FUZZY LOGIC AND NEURAL NETWORKS APPLICATION IN ESTIMATION OF ECONOMIC SECURITY

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Abstract. The paper presents the results of estimation of the level of economic security based on fuzzy logic and neural networks algorithms. The suggested model takes into account the fact of uncertainty of external and internal threats of enterprise economic security. The basis term set was determined as "absolute", "satisfactory", "unsatisfactory" and "critical". The system of weights for initial indicators was estimated. The membership functions for each linguistic term from the initial term set were obtained. The proposed models make it possible to estimate the level of economic security, to analyze the current situation and to predict the future levels of economic security.

Key words: economic security, uncertainty, input indicators, output indicators, fuzzy logic, fuzzy inference, neural networks.

Introduction. Currently economic security of state is one of the core factors that determine the control decisions in socio-economic sphere on macro level. Moreover, economic security of state is the origin of many threats for enterprises. Such threats may cause significant losses and slow down economic growth. That is why effective development of enterprise should be based on security of its economic activity.

Today interests of socio-economic security require fair and overall monitoring of economics and society. Such monitoring should use core groups of indicators of economic security. The monitoring includes analysis and prediction of indicators and implementation of control mechanisms that reduce the level of threats or eliminate them to achieve the sustained development. Estimates of the level of economic safety make it possible to analyze effectiveness of enterprise development, find problem

segments and prevent possible future threats for business. Hence the task of constructing the models of economic security level estimation for socio-economic systems on micro level is one of the most actual nowadays. The article is aimed to construct the models of economic security level estimation for Ukrainian industry enterprises.

Literature Survey. In modern circumstances of development the majority of enterprises in Ukraine face the problem of forming and implementing the system of economic security. In modern literature there are different methodological approaches to estimation of economic security. They may be classified on the following groups: indicated, renewable, resource-functional and program-target.

Indicated approach implies the formation of the set of indicators. The indicators describe core directions of enterprise activity in different functional spheres. The level of economic security is estimated as the result of comparisons of actual and marginal values of initial indicators. Then the integral index is formed. It consists of all initial indicators with different weights. The problems of implementation for this approach are the following. The set of initial indicators should represent all possible threats. The threshold values for each indicator should be proved. The qualitative indicators should be estimated correctly.

Renewable approach only takes into account the internal indicators of enterprise development. As the result it is impossible to estimate all functional parts of economic security, to analyze the impact of external threats on enterprise. Resource-functional approach estimates the results of control actions that are aimed to reduce or eliminate the impact of current threats. Program-target approach aggregates indicators of economic security. It is based on algorithms of regression and correlation analysis and multidimensional analysis. However taking into account indicators in statics, not in dynamics, make it impossible to estimate the impact of changes in levels of threats on the level of economic security.

The above problems may be solved in case of applying the fuzzy set theory. Today the fuzzy logic is successfully applied in economic processes' modeling and forecasting. This technique allows obtain reliable estimates in conditions of complex dynamic and uncertain external environment.

The fundamentals of fuzzy logic were introduced by Lotfi Zadeh [1]. Fuzzy logic is a technique for representing and manipulating uncertain information. It is a form of many-valued logic in which the truth values of variables may be any real number

between 0 and 1. It is employed to handle the concept of partial truth, where the truth value may range between completely true and completely false. The ability to asset qualitative inaccurate and incomplete information is the essential advantage of this concept, especially in economic estimations.

Let's review examples of fuzzy logic implementations in economic research. S. M. Marushak offered the algorithm of economic security estimation for enterprise. The algorithm is based on hierarchical fuzzy systems [2]. As a result, the initial dimension of a dataset was reduced. Multidimensional dependencies between inputs and outputs of the model were described accurately. Some other algorithms were applied by T. L. Zubko [3], L. A. Ostankova and N. U. Shevchenko [4]. There are examples of constructing adaptive control systems. N. O. Ivanchenko suggests adaptive system of monitoring and control of economic security of enterprise. The system is aimed to solve complex decision making problems in conditions of fuzzy uncertainty [5]. In total, the effectiveness of fuzzy logic method as identification tool depends on the quality of initial input data set. Only then obtained results will be reliable [4-6].

