Management Systems
in
Production Engineering

2020, Volume 28, Issue 2, pp. 133-138

Date of submission of the article to the Editor: 01/2020
Date of acceptance of the article by the Editor: 03/2020

DOI 10.2478/mspe-2020-0020

COGNITIVE TECHNOLOGIES IN THE MANAGEMENT AND FORMATION OF DIRECTIONS OF THE PRIORITY DEVELOPMENT OF INDUSTRIAL ENTERPRISES

Aleksy KWILINSKI
The London Academy of Science and Business

Aleksandra KUZIOR
Silesian University of Technology

Abstract:
The possibilities of using cognitive technologies in the organization of systematic industrial enterprise management are described in the article. Strategic links are defined in the development of a system of stochastic models of enterprise management based on artificial intelligence. The possibility of introduction of the Perceptron model in the industrial enterprise management with the purpose of identification of "bottlenecks" in the functionality of business activity and improvement of procedures of decision-making in the framework of creation of the program of development and technical re-equipment of the enterprise is proven. The authors offered an organizational and economic mechanism of operation of an industrial enterprise, which includes new means of implementation of managerial actions through the use of a matrix of assessment of the level of implementation of cognitive technologies. The method of determining priority directions for the implementation of cognitive technologies at an enterprise was developed based on the results of the assessment of the depth of penetration of cognitive technologies and the result obtained from their implementation, which additionally takes into account the resource ratio of the implemented technologies defined as the ratio of estimates of the actual level of competencies to what is needed to work with new cognitive technologies, which allows to obtain the planned economic and organizational effect.

Key words: *enterprise management, stochastic model, artificial intelligence, cognitive model, perceptron, neural network, digital innovation, economic effect*

INTRODUCTION

Modern industrial enterprises operate in the conditions of increasing uncertainty and growing international competition. Unstable economic environment, growing consumer demands, the development of information technologies are leading to rethinking of the concepts of strategic development on the basis of advanced technologies in the field of artificial intelligence and the actualization of research in this field. In an environment that is dynamically changing, an enterprise needs to constantly assess its economic activity, financial position, degree of influence of the external environment and competitiveness [6].

The need to improve the mechanisms of operation of industrial enterprises at the introduction of artificial intelligence technologies is further confirmed by the fact that the leading enterprises of the industry today are already actively using these technologies in production and have achieved certain qualitative results. Enterprises actively involved in spreading the experience of their activities in production intellectualization are contributing to the increase in their level of revenue and their market value, and the implementation of a development strategy.

LITERATURE REVIEW

The topic of cognitive technologies is not new. However, the interdisciplinary nature of research related to the development of artificial intelligence forces us to re-examine our knowledge concerning the issues of optimization of processes as the main source of efficiency and the engine of scientific and technological progress.

In this case, the article considers the possibility of using cognitive technologies in the management and formation of directions of the priority development of industrial enterprises. This area of research involves analysis of various aspects of economic activity, not limited only to economics and management.

Among the scientists whose work, in the authors' opinion, are devoted to the problems of this article and deserve

some attention, it would like to note the following authors: [1, 2, 3, 4, 5, 6, 7, 8, 10, 11, 12, 13] and many others. The findings proved that scientific community around the world analysed the cognitive technologies and innovations in management from the different points of views: entrepreneurial activity [14]; macroeconomic stability and social progress [15, 16, 17]; artificial intelligence and new technologies [18, 19, 20, 21, 22, 23, 24, 25].
Today, the digital economy is actively developing, and in the next few years it will be the most important engine of innovation, competitiveness and economic growth in the world [12, 14, 15, 16, 17, 26]. A number of indicators is suggested to measure and define the success of countries in the digital transformation of the economy to the principles of artificial intelligence, one of which is the digital innovation index. Digital innovation contributes to the development of efficient production and service enterprises. You can consider them as one of the drivers for the efficient use of resources and sustainable industrial development. The digital innovation index rating includes 28 EU countries. Their indicators are quite different showing the success of individual member states compared to the EU average of 100. Fig. 1 shows the positions of EU countries in the digital innovation index rating as of the end of 2018.

