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MODEL BASIS OF INFORMATION AND ANALYTICAL SECURITY SYSTEM OF CORPORATE BUSINESS STRUCTURES

Анотація. Робота присвячена питанню розробки модельного базису інформативно-аналітичних систем безпеки корпоративних бізнес структур. Розроблено моделі оцінки загрози формування фінансових криз на різних рівнях

корпоративних структур. Побудовано моделі прогнозування фінансового стану компаній. За допомогою розробленої імітаційної моделі сформовано набір оптимальних стратегічних альтернатив.

Аннотация. Работа посвящена вопросу разработки модельного базиса информационно-аналитических систем безопасности корпоративных бизнес структур. Разработаны модели оценки угрозы формирования финансовых кризисов на разных уровнях корпоративных структур. Построены модели прогнозирования финансового состояния компаний. С помощью разработанной имитационной модели сформирован набор оптимальных стратегических альтернатив.

Abstract. The paper is devoted to the development of a model basis for information and analytical security systems of corporate business structures. Models of estimation of the threat of forming of financial crises at different levels of corporate structures have been developed. Models of the forecast of financial condition of companies have been built. Using the developed simulation model, a set of optimal strategic alternatives has been formed.

Ключові слова: аналіз, корпоративна структура, модель, оцінка, прогнозування, система безпеки, фінансова криза.

Ключевые слова: анализ, корпоративная структура, модель, оценка, прогнозирование, система безопасности, финансовый кризис.

Keywords: analysis, corporate structure, estimation, financial crisis, forecasting, model, security system.

1 Introduction

In the conditions of a dynamically developing digital economy, one of the topical directions of increasing the efficiency of systems of various purposes and levels of hierarchy is the development of qualitatively new security technologies. This is due to the fact that, along with a number of positive synergistic effects, the development of the digital economy carries specific threats and risks. In particular, in the financial and economic sphere, such risks include: an increase in the probability and an increase in

the number of speculative attacks; the depreciation of assets and a unidirectional reaction to "shocks", the effect of the epidemic. The need to monitor and prevent such specific risks and threats requires the transformation of security management systems.

The problem of improving the management of financial and economic security for business structures of the corporate sector is especially relevant, as exactly this sector has the state's prevailing share of profits, trade turnover, the employed population, etc. In particular, in Ukraine the share of the corporate sector takes more than 60% of the employed population and trade. The corporate sector of the eurozone countries makes more than 70% of investment. At the same time, the corporate sector is characterized by the highest level of losses and profitability rate volatility. Financial security and bankruptcy are the result of economic and social upheavals, supply chain disruptions, reduced sales, unemployment, social tensions, etc. Therefore, the focus of modern research is to develop a model basis for information-analytical security systems that allow for the earlier detection of threats of a financial crisis and allow to develop a set of preventive measures aimed at eliminating them and ensuring an acceptable level of financial security.

It should be noted that the pleiad of eminent scientists was successfully engaged in the problem of developing security systems at different levels of the hierarchy. Significant achievements in the development of the categorical basis of the security system mechanisms belong, in particular, to such scientists as O. Baranovsky (2004), M. Yermoshenko (2001), S. Shkarlett (2007), V. Senchagov (2005) and others. V. Geyets (2006), T. Klebanova (2004, 2006), I. Lukyanenko, M. Oliskevich (2017), V. Ponomarenko (2004), R. Rudensky (2009), N. Chernova (2004, 2006), A. Chernyak (2006) and others successfully deal with applied problems related to various aspects of security systems modelling.

Thus, the researches of V. Geyets (2006), T. Klebanova (2004, 2006, 2014), E. Piskun (2014), I. Lukyanenko, M. Oliskevich (2017), V. Ponomarenko (2004), A. Chernyak (2006), Lidiya Guryanova, Stanislav Milevskiy, Lyudmila Bogachkova, Iryna Lytovchenko, Vladislav Polyanskiy (2017) are devoted to the development of models of security mechanisms for systems of different levels of hierarchy, which

include models of the formation of a system of diagnostic security indicators, integrated security assessment, prediction level of threats, security level of the state, region, business structure. In the work of R. Rudensky (2009) the structure of the model basis of the anticipate safety management system was proposed.