The number of successful implementations indicates growing interest in this theory and shows its advantages for the estimation of economic security state. In modern researches it is quite popular to apply neural networks in economic forecasting. Artificial neural networks make it possible to analyze and predict nonlinear nonstationary stochastic processes with high level of noise. A neural network can be designed to detect pattern in input data and produce an output free of noise. The main characteristics of artificial neural networks include large-scale parallel-distributed processing, continuously nonlinear dynamics, collective computation, high fault tolerance, self organization, self learning, and real time treatment [7-10]. Because of high level of uncertainty of threats that determine the total level of economic security, the neural network may be successfully applied for predictions of economic security level.

Findings. The set of models of estimation of economic security was built for meat processing company. The first model is based on fuzzy logic algorithm and aimed to estimate the state of economic security of enterprise. The second model applies neural networks to predict the economic security level of enterprise.

Let's consider the results for fuzzy logic model. In general fuzzy logic algorithm can be defined as the nonlinear mapping of an input data set to a scalar output data.

The algorithm consists of the following stages: initialization, fuzzification, fuzzy inference and defuzzification.

During the initialization stage the linguistic variables and terms are defined and the membership functions are constructed. Fuzzification means conversion of the initial crisp data set into a fuzzy one using fuzzy linguistic variables, fuzzy linguistic terms and membership functions. During the fuzzy inference stage the rules are evaluated and the results of each rule are combined. Defuzzification means mapping fuzzy input into a crisp output using the membership functions.

The results obtained for each stage are presented below. The initial set of available indicators consists of the following ones: return on assets, product profitability, asset turnover coefficient, total liquidity coefficient, absolute liquidity coefficient, quick liquidity coefficient, own circulating assets coefficient, coefficient of autonomy. The initial series are presented in the Table 1.

Table 1. The initial series of indicators

Indicators	*Year*			
	2013	*2014*	*2015*	*2016*
Return on assets	0,06	0,45	0,14	0,08
Product profitability	0,13	1,27	0,27	0,36
Asset turnover coefficient	0,57	0,53	0,61	0,3
Total liquidity coefficient	3,36	0,74	0,85	0,61
Absolute liquidity coefficient	0,46	0,031	0,036	0,041
Quick liquidity coefficient	2,08	0,48	0,45	0,55
Own circulating assets coefficient	-0,55	-0,69	-0,031	1,39
Coefficient of autonomy	0,42	0,09	0,03	-0,15

The basis term set was determined as: “absolute”, “satisfactory”, “unsatisfactory”, “critical”. The output indicator «state» is divided into four terms: «absolute» (from 0,45 to 1), «satisfactory» (from 0,14 to 0,45), «unsatisfactory» (from 0,08 to 0,14), «critical» (from 0 to 0,06). All calculations were made in MatLab. Then we determined the system of weights for initial indicators. Next we obtained membership functions μA(x) for each linguistic term from the initial term set. The parameters of membership functions may be taken from [6]. There are different forms of membership functions such as triangular, trapezoidal, piecewise linear, Gaussian, or singleton. In this paper we use Gaussian function, because it is necessary to take into account the homogeneity of observations:

$$MF(x) = \exp\left[-\left(\frac{x-c}{\delta}\right)^2\right] \quad (1)$$

x1 – Return on assets; x2 – Product profitability, x3 – Asset turnover coefficient, x4 – Total liquidity coefficient, x5 – Absolute liquidity coefficient, x6 – Quick liquidity coefficient, x7 – Own circulating assets coefficient, x8 – Coefficient of autonomy. The results of implementation of the above fuzzy inference system are presented on Fig. 1.

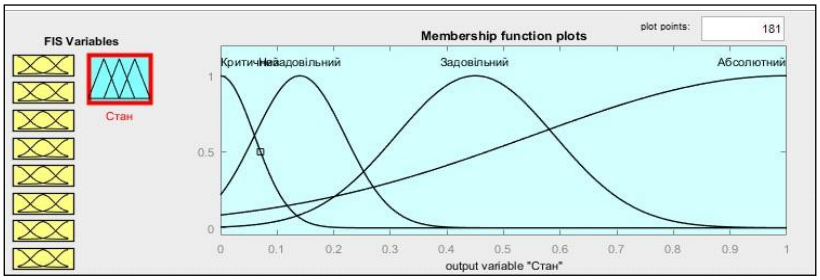

Fig. 1. Membership function for the output indicator

The obtained results are presented in the Table 2.

