, and providing of the knowledge with the specific pointers, in order to easily extract information from the knowledge database in the future.At user request, the decision-making systems should provide any advices in the situation, described by infinity of the input factors and parameters of the management system of economic activities *X1, X2 ….* X_n.

Any rule-based recommender system does not replace the person making the decisions, but only gives recommendations. The recommendations in form of the set of some decisions should most authentically correspond to the situation in the sustainable development system. Thus, the decision-making model for the management system of economic activity with fuzzy description of parameters is based on formalization of the subjective knowledge of specialists - experts.

Formation of the results of the models performance develops in the following manner (Epstein, 2015). In terms of the infinity of *X1, X2 ...* X_n for the elements *x1, x2 ...* x_n which are the parts of the corresponding base sets $x_i \in = XI$, the experts specify the membership degree of the values of fuzzy variables to the base sets. The experts formulate the rules of decision making. Then, for the time moment of t_0 the experts form decision making as the parameters of the corresponding models, and the current coordinates values of the input factors total $(x^0_{1,}x^0_{2,}....x^0_{m,}) \in X1, X2....Xn = X$. The model performance develops in accordance with the diagram from the Figure 4.

The decision-making model produces the decision y, and the user receives the output document with explanations about features of the made decision.

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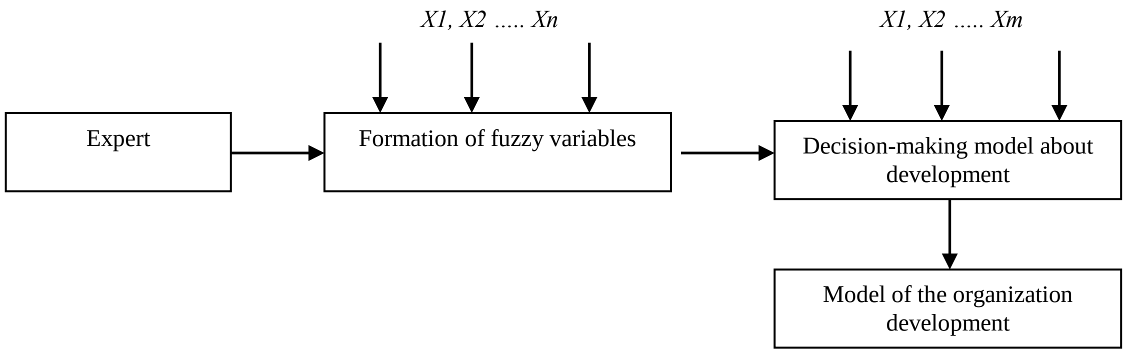

Figure 4. Decision-making model for the organizational development based on artificial intelligence technologies

In terms of making a decision, the decision maker should consider rather large number of factors, which are characterized as linguistic variables with the given term of sets (Smith, (2005). Therefore, the information management and recommendation system should consider all necessary factors as the input variables. In such case, there should be established the basic sets, syntactic and semantic rules for formation of the linguistic variable and its terms of application.

4.3. Application of neural networks in provision of the intelligent management of organizational development

Each artificial neuron forms its current state in the similar manner to the nerve cells of the brain, which can be either excited or inhibited. It has a group of synapses - unidirectional input connections, linked to the outputs of other neurons, and also has the axon - output connection of the reporting neuron, from which the signal (excitation or inhibition) enters the synapses of the following neurons. The general view of the artificial neuron is demonstrated in Figure 5.

At the first approximation, the artificial neuron simulates the features of biological neuron. Therefore, many input signals, specified as $x_{1,}^{0} x_{2,}^{0} \ldots . x_{m,}^{0}$, come to the artificial neuron. The reporting input signals, which are collectively referred as the vector *X*, correspond to the signals coming to the synapses of the biological neuron. Every synapse is characterized with the value of synaptic connection or its weight W_j.

Each signal is multiplied by the corresponding weight *w1*, *w2* ... w_n, and enters the summation unit. Each weight corresponds to "the force" of one synaptic connection. (Infinity of weights is collectively referred as the vector *W*). The summation unit corresponds to the body of biological element, algebraically summarizes the weighted inputs, and forms the value *S*.