In the works of Berneti, S. (2011), Javier De Andres, Pedro Lorca, Francisco Javier de Cos Juez, Fernando Sánchez-Lasheras (2011), Ning Chen, Bernardete Ribeiro, Armando Vieira, An Chen (2013), a method of fuzzy c-means and self-organizing maps of Kohonen are used to classify financial situations and to choose differentiated strategies for financial stabilization. Researches presented in the works of Ko, Yu-Chien (2017), Davidenko N.M. (2012), Matviychuk A.V. (2010), Li S. (2014), Brezigar-Masten A., Masten I. (2012), Klebanova T.S., Chahovets L.O., Panasenko O.V. (2011), Zarei M., Rabiee M., Zanganeh T. (2011), Bahia I. (2013), L. S. Guryanova, T. S. Klebanova, T. N. Trunova (2017) consider the application of methods of discriminant analysis, logit, probit analysis, neural network modelling, fuzzy logic theory for identifying and forecasting the class of financial situations of the security of the enterprises.

Publication of T.S. Klebanova, L.S. Guryanova, I.K. Shevchenko (2014) addresses the development of models for the mechanism of early informing and preventing of the threats in multi-level systems. In the work of Guryanova L.S., Klebanova T.S., Milevskiy S.V., Nepomnyaschiy V.V., Rudachenko O.A. (2017), models of analyzing the dynamics of safety indicators are presented, allowing to identify system components that at certain stages help to increase the overall level of security or, vice versa, create additional threats. The works of A. Roes, R. Glick, (1997), G. Corsetti, M. Pericoli, M. Sbracia, (2005), R. Esprinoza, A. Prazad (2010), touch upon the problem of assessing the effect of infection, analyzing the prolonged impact of threats, identifying the most likely channels of crisis infection.

Crisis development tendencies led to a wide dissemination of researches related to the justification of the financial strategy and the optimization of the financial performance of the enterprise in the conditions of threats. Zelenkov Yuri, Fedorova Elena, Cherkizov Dmitry (2017), Niccolò Gordini (2014) proposed to use genetic

algorithms to optimize the parameters of the financial strategy in order to prevent the transition of enterprises to a class of financial crisis (bankruptcy). Combined optimization and simulation models of financial activity are considered in the works of Klebanova T.S., Guryanova L.S., Kononov O.J. (2006), Barannikov V.V. (2008).

It should be noted that, despite the effectiveness of the approaches proposed by the authors named above, the works do not touch upon the issues of predicting the financial security of corporate business structures. Such structures are characterized by large volumes of accounts payable and receivables, related, in particular, to intrasystem lending; they finance the execution of works, both on system-wide projects, and on local projects of individual companies, etc. The use of traditional approaches to predict the level of financial security of corporate structures reveals their poor prognostic accuracy.

Also, in the mentioned above works insufficient attention is paid to the problem of the complex improvement of the financial management system of corporations. In most cases, the central issue is the development and implementation of tools for local diagnosis of crisis phenomena in individual enterprises. The issues of evaluating the impact of local financial crises on the financial state of the corporate structure as a whole, of predicting the financial crises of the corporate structure with the aim of preventing or localizing the consequences are poorly considered. Due to this, the development of a model basis of the mechanisms of informational and analytical security systems is an urgent way to improve the efficiency of financial activities of corporate business structures.

2 Main modules of information and analytical security system of business structures

The information-analytical security system of business structures offered in the work includes the following main modules:

Module 1. Estimation of threats to the financial security of the corporate business structure. Target orientation of the module is: analysis of the financial condition of the corporation; analysis of the financial condition of subsidiary enterprises (SE);

assessment of the impact of the financial crisis on the SE on the threat of bankruptcy of the corporation as a whole.

Analysis of the financial condition of the corporation involves the solution of such tasks as the forming of an information space for the characteristics of the financial security of corporate business structures; substantiation of classes of financial conditions of the corporation; estimation of the threat of a crisis; identification of the class of financial crisis. These problems are solved using expert, cluster analysis, multiple choice models and neuro-fuzzy networks (Klebanova T.S., Gvozdytskyi V.S., Labunska S.V., Yermachenko I.V., 2018).