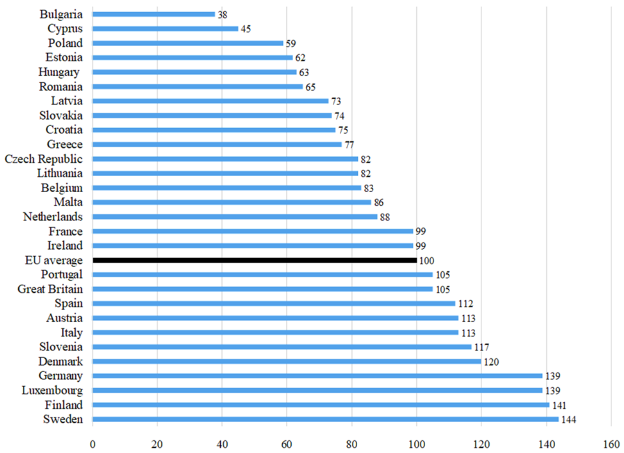
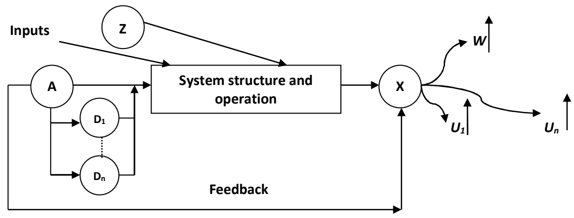


Fig. 1 Positions of EU countries in the digital innovation index rating as of the end of 2018
Source: [9]

In 2018, Sweden was at the top of the digital innovation index rating, with an aggregate index of 144, followed by Finland, Germany, Luxembourg, with indexes of 141, 139, 139, respectively, with a very small gap. These four countries, together with Denmark and Slovenia, with indexes of 120 and 117, form the group of leaders in this rating.
The paper focuses on the forming the list of measures on organization of introduction of cognitive technologies at an enterprise on the basis of the perceptron model was made with the purpose of improvement of procedures of decision-making in the framework of creation of the program of development and technical re-equipment of the enterprise.

METHODOLOGY OF RESEARCH

It is known that economic systems represented as industrial enterprises are complex, probabilistic, dynamic feedback systems (Fig. 2).
The presence of this relationship allows an active control system to adjust the management actions depending on the resulting values of the output parameters and thereby provide more efficient control and optimize the structure using artificial intelligence [8].



where: *Z* – stochastic factors; *A* – production process management body; D_1, ..., D_n – local management layers; *W* – preference scale of a management body; U_1 ..., U_n – preference scale of local management layers

Fig. 2 A general diagram of a cognitive control system of an industrial enterprise with an artificial feedback component

The suggested diagram describes in general terms the operation of any modeling object dividing it into control and operating structures. The diagram of a two-step process of enterprise management is laid in the basis and structure of a two-stage task of stochastic programming using the algorithm of artificial intelligence (Fig. 3).

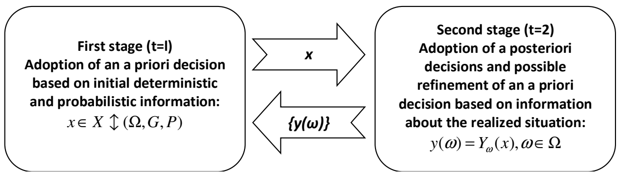


Fig. 3 Diagram of a two-stage process of enterprise management using the algorithm of artificial intelligence

In general terms, a two-stage task of stochastic programming using the algorithm of artificial intelligence is as follows:

$$\max_{x\in X} f_0(x) = \max_{x\in X}\left[\varphi(x) + M_\omega \max_{y(\omega)\in Y_\omega(x)} \varphi_0(x, y(\omega))\right] \quad (1)$$

where:
X – a convex closed finite set that specifies the area of an a priori choice of software decision *x;*
$y(\omega) = y_1(\omega), y_2(\omega)...y_n(\omega)$ – *k*-dimensional vector of an a posteriori decision in a situation $\omega \in \Omega$;
$Y_\omega(x)$ – convex closed finite sets that specify the areas in R^k of an a posteriori choice of decision in a situation through the conditions of choice of the decision *x;*
$\varphi(x)$ – function of the effect of an a priori decision *x;*
φ_0 – function of the indicator that determines the quality of the decision *x* provided that the situation *ω* is realized and the a posterior decision *y(ω)* is taken.
In this regard, in two-stage tasks, a priori decisions have the status of a strategic control, and flexible a posteriori decisions *y(ω)* make sense of tactical controls. It seems the fundamental principle of difference of step-by-step controls is the degree of their flexibility, their duration. From this point of view, for multi-step control processes, a priori $y(\omega^{t-1})$ and a posterior $y(\omega^t)$ may not differ by the

time of their action. In this case, both are referred to tactical decisions with respect to more strategic decision *x*. At that, the a priori decision *x* containing the structural parameters of the system, specifies certain limits for the adoption of flexible operational controls within the artificial intelligence component [2].