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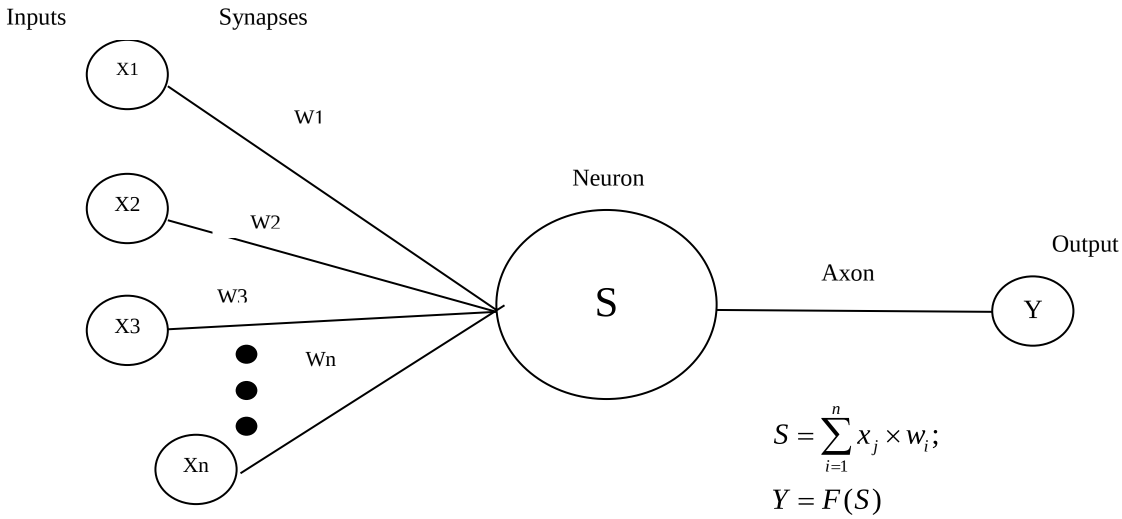

Figure 5. Model of the artificial neuron

Thus, the current state of neuron is defined as the weighted sum of its inputs:

$$S = \sum_{i=1}^{n} x_j \times w_i; \tag{1}$$

The output of neuron is the function of its state: *Y=F(S)*, where *F* is the activation function that provides more accurately simulation of the nonlinear transfer characteristic of the biological neuron, and provides great opportunities to the neural network. Although, one single neuron is able to realize the simple recognition procedures, the power of neural computations arises from the neuron connection in networks.

Large and more complex neural networks usually have the large-scale computational capabilities. Although, there were created the networks of every imaginable configuration, the layer-by-layer organization of neurons copies the layered structures of the certain parts of the brain. It turned out that such multilayer networks have more significant capabilities than single-layer networks, and for several recent years there were developed various algorithms to train them. Also, the multilayer networks can be formed in view of the cascades of layers. The output of one layer is the input for the following layer (Carley, 2003).

The neural network with backpropagation algorithm consists of several layers of neurons, moreover each neuron of the previous layer is connected to each neuron of the next layer. In most practical applications, it is sufficient to consider the two-layer neural network, which has the input (hidden) layer of neurons and the output layer (Figure 6).

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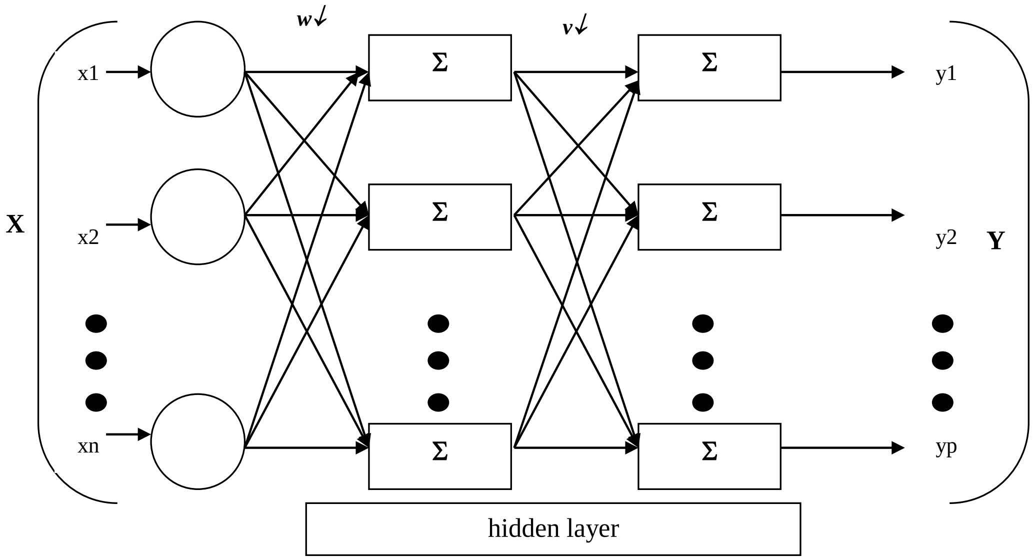

Figure 6. Neural network with backpropagation algorithm

The matrix of weight coefficients from the inputs to the hidden layer shall be denoted by *W*, and the matrix of weights connecting the hidden and the output layers – by *V*. As for indexes, we shall accept the following notations: the inputs are numbered by the index *i* only, the elements of the hidden layer – by the index *j*, and the outputs – by the index *k*. The number of network inputs is set to *n*, the number of neurons in the hidden layer – *m*, the number of neurons in the output layer – *p*. Let the network train towards the following sample $(X^t, D^t), t = \overline{1, T}$.

In terms of neural network learning, the objective is to minimize the target error function, which is located by the least square adjustment method (Chiang, (1992):

$$E(W,V) = \frac{1}{2}\sum_{k=1}^{p}(y_k - d_k)^2, \tag{2}$$

where y_k is set to the obtained real value of the *k* output of the neural network, when one of the input patterns of the sample is supplied to it;

d_k – the required (target) value of the *k* output for the reporting pattern.