During analysis of the financial conditionan estimation of the threat of the crisis and identification of the crisis class at SE, assessment of deviations of financial indicators from the normative values are carried out. The solution of these tasks is based on the neuro-fuzzy approach.

Evaluation of the impact of the financial crisis at SE on the threat of bankruptcy of the corporation assumes the analysis of the nature of the relationships between SE and parent enterprises, the financial flows between all corporate structural units; forming of linguistic terms and rules of recognition; the calculation of evaluation of the crises impact at SE on the threat of bankruptcy of the corporation. To implement these tasks the theory of fuzzy logic is used.

The model basis of the module 1 includes *model M1 – model of estimation the threat of forming of financial crisis in a corporation; model M2 – model of estimation the threat of forming of financial crisis at the subsidiaries of the corporate structure; model M3 – model of evaluation of the impact of crisis events at the subsidiaries on the financial condition of the corporation.*

Module 2. Forecasting the financial condition of SEs and of corporation as a whole. In this module, financial indicators are diagnosed, the levels are synthesized, and the threat of the crisis at the subsidiaries and the corporation as a whole is estimated in perspective period. The solution of the tasks of this module is carried out using the "Caterpillar" method. The model basis of the module is formed by *models M4 – models*

of forecasting the financial indicators (Guryanova L.S., Gvozdytskyi V.S., Dymchenko O.V., Rudachenko O.A., 2018).

Module 3. Anti-crisis management. In this module, the development of the anti-crisis management scheme is carried out, optimal anti-crisis measures are determined, and the quality of measures is assessed. These tasks are solved with the help of decision-making methods, additive convolution, simulation modelling and system dynamics. The model basis of the module is formed *by models M5 – models of forming of strategic security alternatives* (L. S. Guryanova, T. S. Klebanova, T. N. Trunova, 2017).

Thus, suggested above modules support the implementing of proactive anti-crisis management in a corporation which is aimed at preventing the emergence of a crisis state, both in individual elements and the corporate system as a whole.

The developed model basis was tested in the activity of corporate business structures. The model of estimation of the threat of a crisis at the parent enterprise of the corporation (model M1) was built on the basis of 36 non-state parent enterprises of the corporate structures of the agricultural sector of Ukraine, of which 12 are bankrupt, and 24 belong to sustainably functioning corporations. The model of estimation of the threat of forming of financial crises at subsidiaries (model M2) was built on the basis of 40 non-governmental subsidiaries of Ukrainian agricultural corporations, of which 24 belong to normally functioning enterprises and 16 belong to the class of bankrupts. These models were tested in the activities of the parent enterprise of the agricultural corporation and of its 5 subsidiaries. Models M3-M5 are developed on the basis of data from the parent enterprise and subsidiaries of corporate structures.

3 Neuro-fuzzy models of the estimation of the threats to financial security in corporate structures

In accordance with the above content of the modules of the proposed information-analytical system in the *first module* at the first step of the research such task was carried out as the formation and justification of the information space for research. The a priori list of factors that affect the threat of crises included 36 financial indicators divided into 5 groups. To reduce the information space posteriori list of

indicators was obtained by expert evaluation which presents the most important indicator in each of 5 groups. The values of the consistency coefficients of experts' opinions are given in Table 1.

Table 1

Dividing the values of the estimates of Y into clusters

Characteristic	Dividing into			
	3 clusters	4 clusters	5 clusters	6 clusters
Number of objects in clusters	cluster 1 – 5 objects cluster 2 – 13 objects cluster 3 – 59 objects	cluster 1 – 5 objects cluster 2 – 12 objects cluster 3 – 10 objects cluster 4 – 50 objects	cluster 1 – 4 objects cluster 2 – 4 objects cluster 3 – 10 objects cluster 4 – 32 objects cluster 5 – 27 objects	cluster 1 – 10 objects cluster 2 – 4 objects cluster 3 – 1 object cluster 4 – 3 objects cluster 5 – 32 objects cluster 6 – 27 objects
The value of the total intragroup variance	47,39	43,36	41,23	43,20

The values of the concordance coefficient which vary in the range from 0.6 to 0.8, the results of estimating the statistical significance of the coefficients made it able to conclude that the results of the examination can be used in further research. Thus, the final system of indicators, which was used to construct the neural-fuzzy *model M1*, included the following indicators: X1 – the coefficient of usefulness of fixed assets; X2 – quick liquidity ratio; X3 – coefficient of financial autonomy; X4 – turnover ratio of assets; X5 – profitability of activity.