There introduced the component H_ω – the operator that maps the points of the set Y_ω into the points of the set *X* in the task (1):

$$H(\omega)y(\omega) = x; y(\omega) \in Y_\omega(x), \omega \in \Omega \qquad (2)$$

where:

the operator H_ω is the matrix of a special row-diagonal structure that reflects many tactical decisions in many strategies.

The formula (2) means that the tactical decision *y(ω)* is related to strategic *x* and that the latter specifies some framework for variations of tactical decisions *y(ω)*. The content of some inertia of strategic decisions is dictated by the structure of the task and reflects the fact that the vector *x* is independent from the chance constraints of the task at the initial stage. On the other hand, the ratio (2) reflects the fact that strategies are invariant to situation instances, and tactical decisions are flexible and can change depending on situations. In a multi-stage task, tactical a priori decisions depend on situations implemented in previous moments: $y(\omega^{t-1})$, and tactical a posteriori decisions – on situations, including the one that is being implemented at the current moment: $y(\omega^{t})$. In the suggested interpretation, the task (1) with linear constraints is written as follows:

$$\max_{x\in X} f_0(x) = \max_{x\in X}\left[\varphi(x) + M_\omega \max_{\substack{y(\omega)\in Y_\omega(x)\\ Hy(\omega)=x,\omega\in\Omega}} \varphi_0(x, y(\omega))\right] \qquad (3)$$

under conditions:

$$\begin{aligned} &1)\ A^0x \le b^0;\\ &2)\ A(\omega)x + B(\omega)y(\omega) \le b(\omega);\\ &3)\ Hy(\omega) = x;\\ &4)\ x \ge 0; y(\omega) \ge 0;\ \omega \in \Omega. \end{aligned} \qquad (4)$$

where:

f_0 – control objective function;

$\omega \in \Omega$ – random system situation in a continuous state space;

C^0 – strategic coefficient vector;

C(ω) – random tactic coefficient vector;

$A^0 b^0$ – matrix and vector, respectively, of the deterministic constraints of the first stage;

A(ω),B(ω), – random matrices of cost standards and operational technological methods, respectively;

b(ω) – random constraint vector of the second stage;

H – strategic relationship matrix; conditions: 1) deterministic constraints of a strategic vector; 2) chance constraints of tactic and strategic vectors; 3) strategic relationship.

The task (3) is known as a stochastic programming task with strategic relationships. We consider a linear two-stage stochastic task with strategic relationships and finite set Ω. For the purpose it is necessary to fulfill the following conditions [13]. Suppose that in (3) the sets *X* and $Y_\omega(x)$ are convex polyhedrons specified by the systems of linear inequalities; functions *φ(x)*, $\varphi_0(x, y(\omega))$ are linear, and the set of random situations *Ω* = {*1,2,...N*} is finite, and the situations are distributed with probability of $p_1, p_2, ..., P_n$. Then the task (3) in the full interpretation, subject to constraints, takes the following form:

$$\max_x f_0(x) = \max_x \left[C^0,(x) + \textstyle\sum_{v=1}^{N} p_v \max_{yv}(C_v, y_v)\right] \qquad (5)$$

under conditions:

$$\begin{aligned} &1)\ A^0x \le b^0;\\ &2)\ A_v x + B_v y_v \le b_v; v = 1 \dots N;\\ &3)\ Hy_v = x; v = 1 \dots N;\\ &4)\ x \ge 0; y_v \ge 0;\ v = 1 \dots N. \end{aligned} \qquad (6)$$

According to the studies conducted, it is found that any enterprise is an open system that exchanges information with the environment and is not a self-sufficient entity.