The neural network learning process is done through the well-known optimization method of gradient descent, that means at each iteration step, the weight change is estimated according to the formula:

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$$w_{i,j}^{N+1} = w_{i,j}^{N} - \alpha \frac{\partial E}{\partial w_{i,j}},$$

$$v_{i,k}^{N+1} = v_{i,k}^{N} - \alpha \frac{\partial E}{\partial v_{i,k}}. \tag{3}$$

where α is set to the parameter, determining the learning rate.

Since the systems of information support of decision-making processes usually function on the basis of the analysis of expert subjective knowledge, then the important task of selection of experts shall be resolved, as well as the equally important task of the procedure of acquiring and formalizing of their knowledge within frames of the organizational development concept.

In the system of information support of decision-making processes, there can be applied different models of fuzzy inference. Among the reporting models, we shall specify the following ones, which are the subjects for study. The fuzzy inference model can be constructed on the basis of matching in form of the accurate correspondence to sets of the fuzzy situations (described by tuples of fuzzy variables), as well as the made decisions. Also, the fuzzy inference model can be constructed as fuzzy relation on the direct product of the infinity of fuzzy inference rules and the fuzzy infinity of made decisions.

It is possible to determine the so-called fuzzy pattern situations by expertise, which will be corresponded to the certain decisions. The work of the fuzzy inference model consists in identifying of some real fuzzy situations (which appeared on the object under study) for the specific point in time, finding of the most "convenient" fuzzy pattern situation for the reporting real fuzzy situation, and then form the relevant decision.

4.4. Model of the combinatorial artificial intelligence

It is well-known the decision-making model on the basis of describing of the input variables as linguistic variables, and matching process between the sets of fuzzy variables (from the terms of linguistic variables) and elements of the infinity of decisions. The reporting model is called the combinatorial model, because it defines the classes of sets of fuzzy variables corresponding to the certain decisions. The current paragraph considers the main points of the model and its application features in tasks of the fuzzy choice in the management of economic activities, and determining the growth rates of the organization (Crouhy et. al. (2006).

The input variables (factors) that determine the primary data for decision-making processes, in ensuring sustainable development, are usually given in the form of linguistic variables. The model operates in accordance with the following rules. At first, they measure (determine) the physical component value of the point $(x_{1,}^{0} x_{2,}^{0} \ldots x_{n,}^{0}) \in X$, and then substitute these values in the membership function μ_{Li} of the pattern classes L_j. Then they calculate the values $\mu_{Li}(x_{1,}^{0} x_{2,}^{0} \ldots x_{n,}^{0}),\ j = 1, |H|$. Among all values of μ_{Li}, they

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find the maximum value $\mu_{LS} = \max_j (x^0_{1,} x^0_{2,} ....x^0_{n,})$, and make the decision h_s, with the membership degree of μ_{LS}.

The further consideration of all features of building the model of sustainable development based on the combinatorial model of artificial intelligence will be realized through the example.

Let the infinity of parameters of the directions of strategic development of the organization to be determined by three components only *x1, x2 and x3*, defined on the infinity of *XI, X2, and X3*, respectively. Also, we shall define the linguistic variables describing the state changes to the infinity of *XI, X2 and X3*, as α, β, γ, respectively (Hofacker and Vetschera, (2001). Let suppose the term sets of the reporting linguistic variables:

$$T(\alpha) = \{\alpha_1, \alpha_2 ....\alpha_r\}; T(\beta) = \{\beta_1, \beta_2 ....\beta_w\}; T(\gamma) = \{\gamma_1, \gamma_2 ....\gamma_d\} \tag{5}$$

On base of the infinity of decisions *X4*, which determines the monitored range of made decisions (for example, the sum of investment in the monetary terms), we shall define the linguistic variable δ, which term infinity has the following form:

$$T(\delta) = \{\delta_1, \delta_2 ....\delta_m\} \tag{6}$$

The experts usually specify the following fuzzy sets:

$$\begin{aligned}
\tilde{C}(\alpha_i) &= \left\{ \prec \mu_{c(\alpha i)} \times \frac{x_1}{x_1} \succ \right\}, x_1 \in X1, i = \overline{1, r}; \\
\tilde{C}(\beta_i) &= \left\{ \prec \mu_{c(\beta i)} \times \frac{x_2}{x_2} \succ \right\}, x_2 \in X2, i = \overline{1, w}; \\
\tilde{C}(\gamma_i) &= \left\{ \prec \mu_{c(\gamma i)} \times \frac{x_3}{x_3} \succ \right\}, x_3 \in X4, i = \overline{1, d}; \\
\tilde{C}(\delta_i) &= \left\{ \prec \mu_{c(\delta i)} \times \frac{x_4}{x_4} \succ \right\}, x_4 \in X4, i = \overline{1, m}.
\end{aligned} \tag{7}$$

where:

$\mu_{c(\alpha i)}, \mu_{c(\beta i)}, \mu_{c(\gamma i)}, \mu_{c(\delta i)}$ are membership functions, which are formed by the expert survey method. For the classification model, the space of parameters for ensuring the organizational development is considered as three-dimensional space, which specifies the states in form of the situations defined by the sets of elements of the linguistic variables term sets α, β, γ (Wauters, Vanhoucke, (2015). The made decisions on the direction of development of the organization from the term set $T(\delta) = \{\delta_1, \delta_2 ....\delta_m\}$ of the linguistic variable δ, are corresponded to the required situations. As a result, the model will be presented in form of the situation-decision table, which general view is presented in the Table 1.