As the resultant variable Y of the neural-fuzzy model M1, the estimation of the threat of the formation of a financial crisis in the corporation is used. To scale the values of the Y estimator, a cluster analysis was performed. A comparative analysis of the quality of different variants of partitioning the original population into 3, 4, 5, and 6 clusters obtained using the k-means method showed that the best partition is the partitioning into 5 clusters.

The values of the functional of the decomposition quality – the total intragroup dispersion – are given in table 1. The resulting partition was used as the basis for

interpreting the scale of Y values: 1 - the threat of a crisis is very low; 2 - low level of threat; 3 - average threat level; 4 - high level of threat; 5 - a very high level of threat to the loss of financial security.

The construction of the neural-fuzzy model of estimation of the threat of financial crises at the parent enterprise of the corporation was carried out in Matlab package. Input parameters (input) of the model are five selected indicators X1-X5, the resultant variable (output) is an estimation of the threat of crisis forming (Y). The structure of the fuzzy inference system (FIS) was generated in the packet of the selected type (Sugeno). Based on the results of the research, the number of linguistic terms (for all 5 inputs) and the type of membership functions have been chosen by the selection method to achieve the best results of constructing the model (obtaining the least error). Thus, for each of the input variables X1-X5, 3 linguistic terms were assigned; the triangle type was chosen as the type of membership functions. The rules of fuzzy inference were formed automatically; each fuzzy rule is checked on the logical and theoretical economic content, on the lack of contradictions. So, all the formed rules turned out to be adequate, and there is no need for their editing. Thus, the structure of the generated Sugeno fuzzy inference system has the following form: it contains 5 input variables (input1 = X1-input5 = X5), 15 terms (3 terms per input variable), 243 fuzzy rules, 1 output variable Y, 243 terms of output variable. To train the neural network, a hybrid method was chosen that is a combination of the least squares method and the method of decreasing the inverse gradient, and 40 training cycles were established. Testing of the constructed neural-fuzzy system showed that the average error is 0.10985%. Thus, it is advisable to use the constructed model in further research.

In particular, based on the model, it was determined that the value of the resulting variable Y at the end of the period under study for the analyzed agricultural corporation is -0.541, i.e. the probability of bankruptcy of this enterprise is very low.

In the second stage of the research a model of estimation the threat of crisis forming at corporate subsidiaries was constructed (*model M2*). A tool of neuro-fuzzy networks was used, and a corresponding model was constructed in a similar way. It should be noted that to construct a neural-fuzzy model, the trapezoidal functions of the

input factors and the linear type of the membership function of the initial (resulting) variable were used, since this combination made it possible to obtain the smallest prediction error equal to 0.0012%.

The dynamics of the change in the value of the threat of financial crises forming at the subsidiaries of the corporation showed that the most problematic are enterprises No. 2 and No. 4, which during the past four years had an increase in the threat of bankruptcy. The enterprise No. 3 is also at risk, which has a sharp increase in the complex indicator of the threat of bankruptcy by the end of the period. Thus, for three out of five subsidiaries, the probability of bankruptcy is estimated as average and very high, which leads to the need to investigate the impact of the situation on the financial condition of the corporation as a whole and the development of adequate preventive measures.