Table 2. Modeling results

Terms	*Indicators*			
	X_1	X_2	X_3	X_4
absolute	[0.45;1]	[1.27;1]	[0.61;1]	[3.36;1]
satisfactory	[0.14;0,45]	[0.36;1.27]	[0.57;0.61]	[0.85;3.36]
un-satisfactory	[0.08;0,14]	[0.26;0.36]	[0.53;0.57]	[0.74;0.85]
critical	[0;0.06]	[0;0.12]	[0;0.29]	[0;0.61]
	X_5	X_6	X_7	X_8
absolute	[0.46;1]	[2.08;1]	[1.39;1]	[0.42;1]
satis-factory	[0.041;0.46]	[0.55;2.08]	[-0.031;1.39]	[0.09;0.42]
un-satisfactory	[0.037;0.041]	[0.48;0.55]	[-0.55;-0.031]	[0.04;0.09]
critical	[0;0.03]	[0;0.45]	[0;-0.69]	[0;-0.15]

The economic security level for the meat processing company is 0.56 (Fig. 2). This is absolute level of economic security according to the Table 3.

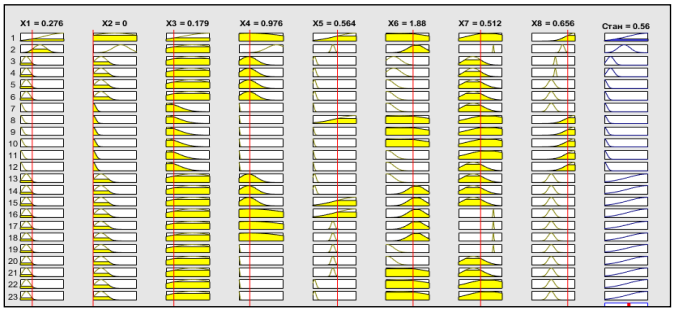

Fig. 2. The process of estimation in MatLab

Finally the output Y is calculated for certain input values of X1, X2, X3, X4, X5, X6, X7 and X8 (see Table 3).

Table 3. Final results

Indicator	*Terms*			
	absolute	*satisfactory*	*unsatisfactory*	*critical*
Y	0,45; 1	0,14; 0,45	0,08; 0,14	0; 0,06

Let's describe zones for the level of economic security. Zone 1 means the absolute economic security from current and strategic points of view. The enterprise is characterized with stable economic growth, effective resource control, the low probability of essential impact from external and internal threats. The management goal is to development of the current advantages. Zone 2 means satisfactory level of economic security. The current level of profit sufficient. But the development is unstable and sensitive to different changes in external sphere. Some changes may cause the transition into critical zone number four. The management goal is to improve efficiency of resource control and to form conditions for long-term economic security. Zone 3 is unsatisfactory zone between the conditions of security and non-security. The enterprise has the facilities for stable functioning in perspective. The management goal is to expand the current advantages to provide reproduction. Zone 4 is critical. Enterprise demonstrates unstable development and significant negative tendencies. Problems in resource control may cause reduction in production capacity. The perspective in this case is bankruptcy. The management goal is to implement urgent anti-crisis activities.

The obtained modeling results give the opportunity for optimization of the adequate bounds of the economic security level. This task is solved according to fuzzy inference system of Mamdani type. The input indicator «Return on assets» is divided into four terms: «absolute» (from 0,45 to 1), «satisfactory» (from 0,14 to 0,45), «unsatisfactory» (from 0,08 to 0,14), «critical» (from 0 to 0.06). The input indicator «Product profitability» is divided into four terms: «absolute» (from 1,27 to 1), «satisfactory» (from 0,36 to 1,27), «unsatisfactory» (from 0,26 to 0,36), «critical» (from 0 to 0,12). The input indicator «Asset turnover coefficient» is divided into four terms: «absolute» (from 0,61 to 1), «satisfactory» (from 0,57 to 0,61), «unsatisfactory» (from 0,53 to 0,57), «critical» (from 0 to 0,29). The input indicator «Total liquidity coefficient» is divided into four terms: «absolute» (from 3,36 to 1),

«satisfactory» (from 0,85 to 3,36), «unsatisfactory» (from 0,74 to 0,85), «critical» (from 0 to 0,61). It is crucial to visualize the fuzzy surface for indicators to have the opportunity of relationships analysis between them. The fuzzy surfaces for some pairs are presented on Fig. 3-4.