Table 1. Table of compliance "situation - decision"

α	β	γ	δ
$\alpha 1$	$\beta 1$	$\gamma 1$	$\delta 1$
$\alpha 1$	$\beta 1$	$\gamma 1$	$\delta 1$
$\alpha 1$	$\beta 1$	$\gamma 1$	δk
$\alpha 1$	$\beta 1$	$\gamma 2$	$\delta 1$
$\alpha 1$	$\beta 1$	$\gamma 2$	$\delta 3$
$\alpha 1$	$\beta 1$	$\gamma 2$	δp
αr	βw	$\gamma d - 1$	$\delta 3$
αr	βw	$\gamma d - 1$	$\delta 4$
αr	βw	γd - 1	δm
αr	βw	γd	δk
αr	βw	γd	δn
αr	βw	γd	δm

Thus, after determining parameters of the vector of organizational development and presenting these parameters in view of the point $(x^0_{1,} x^0_{2,} ....x^0_{n,}) \in X$, then we obtain the numeric values of the membership degrees $\mu_{c(\alpha i)}, \mu_{c(\beta i)}, \mu_{c(\gamma i)}, \mu_{c(\delta i)}$.

The reporting values of the membership degrees $\mu_{c(\alpha i)}, \mu_{c(\beta i)}, \mu_{c(\gamma i)}, \mu_{c(\delta i)}$ are substituted into the following formula:

$$\mu_{Lj}(\Psi) = \underset{i=1,ni}{V} \mu_{\alpha 1}(x_1) \& \mu_{\alpha 2}(x_2) \& ... \mu_{\alpha n}(x_n),$$
$$x_{\ i} \in = XI, = i = \overline{1,} nmj = \overline{1, |H|} \tag{8}$$

where:

n_i is set to the number of sets $\alpha_i^1......\alpha_n^1$, belonging to the *j*-y splitting class.

Then there should be determined the splitting class *Ls*, which has the highest value of the function μ_{LS}. After that, there is formed the recommendation on decision making h_s about beginning of development of the organization (Jin & Levitt, (1996). Also, the classification model can be realized taking into account the measures of preferential choice of the development decision.

In terms of the reporting approach, each of the possible variants S_j of combining of the organizational development parameters and possible development decisions, is matched with the advantage degree p_j, specified by the experts.

Then the table of compliance "situation - action" will take the view of the Table 2.

Table 2. Table of compliance "situation - action"

S	α	β	γ	δ	*P*
S1	α_1	$\beta 1$	$\gamma 1$	$\delta 1$	*P1*
S2	$\alpha 1$	$\beta 1$	$\gamma 1$	$\delta 1$	*P2*
Sk	$\alpha 1$	$\beta 1$	$\gamma 1$	δk	*Pk*
Sk+1	$\alpha 1$	$\beta 1$	$\gamma 2$	$\delta 1$	*Pk+1*
Sk+2	$\alpha 1$	$\beta 1$	$\gamma 2$	$\delta 3$	*Pk+2*
St	$\alpha 1$	$\beta 1$	$\gamma 2$	δp	*Pt*
Sp	αr	βw	γd - 1	$\delta 3$	*Pp*
Sp+1	αr	βw	γd - 1	$\delta 4$	*Pp+1*
Sn	αr	βw	γd - 1	δm	*Pn*
Sg	αr	βw	γd	δk	*Pg*
Sg+1	αr	βw	γd	δn	*Pg+1*
Sm	αr	βw	γd	δm	*Pm*

Decision making on the direction of organizational development is realized as follows. For the takt time t_0, there are specified the parameters of the organizational development vector in form of the point $(x^0_{1,}x^0_{2,}....x^0_{n,}) \in X$, and determined the numeric values of the membership degrees $\mu_{c(\alpha i)}, \mu_{c(\beta i)}, \mu_{c(\gamma i)}, \mu_{c(\delta i)}$. The values of the membership degrees are substituted into the formula (8), and then the splitting class *Ls* is determined, which has the highest value of the function μ_{LS}. The decisions and advantage degrees are matched to the received splitting class *Ls*. Then, there are determined the certain decision in accordance with the adopted rules. The rules can develop as follows:
1. the decision is made, based on the highest value of the degree of preferential choice:

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$$\delta_j : j = \max_l \_ p_l^i \tag{9}$$

2. the decision is chosen in a random manner from the subset of decisions, formed by the splitting class *Ls*. The subset is determined by the task of the acceptable level of values of the degrees of preferential choice, so the fixed $p_l^i{}_{dop}$ is specified by the subset P_i^*, according to the conditions:

$$p_l^i \in P_i^*, \_if \_ p_l^i \geq P_{l\_dop}^i \tag{10}$$

then the uniformly distributed number is generated within the range [0,1], and according to the scheme of random events there is chosen the single one from the infinity of decisions, which has the degree of preferential choice belonging to the subset P_i^*.