In the third stage of the research the evaluation of the impact of the threats of crisis forming at subsidiaries on the probability of bankruptcy of the corporation as a whole was carried out. As it was said above, the mathematical apparatus of fuzzy logic is used to construct *M3 model*. Denote by V a complex indicator of the degree of influence of subsidiary's financial condition on the overall corporation's condition. The higher value of the V – the higher the degree of influence. This complex indicator takes values in the range from 0 to 1. The system of indicators for evaluation the impact of crisis threat at subsidiaries on the financial condition of the corporation as a whole was selected on the basis of an analysis of corporate performance and statistics of bankruptcy procedures. This system of indicators includes: X1 – the share of subsidiary's revenue in the corporation; X2 – the nature of production links; X3 – the presence of subsidiary's granddaughter companies; X4 – the share of subsidiary's authorized capital in the corporation; X5 – the share of external accounts payable. Herewith, the factor "X2" can take one of three values: "0" – with the object type of the production structure (if an enterprise produces and sells finished products independently, and does not transfer its products to the following enterprises in the chain of production of the corporation's finished products) "1" – with the technological type (if the enterprise produces the products which are necessary for the ordinary

production of another enterprise in the corporation),"2" – with a mixed type. Factor "X3" can take two values: "0" – if the enterprise does not have subsidiaries; "1" – if it has.

The set of membership functions (of a trapezoidal type) of complex indicator V is given as follows:

$$\mu v1=(0; 0; 0.15; 0.25);$$

$$\mu v2=(0.15; 0.25; 0.35; 0.45);$$

$$\mu v3=(0.35; 0.45; 0.55; 0.65);$$

$$\mu v4=(0.55; 0.65; 0.75; 0.85);$$

$$\mu v5=(0.75; 0.85; 1; 1),$$

where μv1-5 are the membership functions of the indicator V, which correspond to all variants of the corporation's dependence on subsidiary: from almost its absence (μv1) to the maximum (μv5).

For the chosen indicators of the financial condition of the enterprise Xi, the linguistic variables Li "Level of indicator Xi" were set (5 subsets of levels from "very low" to "very high"). The levels of the values of the selected indicators and the corresponding membership functions are shown in Table 2.

Table 2

Rules for recognizing the degree of influence of the threat of the emergence of crisis events at the subsidiaries on the bankruptcy of a corporation

Value Range	Degree of influence	The membership function
0<=V<=0.075	Very low (V1)	1
0.075<V<0.125	Very low (V1)	μ1=10*(0.25-V)
	Low (V2)	μ2=1- μ1
0.125<=V<=0.17	Low (V2)	1
0.17<V<0.2	Low (V2)	μ2=10*(0.45-V)
	Medium (V3)	μ3=1- μ2
0.2<=V<=0.35	Medium (V3)	1
0.35<V<0.4	Medium (V3)	μ3=10*(0.65-V)
	High (V4)	μ4=1- μ3
0.4<=V<=0.6	High (V4)	1
0.6<V<0.65	High (V4)	μ4=10*(0.85-V)
	Very high (V5)	μ5=1- μ4
0.65<=V<=1	Very high (V5)	1

The calculated values of the complex indicator of the degree of influence of threats to the formation of crisis events at SE on the financial condition of the corporation as a whole are presented in Table 3.

Table 3

Recognition of the degree of influence of enterprises on the financial condition of the corporation

Enterprise	Value of V	Degree of influence	The membership function
Enterprise №1	0,57	*High*	*1*
Enterprise №2	0,43	*High*	*1*
Enterprise №3	0,23	*Medium*	*1*
Enterprise №4	0,37	*Medium*	*0,13*
		High	*0,87*
Enterprise №5	0,24	*Medium*	*1*

As can be seen from Table 3, all five investigated subsidiaries of the have a significant impact on the financial condition of the corporate structure as a whole. Enterprise No. 1 is the core of the entire corporation. This enterprise accounts for 70% of the total corporate revenues. Enterprise No. 2 ranks second in this indicator, but it shows a significant increase in production and sales of products over the past few years. Enterprises No. 3-5 occupy a small share in the corporation's revenues. The main goal of incorporating these enterprises into the corporate structure is to provide the leading enterprises with the necessary raw materials: different grains and sugar. Deepening the crisis at one of these enterprises will necessarily affect the activities of the two main profitable factories of the corporation, and this, in turn, will provoke the deterioration of the financial condition of the whole corporation.