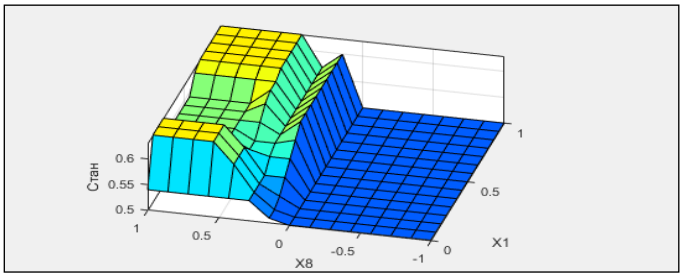

Fig. 3. The fuzzy surface for X1 and X8.

According to the obtained results the enterprise belongs to the crysis group and has the critical value of the economic security level.

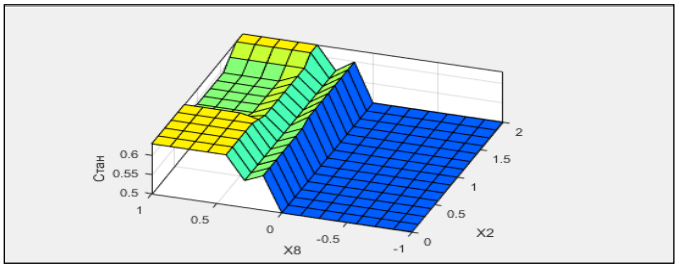

Fig. 4. The fuzzy surface for X2 and X8.

Let’s consider the results of neural network modeling. The multilevel neural network is built. It is aimed to forecast the level of economic security of enterprise. Multilevel network of estimation of economic security is presented as the system of linguistic variables. It is based on fuzzy terms. The sensitivity analysis according to quality criteria was held for different types of networks. Probabilistic and radial basis neural networks were chosen as the most preferable ones for predictions of economic security level. The error matrix was calculated for the obtained network. It makes it possible to estimate the number of truthful and not truthful observations for each indicator. The analysis of quality criteria show that the total adequacy level of model’s training is near 83%, the total adequacy level of model’s testing is near 75%. Based on these criteria the final model was determined as radial basis network. The final configuration of the network is determined as (8-20-3). The results of sensitivity

analysis show that indicators x3, x2, x7, x8 and x5 make the highest impact on the output indicator. The level of impact for x1, x6 and x4 is much lower.

Conclusions. The reliable complex of models of economic security should consist of several blocks. Each block is aimed at a solution of a particular task according to the primary goal. The primary goal may be formulated as following: to estimate the current state of economic security and to determine the satisfactory level of economic security in the forecast period. To achieve the goal, two models were suggested. The models are based on fuzzy logic theory and artificial neural networks.

The majority of researches of the problem use such methods as adaptive forecasting to obtain the estimates of future level of economic security. The task of classification is solved rather successfully by applications of the multidimensional analysis theory, such as cluster analysis and pattern recognition. But those techniques can't take into account the high level of uncertainty of external environment in which the modern enterprises act. That is why fuzzy logic theory and neural networks were applied to achieve the goal. They estimate the level of economic security, analyze the current situation and predict the future states of the enterprise in conditions of uncertainty. Modeling enterprise economic security according to fuzzy logic technique makes it possible to estimate the level of economic security, to interpret the obtained results, to optimize the acceptable quantitative bounds of economic security level. Moreover, the model proposes adequate and accurate estimates of not only quantitative but also qualitative characteristics of enterprise economic security. That is why fuzzy logic results may be used in decision making process.

Modeling economic safety of enterprise according to neural networks makes it possible to determine the type of state according to available classification with high level of reliability. The advantage of the proposed approach is the possibility to take into account probabilistic nature of the economic security, to adapt to the conditions of the functioning of the enterprise. The models make it possible to prevent critical situations in time and to decrease the level of threats. Thus, the fuzzy logic theory and neural networks applications in modeling of economic security are of great importance and value. Future research should be concerned to detecting the probability of economic security threats. It will make possible to provide different scenarios of development and to decrease the possible level of costs caused by falling into crisis state.

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