RESULTS OF RESEARCH AND DISCUSSION

In view of the foregoing, let's move on to cognitive technologies (Perceptron model) in the industrial enterprise management: methodical factor. A neural network is a complex visualized model consisting of a set of homogeneous elements – cybernetic neurons (nodes). The diagram of combining neurons into a network forms a multi-layered structure. A neural network aimed at describing the operation of an enterprise always has: one input layer, one output layer, many intermediate functional layers. The perceptron model is a neural network of a developing system with a "change management unit" [4]. The structure of the perceptron for an industrial enterprise can be three-layered and have the following form (Fig. 4).

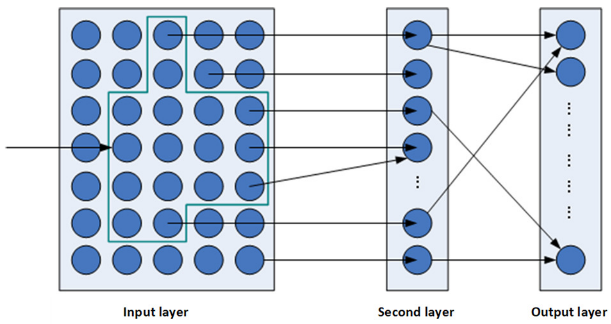


Fig. 4 Perceptron structure as a model of cognitive control in an enterprise

The specificity of the model is to describe the relationship between layers. The links between the elements of the first and second layers are established in a random manner. The linking coefficients *"e"* between the 2nd and 3rd layers are fixed. The outputs of each element have two values: 1 or 0. The flexibility of the structure of the perceptron is provided by changing the linking coefficients *"e"* between the elements of the second and third layers. In order to form a recognition perceptron, the first layer is shown these patterns. For each layer, a pattern is indicated, a response that the specified layer must generate. In accordance with the set rules, a perceptron forces to change the linking coefficients until the required management response is obtained in an enterprise [7, 10, 18, 19, 20, 24].

Neurons are combined into a network as a result of the output of the *i*-th neuron (y_i) connecting to one of the inputs (x_j) of the other *j*-th neuron. At the same time the output variable y_i ismatched with the input variable x_j. The weighting factor c_{ij} characterizes the sign and strength of the relationship between variables x_i and x_j. There is a possibility of an inverse relationship when the output of the i-th neuron connects with the j-th input of the j-th neuron. As a rule, coefficients $c_{ji} \neq c_{ij}$.

An important property of a neuron is its plasticity, that is, the ability to change parameters in the control process. We distinguish two types of plasticity: synaptic (change of c_{ij}) and neuron (change of the height of neuron threshold c_{0j}). Threshold plasticity is reduced to synaptic one with the help of the following method. To the number of inputs of the j-th neuron one more dummy x_0 is added, to the input x_0 a constant signal is sent, which is equal to +1 (Fig. 5). The weighting factor of this input c_{0j} is modified during the process management of an enterprise. The factor modification is equivalent to the shift of the neuron threshold.

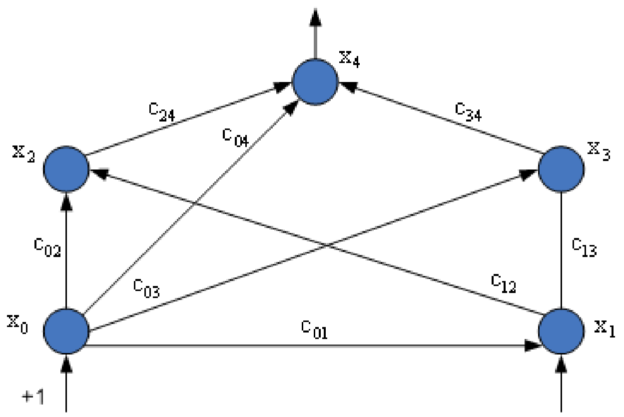


Fig. 5 Variant of the neural network for sustainable enterprise management

The rule of modification of weighting factors was proposed by a scientist D. Hebb and can be formally described as follows. Suppose the time of the management response of the enterprise is divided into cycles, and in the k-th cycle, two variable neural networks had the values of x_i^k and x_j^k. Then the weight of the link between the variables increases by the value of:

$$\Delta c_{ij}^k = x_i^k x_j^k \tag{7}$$

In the case of binary variables, the increment is either +1 (when the signs of x_i^k and x_j^k are equal) or – 1 (when the signs are different) [5]. If the initial weight of the link was 0, then the weight of the link to the p-th cycle would then be:

$$c^{pij} = \sum_1^p x_i^k x_j^k \tag{8}$$

where:

x_i^k and x_j^k are the states of two neurons in the k-th cycle;

p – number of cycles of management influence.