Thus, the constructed model allows to adequately evaluate the impact of the crisis threat at SEs on the corporation condition. Based on the results of modelling, all enterprises have a significant impact on the financial condition of the corporation. Taking into account the fact that the threat of bankruptcy of the enterprise No. 4 is very high based on the results of the simulation of the crises threat estimation at SEs, then the efficiency of this particular subsidiary should be given the greatest attention by the

corporation management. In order to adequately assess the possible threats to the corporation, it is necessary to predict the future condition of each subsidiary and how the forecasted situation at subsidiaries will affect the financial condition of the corporation as a whole.

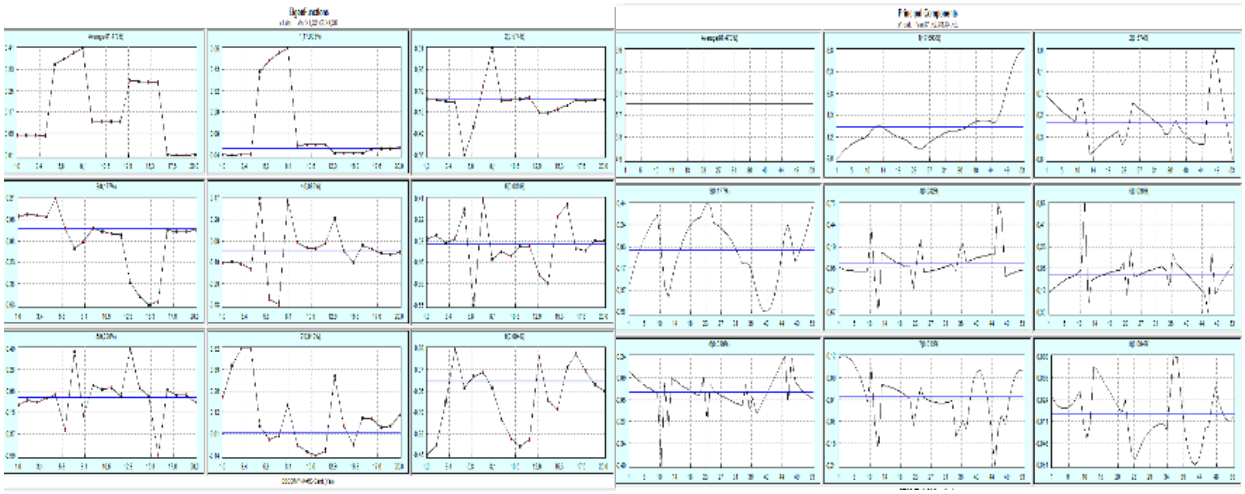
4 Models of forecasting financial indicators of the corporate business structure

In the *second module* the construction of models of forecasting the financial indicators (*model M4*) is carried out. The "Caterpillar" method is used as a tool for forecasting. The choice of this method for studying the structure of time series is explained by the fact that it combines the advantages of many other methods, in particular, Fourier analysis and regression analysis. The essence of the method consists in converting one-dimensional series into multidimensional using one-parameter displacement procedure; in study of the obtained multidimensional trajectory on the basis of analysis of the principal components (singular decomposition); in recovery (approximation) of the series for selected main components.

Forecasting using the caterpillar method was carried out in Caterpillarssa 3.4 software package. Note that realization of the method was carried out simultaneously for all series (X1-X5), as they have the same dimension. This program allows conducting multi-dimensional research.

Based on the results of the analysis of the chart of the initial series of financial indicators of enterprise No. 1 and of the series of average covariances, it was concluded that the series have an annual periodicity, that is, the length of the track must be a multiple of 12. For this case, it is advisable to select a track length of 4. A centering procedure was also carried out.

For the analysis of the principal components (PC), in the caterpillar method analysis of the characteristics of eigenvalues and eigenfunctions of the covariance matrix is used. One-dimensional graphs of the eigenfunctions and of PC are shown on Fig. 1.