In terms of building of the decision-making systems for the management of economic activities, the advantage of the classification model consists in the ability to establish rather full compliance between the sets of fuzzy variables, characterizing the system state (the organization itself), and elements of the infinity *H* of decision making about the development parameters.

4.5. Combinatorial model of artificial intelligence for decision making about the organizational development

It is well-known the method of building of the decision-making models based on choice of decisions, taking into account the real fuzzy situations which developed on the studied object, as well as their matching with the fuzzy pattern situations. The experts specify the list of fuzzy pattern situations. Also, the experts match the combinatorial decision for each fuzzy pattern situation. The task of making a decision on development comes down to matching of the real state of the organization with the pattern states. It is necessary to specify the most convenient pattern situation of the real situation, and then in accordance with the reporting fuzzy pattern situation, there is made the combinatorial decision on the development parameters (Muggleton, (2014). The Figure 7 demonstrates the main point in work of the combinatorial model of artificial intelligence decision-making on development of the organization.

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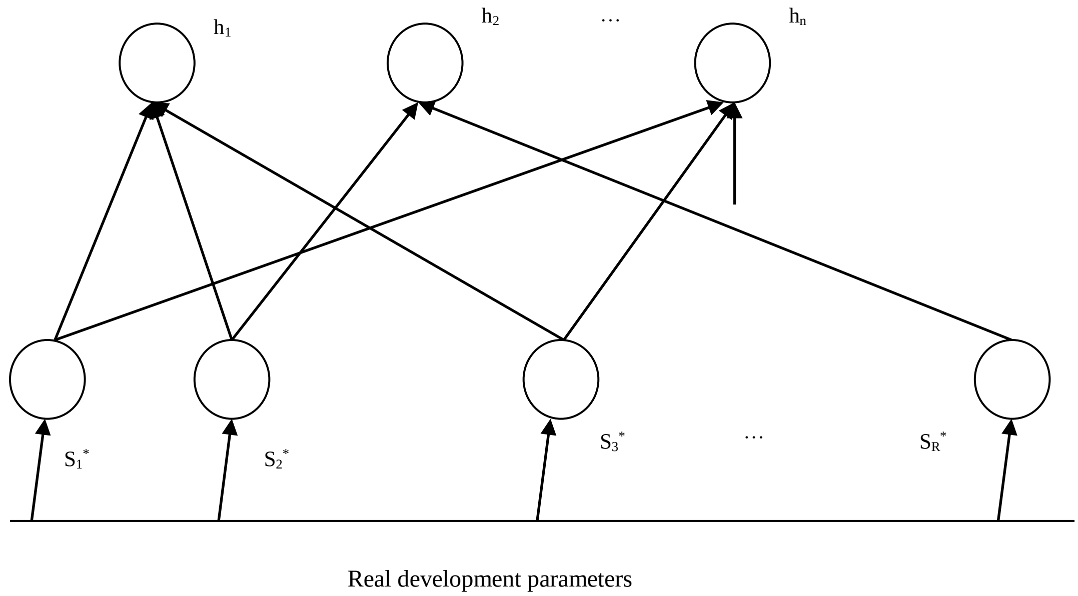

Figure 7. Real development parameters in the model of decision making artificial intelligence ((Muggleton, (2014)

The pattern situations about possible states of the organizational development are specified in form of elements of the large set $S^* = \{S_1^*, S_1^* ... S_R^*\}$, the infinity of decisions and parameters of the organizational development consists of elements *h1, h2, .., h*$_m$.

Let consider the basic foundations of fuzzy logics, which are applied to build the combinatorial model of variations of the organization development. The fuzzy situation *S* is called as the second level fuzzy set:

$$S = \left\{ \prec \mu_s \frac{\alpha_i}{\alpha_i} \succ \right\}, \alpha_i \in A \tag{11}$$

where $\{\alpha_1, \alpha_2 .... \alpha_r\}$ is set to be the *i* linguistic variable, characterizing the *i* component of the fuzzy state *S*. The set *A* has the following form:

$$A = \{\alpha_1, \alpha_2 .... \alpha_n\} \tag{12}$$

We can use the following fuzzy situation as the example, which determines the development prospects for organization: {"0.1/"large">, <0.8/"medium">, <0.4/"small"> /"guarantee of sustainable development">, "0.2/"large">, <0.6/"small">, <1.0/"medium">, <0.6/"small"> /"annual income level">, "0.3/"large">, <0.6/"medium">, <0.1/"small"> /"money saving ">}.