This way we obtain a neural network model (perceptron) that describes the process of enterprise management.

The method of determining priority directions for the implementation of cognitive technologies in an industrial enterprise establishes the basic approaches to the analysis of the reached depth of their penetration (on the basis of self-assessment), their resource support, and gives recommendations on the formation of the list of cognitive technologies for the priority implementation, which ensure the achievement of the planned organizational and economic effect [12]. Table 1 presents the variant of the final matrix of the level of implementation of cognitive technologies in the enterprise.

Table 1
Basic evaluation matrix for implementation of cognitive technologies in the enterprise

Neuron link no.	Metric (form) name	Evaluation levels			Task not appropriate for implementation
		Low (bottleneck)	Average	High	
Section 1. Assessment of the level of implementation of cognitive technologies in the enterprise					
1	Assessment of the level of automation of the stages of cognitive management taking into account the efficiency of resource support	*V*	*V*	*V*	*V*
2	Assessment of the level of automation of data transmission from the neural network to the next stage of management	*V*	*V*	*V*	*V*
3	Assessment of the level of cognitive control effectiveness in the development of new products	*V*	*V*	*V*	*V*
n		*V*	*V*	*V*	*V*

The final matrix is filled on the basis of the summary generalized estimates of economic and organizational effects of management at the enterprise (production, marketing, financial, personnel effects). In the corresponding fields of the matrix the symbol *"V"* is entered, which indicates the received estimate [3]. The calculation of the relative normalized level of implementation of cognitive technologies is performed by the formula:

$$P = \frac{3 \times n_b + 2 \times n_c + 1 \times n_n}{3(m-n)} \tag{9}$$

where:

P – relative normalized level of implementation of cognitive technologies;

n_b – number of metrics that received a high rating;

n_c – number of metrics that received an average rating;

n_n – number of metrics that received a low rating;

n – number of metrics marked in the "task not appropriate for automation" column (rated "0");

m – number of metrics in the form.

The final matrix allows to present the picture as a whole and to mark "bottlenecks" understood as the directions for the implementation of enterprise cognitive technologies that were rated as "low level". The sequence of formation of the matrix for determining priority directions for the implementation of enterprise cognitive technologies is presented in the Fig. 6.

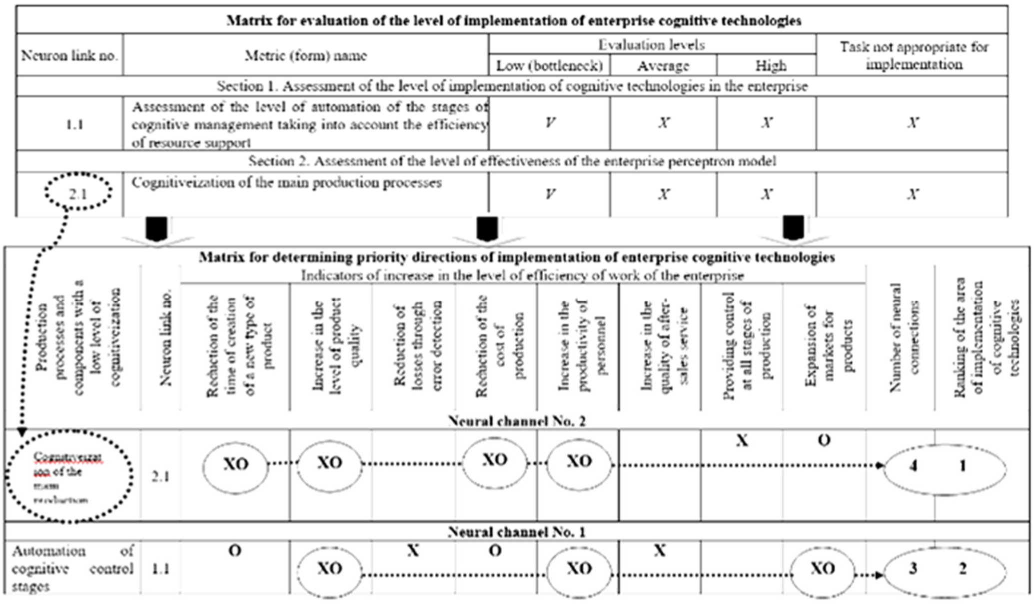


Fig. 6 Matrix form of the perceptron model for determining priority areas of functional development of an industrial enterprise