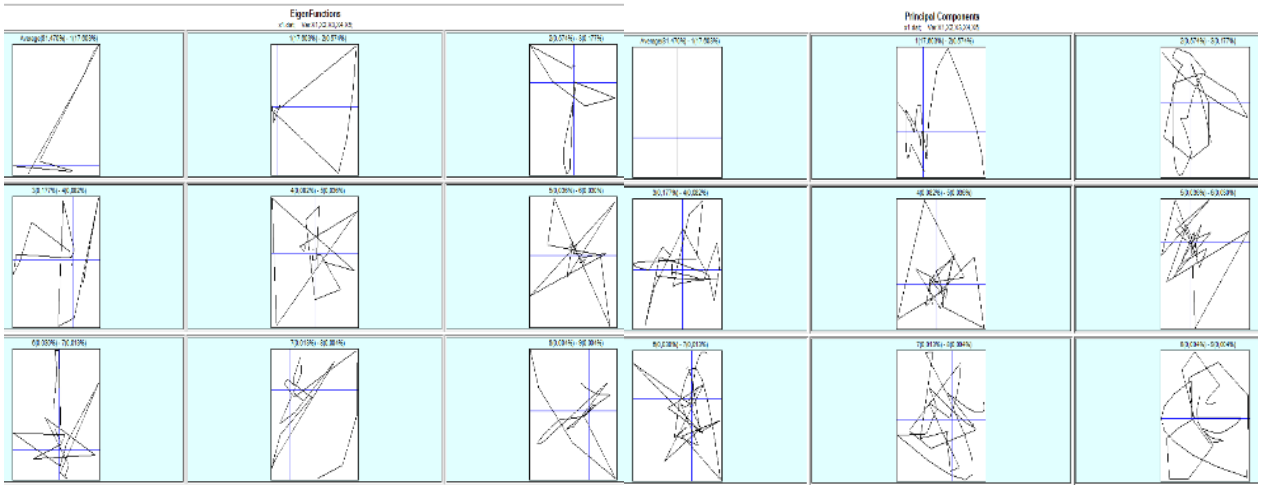


a) of eigenfunctions b) of principal components

Fig. 1. One-dimensional graphs of eigenfunctions and PC

Based on the results of visual analysis of one-dimensional graphs (Fig. 1), it is impossible to infer whether a certain PC is a component of the trend. That is, all pairs of PC can be regarded both as a trend and as a low-frequency component. The most obvious is the presence of a semiannual (PC 3-6) periodicity.

To facilitate the partitioning of PC into pairs, two-dimensional graphs of eigenvectors and of principal components are used (Fig. 2).



a) of eigenfunctions b) of principal components

Fig. 2. Two-dimensional graphs of eigenfunctions and PC

The harmonic component with an entire period is represented as a regular polygon with the number of vertices equal to the period value. When the amplitude

changes, the polygon turns into a spiral. Reconstructed results of the time series are shown on Fig. 3.

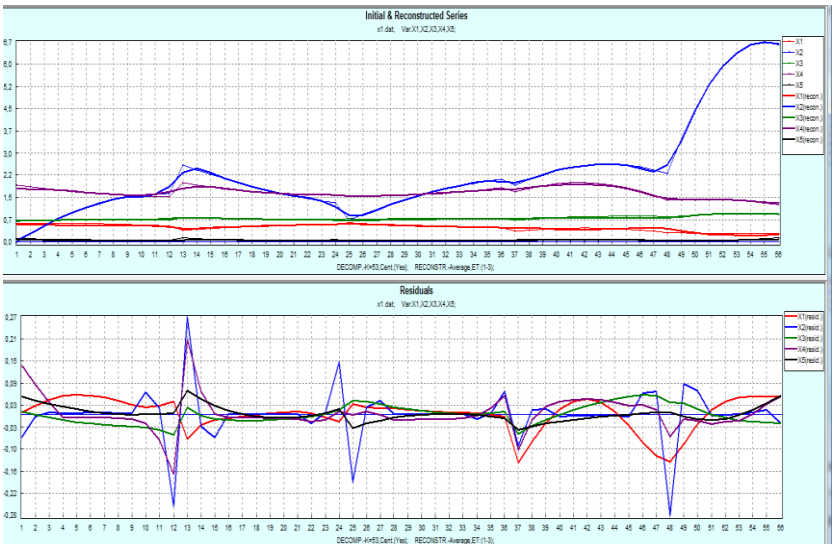


Fig. 3. Recovered values and errors

As can be seen from the figure, the initial and reconstructed series practically coincide, since the share of the first three PC together with mean in the dispersion of the series is 99.8%. The mean absolute percentage error of approximation for the time series of indicators X1-X5 equals appropriately 7.78%; 2.15%; 2.59%; 1.80%; 5.70%, which allows us to speak about high accuracy of the forecast. Point and interval forecast of financial indicators for the period of anticipation, equal to 12 months, is shown on Fig. 4.