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The state of development prospects for the organization is characterized with some real fuzzy situation S_i. The experts specify the fuzzy pattern situations S_j for the further decision making. In order to determine the proximity degree of real and fuzzy pattern situations, we apply such operations of the fuzzy logics as specifying the degree of inclusion, determining the degree of fuzzy alignment, determining the degree of fuzzy equivalence. The degree of inclusion $S_i \rightarrow S_j$, $S_i \subset S_i^*$ is determined according to the formula:

$$\begin{aligned} &v(S_i,\ S_i^*) = \underset{y \in Y}{\&} v(\mu_{Si}(y), \mu_{Sj}(y)), \\ &v(A, B) = \underset{x \in X}{\&} (\mu_A(x) \rightarrow (\mu_B(x)), A \rightarrow B = max(1-A, B). \end{aligned} \tag{13}$$

The degree of fuzzy alignment of two fuzzy infinities S_i. and S_j^* is determined according to the formula:

$$\mu(S_i,\ S_j^*) = \underset{y \in Y}{\&} v(\mu_{Si}(y), \mu_{S*i}(y)), \mu(S_i,\ S^*{}_j) = v(S_i,\ S_j^*) \& v(S_i,\ S_j^*) \tag{14}$$

The degree of fuzzy alignment $\mu(S_i,\ S_j^*)$ is determined by:

$$\begin{aligned} &\mu(S_i,\ S_j^*) = \underset{y \in Y}{\&} v(\mu_{Si}(y), \mu_{S*i}(y)), \mu(S_i,\ S^*{}_j) = v(S_i,\ S_j^*) \& v(S_i,\ S_j^*) \\ &\mu(S_i,\ S_j^*) = \underset{y \in Y}{\&} \mu(\mu_{Si}(y_i), \mu_{S_i^*}(y_i^*)), \\ &C(\mu_{\mu_{Si}(y_i)}(T_k^i), (\mu_{\mu_{S^*{}_i}(y_i)}(T_k^i) = (\mu_{\mu_{Si}(y_i)}(T_k^i) \longleftrightarrow (\mu_{\mu_{S^*{}_i}(y_i)}(T_k^i), \\ &C(\mu_{\mu_{S1}(y_1}(T_k^i), (\mu_{\mu_{S^*{}_1}(y_1)}(T_k^i) = (\mu_{\mu_{S1}(y_1)}(T_k^i) \longleftrightarrow (\mu_{\mu_{S^*{}_1}(y_1)}(T_k^i), \\ &then\_\mu_{\mu_{Si}(y_i)}(T_k^i) \text{Ų} (1-t, t)\_and\_\mu_{\mu_{S^*{}_1}(y_1)}(T_k^i) \text{Ų} (1-t, t), \\ &C(\mu_{\mu_{Si}(y_i)}(T_k^i), (\mu_{\mu_{S^*{}_i}(y_i)}(T_k^i) = 1, \_then\_\mu_{\mu_{Si}(y_i)}(T_k^i) \in (1-t, t), \\ &or\_(\mu_{\mu_{S^*{}_i}(y_i)}(T_k^i) \in (1-t, t). \end{aligned} \tag{15}$$

The fuzzy equivalence operations are determined according to the formula:

$$A \rightarrow B = \min \{ [\max(1-A, B)], [\max(1-B, A)] \}. \tag{16}$$

Let consider the description of various fuzzy situations. In such case, the real parameters of the object shall be given as the set $X = [X1, X2 ... Xn]$.

For each parameter X_i, there is the given definition area $X(I) = [di_{\min}, di_{\max}]$, where di_{min} is set to be the minimum limit of the definition area, and di_{max} – the maximum limit of the definition area of the fuzzy variables from the term set of the linguistic variable, specified on the base infinity X_i.

According to the definition (11), the fuzzy pattern situations S_j are specified as follows. The fuzzy pattern situations have the symbol "*" located at the top right, and the symbol is not used to indicate the real fuzzy situations. The experts specify the number of fuzzy pattern situations for development of the organization $R = \left|S^*\right|$, where $S^* = \left\{S_1^*, S_1^* \dots S_R^*\right\}$ is the infinity of fuzzy pattern situations, and for every fuzzy situation S_k the experts formed the values of the membership degrees of fuzzy large quantities $\mu_{Sk(\alpha i)}$, defined for the corresponding linguistic variables (Ran Gilad-Bachrach et. al. 2016).
Following the provided expert surveys, we shall receive:

a) n is set to be the number of linguistic variables, characterizing the direction of organizational development;

b) infinity of the linguistic variables:

$$\left\{\prec \alpha_i, T(\alpha_i), XI, G_i, M_i \succ\right\}, i = \overline{1,n} \tag{17}$$

c) given fuzzy sets:

$$\tilde{C}(\alpha_j^i) = \left[\prec \mu_{\alpha_j^i} \times \frac{x_1}{x_1} \succ\right], x_{\ i} \in = XI \tag{18}$$

d) given fuzzy sets of the second level:

$$S^* = \left\{\tilde{S}^*_{k=} \left\{\prec \mu_{Sk^*} \frac{\alpha_i}{\alpha_i} \succ\right\}\right\}, i = \overline{1,n}, k = \overline{1,R} \tag{19}$$