We note that in the matrix of priority areas these indicators are marked with the character "*V*". Next, we find the number of neural connections, that is, the number of nodes in each row that simultaneously contain the characters "*X*" and "*V*" and specify that number in the column of the number of neural connections [11]. The ranking of processes and components of cognitive support of production with a low rating by the importance of increasing their level for the activity of the enterprise is carried out in descending order of the number of neural connections. The tasks of improving the processes and components of digital production that have the highest number of neural connections are referred to priority tasks. The tasks that have a minimum number of neural connections within the perceptron model of enterprise management are referred to the tasks that do not require an operative decision. The creation of a matrix of priority areas of functional development allows to go to the detalization of indicators requiring increase in the number of priority tasks of enterprise development, and preparation of proposals on the composition of the necessary management measures.

CONCLUSIONS

In the paper was formed the list of measures on organization of introduction of cognitive technologies at an enterprise on the basis of the perceptron model was made with the purpose of improvement of procedures of decision-making in the framework of creation of the program of development and technical re-equipment of the enterprise. The authors offered an organizational and economic mechanism of operation of an industrial enterprise, which includes new means of implementation of managerial actions through the use of a matrix of assessment of the level of implementation of cognitive technologies. The method of determining priority areas for the implementation of cognitive technologies at an enterprise was developed based on the results of the assessment of the depth of penetration of cognitive technologies and the result obtained from their implementation, which additionally takes into account the resource ratio of the implemented technologies defined as the ratio of estimates of the actual level of competencies to what is needed to work with new cognitive technologies, which allows to obtain the planned economic and organizational effect.

REFERENCES

[1] F.R. David. *Strategic Management. Concepts and Cases.* Harlow: Pearson Education Ltd., 2013.

[2] G. Deco and B. Schermann. “A hierarchical neural system with attentional top-down enhancement of the spatial resolution for object recognition”. *Vision Research,* vol. 40, no. 20, pp. 2845-2859, 2000.

[3] I. Hofacker and R. Vetschera. “Algorithmical approaches to business process design”. *Computers & Operations Research,* no. 28, pp. 1253-1275, 2001.

[4] I. Kudelska and K. Kudelska. “Zarządzanie magazynem z wykorzystaniem sieci neuronowych”, in *Rozwój i doskonalenie funkcjonowania organizacji*. P. Pypłacz and D. Dudek, Eds. Częstochowa: Wydawnictwo Wydziału Zarządzania Politechniki Częstochowskiej, 2016, pp. 120-131.

[5] J. Łęski. *Systemy neuronowo-rozmyte.* Warszawa: Wydawnictwo Naukowo Techniczne, 2008.

[6] V. Makedon, S. Drobyazko, H. Shevtsova, O. Maslosh, M. Kasatkina. “Providing security for the development of high-technology organizations”. *Journal of Security and Sustainability Issues,* vol. 8, no. 4, pp. 757-772, 2019.

[7] S. J. Russell and P. Norvig. *Artificial intelligence: a modern approach.* Third Edition. Malaysia; Pearson Education Limited, 2016.

[8] J. Schmidhuber. “Deep learning in neural networks: An overview”. *Neural Networks,* vol. 61, no. 1, pp. 85-117, 2015.

[9] Stanford University. “One Hundred Year Study on Artificial Intelligence (AI100). Defining AI”, https://ai100.stanford.edu/2016-report/section-iwhat-artificial-intelligence/defining-ai. [Dec. 18, 2019].

[10] Z. Stęgowski. *Sztuczne sieci neuronowe,* Kraków: Wydawnictwo Naukowo-Techniczne, 2004.

[11] I.G. Vaccaro, J.J. Jansen, F.A. Van Den Bosch, and H.W. Volberda. “Management innovation and leadership: The moderating role of organizational size”. *Journal of Management Studies,* vol. 49, no. 1, pp. 28-51, 2012.

[12] M. Varmus. “Comparison of Selected Concepts Strategies”. In: *Theory of Management.* Part 1. EDIS: University of Zilina, 2009.