Let consider the example of the task of the infinity S^* of the fuzzy pattern situations. In such case, the experts determined that the number $R=3$, in other words $S^* = \left\{S_1^*, S_1^* \dots S_R^*\right\}$, and the number of linguistic variables $N=5$. The experts determine the values of the membership degrees:

$$\mu_{Sk^*}(\alpha_i), k = \overline{1,5}; i = \overline{1,3} \tag{20}$$

For example, let consider that the infinity of the fuzzy pattern situations of the organization development has the form as follows: S^*{{"0.9/ "unsatisfactory">, <0.5/ "satisfactory">, <0.1/ "good" >/ "first parameter of the state">,
"0.7 / "unsatisfactory">, <0.6/"satisfactory">, <0.15 / "good" > / "second parameter of the state">, "0.6 /"unsatisfactory">, <0.7/"satisfactory">, <0.3/"good"> / "third parameter of the state"> ,
"0.4/ "unsatisfactory">, <0.8/ "satisfactory">, <0.5/"good">/"fourth parameter of the state">, "0.2/"unsatisfactory> <0.9/ "satisfactory">, <0.6 / "good"> / "fifth parameter of the state">}, {"0.5/"unsatisfactory">, <0.5/ "satisfactory">, <0.5/"good">/"first parameter of the state">, "0.4/"unsatisfactory">, <0.55/"satisfactory> <0.6/"good">/"second parameter of the state">, "0.7/"unsatisfactory">, <0.6/"satisfactory">, <0.05/"good">/"third parameter of the state">, "0.2/"unsatisfactory">, <0.75/ "satisfactory">, <0.3/"good">/"fourth parameter the state">, <<0.1

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/"unsatisfactory) ", <0.9/ "satisfactory">, <0.25/"good>/"fifth parameter of the state">}, {"0.1/"unsatisfactory">, <0.9/ "satisfactory">, <0.5/"good">/"first parameter of the state">, "0.2/"unsatisfactory">, <0.85/ "satisfactory">, <0.45/"good">/"second parameter of the state) ", "0.3/"unsatisfactory">, <0.8/ "satisfactory">, <0.4/"good">/"third parameter of the state">, "0.4/"unsatisfactory">, <0.7/ "satisfactory">, <0.35/"good">/"fourth parameter of the state">, "0.5/"unsatisfactory">, <0.6/"satisfactory">, <0.5/"good">/"fifth parameter of the state">}}.

The Figure 8 demonstrates the variant of the task of some hypothetical membership functions within frames of determining the parameters of the organization development.

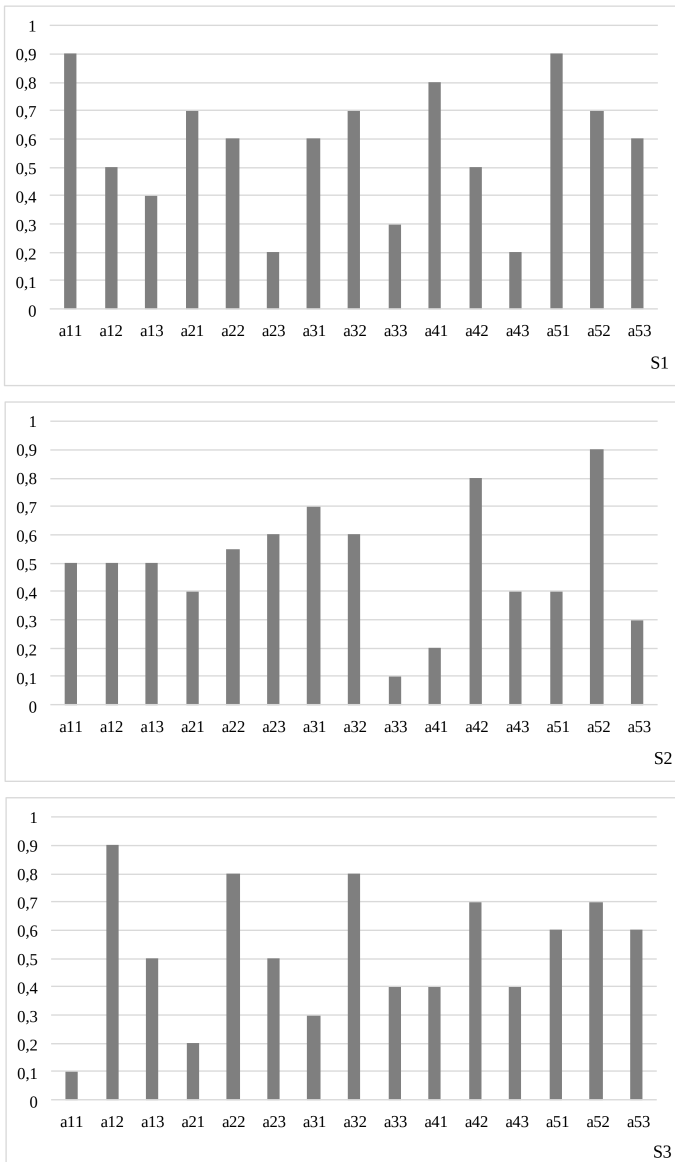

Figure 8. Variants of hypothetical membership functions within frames of determining the parameters of the organization development

It should be noted that in the general case, the membership functions have the continuous appearance. In the Figure 8 the functions have the discrete splitting, due to the fact that within frames of development of the program of the decision making system, the information-managing membership functions can not be applied in the analog form (Siau and Wang, (2018).

There can be such event, which has the given real fuzzy situation $\tilde{S}$ is not fuzzy equal to any of the fuzzy pattern situations $\tilde{S}_i^*$. In such case, the proximity of the real and fuzzy situations is determined using the concept of fuzzy entirety of the situation.
The fuzzy (*p* - *q*) entirety of the situation is set to be such similarity of situations, when the fuzzy values of all features in the situations are fuzzy equal, except for the fuzzy values of no more than *q* features (*p* – the number of linguistic variables).

The degree (*p*-*q*) – entireties $\chi_{p-q} = (\tilde{S}_{i,} \tilde{S}_j^*)$ of the situations $\tilde{S}_{i,}$ and $\tilde{S}_j^*$, which are determined as follows:

$$\chi_{p-q} = (\tilde{S}_{i,} \tilde{S}_j^*) = \underset{y \in Y/Yd}{\&} \mu(\mu_{si}(x), \mu_{si^*}(x)), \left|X_q\right| \prec q, \tag{21}$$

the feature x_k belongs to Xq, if $\mu(\mu_{si}(x), \mu_{si^*}(x)) \prec t$.

The fuzzy matching on elements of the infinity S^* of the fuzzy pattern situations and elements of the set *H* of decision making is given as the threesome of large quantities, including F as the fuzzy set in S^* x *H*.

We believe that allocation of the pattern situations in the system ensures the further sustainable development of the organization, because they are used for matching in form of the fuzzy compliance of the made decisions. It is the major advantage of the model, because in such case there is no need to specify the rules of decision making, which simplifies the adjusting procedure of the information-managing and decision making system, built with application of the model. There are possible to apply some variants of simplification of the model, which are connected, for example, with the task of the accurate correspondence between elements of the infinity of pattern situations and elements of the infinity of the made decisions on the development parameters.

5. Discussion

The recommendations of such studies can be formed in direction of the formal definition of the fuzzy selection methods in the modified selection based on the Pareto criterion, the fuzzy lexicographic selection method, the fuzzy selection by weighted criterion, the fuzzy majority selection method. New models of artificial intelligence of fuzzy cumulative-extreme selection can be built in direction of the formal definition of the fuzzy choice rules in terms of fuzzy formulation of the selection criteria for the methods of sustainable development of the organizations.

The new models of fuzzy selection allow considering the results of fuzzy selection as enclosure of fuzzy relation in the criteria space – the set of fuzzy univariate criteria that will characterize the state of the system of sustainable development. There can be formed new mechanisms of fuzzy selection, which selection function is formed from the selection functions by individual fuzzy relationships, and the selection process can take several stages. There was formally defined the mechanism of sequence fuzzy selection, and the mechanism of parallel fuzzy selection.

Conclusions

The article covered the conditions of application of the artificial intelligence technologies to build the decision making models on the directions and benchmark parameters of the organization development. It was stated that the fuzzy selection is determined by the fuzzy selection rules, which structure includes the fuzzy relations, involved in the selection process and subject to processing by the artificial intelligence model.

There were determined the variants of fuzzy inference models that can be applied in the management information system to ensure the organization development. There was developed the methodological approach for subjective decision making in form of the multidimensional model based on the combinatorial model of artificial intelligence for decision making on the organizational development. There were developed the classification model, the calculation model of the truth degree of fuzzy inference rules, the situational model of decision making, the model of fuzzy selection of decision making variants. Also, the article compared the models and described the methods of formalization of parameters in management of the organizational development.

The article developed the general requirements to simulation methods and the structure of decision making system for the systems of development management. Thus, the decision-making model for the management system of economic activity with fuzzy description of parameters is based on formalization of the subjective knowledge of specialists - experts (heads of the organization).

There was formally defined the fuzzy selection method based on the set-theoretic approach, with usage of capacities of the analysis of the fuzzy initial parameters and the fuzzy assignment of decision-making rules. The fuzzy selection method is mainly determined by the fuzzy selection rules, which logic meaning, qualitative and quantitative characteristics (components) are determined by experts.

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Aleksandra KUZIOR, Ph.D., Doctor of Science of Humanities, Associate Professor, Faculty of Organization and Management, Silesian University of Technology
ORCID ID: orcid.org/0000-0001-9764-5320

Aleksy KWILINSKI, Ph.D. (Economics), The London Academy of Science and Business, London, England
ORCID ID: orcid.org/0000-0001-6318-4001

Volodymyr TKACHENKO, Ph.D., Doctor of Science of History, Professor, The London Academy of Science and Business, London, England; Kyiv National University of Construction and Architecture, 31, Povitroflotsky Avenue, 03680, Kyiv, Ukraine.
ORCID ID: orcid.org/0000-0003-2114-7194