[13] M. Wauters, M. Vanhoucke. “A comparative study of Artificial Intelligence methods for project duration forecasting”. *Expert Systems with Applications,* no. 46, pp. 249-261, 2015.

[14] V. Boiko, A. Kwilinski, M. Misiuk, L. Boiko. “Competitive advantages of wholesale markets of agricultural products as a type of entrepreneurial activity: the experience of Ukraine and Poland”. *Economic Annals-XXI,* vol. 175, no. 1-2, pp. 68-72, 2019. https://doi.org/10.21003/ea.V175-12

[15] Y. Bilan, T. Vasilyeva, O. Lyulyov, T. Pimonenko. “EU vector of Ukraine development: Linking between macroeconomic stability and social progress”. *International Journal of Business and Society,* vol. 20, no. 2, pp. 433-450, 2019.

[16] T. Vasylieva, S. Lyeonov, O. Lyulyov, K. Kyrychenko. “Macroeconomic stability and its impact on the economic growth of the country. *Montenegrin Journal of Economics,* vol. 14, no. 1, pp. 159-170, 2018.

[17] N. Dalevska, V. Khobta, A. Kwilinski, S. Kravchenko. “A model for estimating social and economic indicators of sustainable development. *Entrepreneurship and Sustainability Issues,* vol. 6, no. 4, pp. 1839-1860, 2019. https://doi.org/10.9770/jesi.2019.6.4(21)

[18] A. Kwilinski. “Mechanism of modernization of industrial sphere of industrial enterprise in accordance with requirements of the information economy”. *Marketing and Management of Innovations,* no. 4, pp. 116-128, 2018. http://doi.org/10.21272/mmi.2018.4-11

[19] A. Kwilinski. “Implementation of Blockchain Technology in Accounting Sphere”. *Academy of Accounting and Financial Studies Journal,* vol. 23, no. SI2, pp. 1-6, 2019.

[20] A. Kwilinski, N. Dalevska, S. Kravchenko, I. Hroznyi, & I. Kovalenko. “Formation of the entrepreneurship model of e-business in the context of the introduction of information and communication technologies”. *Journal of Entrepreneurship Education,* vol. 22, no. SI1, pp. 1-7, 2019.

[21] V. Tkachenko, A. Kwilinski, I. Tkachenko, P. Puzyrova. “Theoretical and methodical approaches to the definition of marketing risks management concept at industrial enterprises”. *Marketing and Management of Innovations,* no. 2, pp. 228-238, 2019. http://doi.org/10.21272/mmi.2019.2-20

[22] A. Kuzior, A. Kwilinski, V. Tkachenko. “Sustainable development of organizations based on the combinatorial model of artificial intelligence”. *Entrepreneurship and Sustainability,* vol. 7, no. 2, pp. 1353-1376, 2019. http://doi.org/10.9770/jesi.2019.7.2(39)

[23] A. Kwilinski, V. Tkachenko, A. Kuzior. “Transparent cognitive technologies to ensure sustainable society development”. *Journal of Security and Sustainability Issues,* vol. 9, no. 2, pp. 561-570, 2019. http://doi.org/10.9770/jssi.2019.9.2(15)

[24] V. Tkachenko, A. Kuzior, A. Kwilinski. “Introduction of artificial intelligence tools into the training methods of entrepreneurship activities”. *Journal of Entrepreneurship Education,* vol. 22, no. 6, pp. 1-10, 2019.

[25] A. Kwilinski. “Mechanism of formation of industrial enterprise development strategy in the information economy”. *Virtual Economics,* vol. 1, no. 1, pp. 7-25, 2018. https://doi.org/10.34021/ve.2018.01.01(1)

[26] European Political Strategy Centre (European Commission). “The Age of Artificial Intelligence: Towards a European strategy for Human-Centric Machines”. *EPSC Strategic Notes,* no. 29, pp. 1-14, March 27, 2018. https://doi.org/10.2872/23955

Aleksy Kwilinski
ORCID ID: 0000-0001-6318-4001
The London Academy of Science and Business
120, Baker Street, London, W1U 6TU, United Kingdom
e-mail: a.kwilinski@london-asb.co.uk

Aleksandra Kuzior
ORCID ID: 0000-0001-9764-5320
Silesian University of Technology
Faculty of Organization and Management
26-28, Roosevelta Street, 41-800 Zabrze, Poland
e-mail: aleksandra.kuzior@polsl.pl