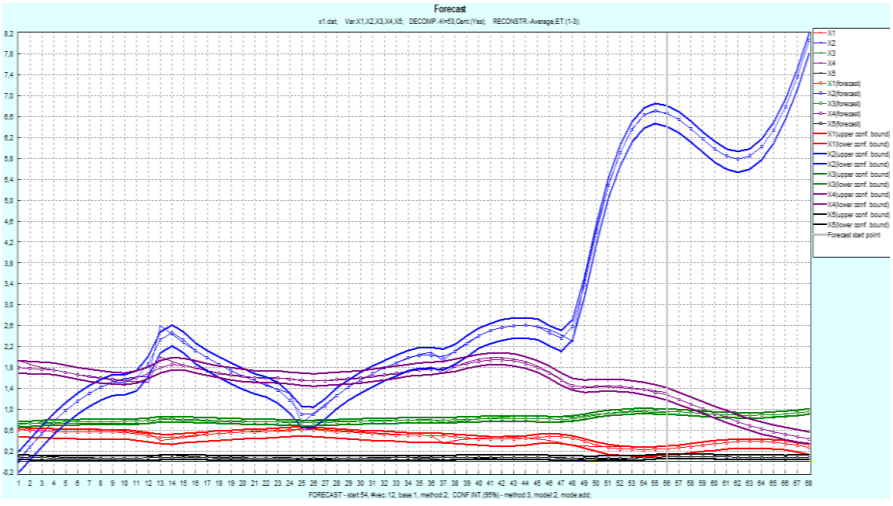


Fig. 4. Graphs of forecast values

Similarly, models of time series of financial indicators X1-X5 for enterprises N2-N5 were constructed. The obtained results made it possible to conclude about the effectiveness of the application of the caterpillar method in forecasting the financial activity of corporations.

The obtained forecast values were considered as initial data in estimation of the threat of crises forming in the prospective period based on neural-fuzzy models. The results of modelling for all subsidiaries and corporation as a whole are given in Table 4.

Table 4

Forecasted values of the threat of financial crises forming in the corporate system

Enterprise	Retrospective value	Forecasted value		
		Pessimistic	Realistic	Optimistic
Enterprise №1	-0,320	-0,216	-0,535	-0,623
Enterprise №2	0,513	0,495	0,501	0,374
Enterprise №3	0,481	0,757	0,735	0,565
Enterprise №4	1,337	1,241	1,031	0,839
Enterprise №5	0,000	-0,163	-0,188	-0,189
Corporation as a whole	-0,541	0,396	0,113	-0,182

As can be seen from the table, the financial condition of the corporation as a whole will significantly worsen: the estimation of the threat of forming the financial crises will increase from -0.541 to 0.396 according to the pessimistic forecast and to -0.182 in the optimistic scenario.

Thus, based on the results of the simulation, it can be concluded that the current financial condition of the corporation is characterized by a very low threat of a crisis, but at the same time, some of the subsidiaries of the corporation have a significant threat of bankruptcy. This can lead to a significant deterioration in the financial condition of the corporation as a whole in the prospective period, which was proved by constructed forecasting models. The current situation requires the development of preventive measures and optimization of the financial performance of subsidiaries, which will ensure the sustainable functioning of the corporate structure as a whole.

5 Models of the forming of ensuring the security strategy of the corporate business structure

In the *third module*, alternative strategies are being developed to ensure the financial security of local and corporate business structures. To do this, the simulation model of financial activity is used – *model M5*, based on the method of system dynamics. The simulation model includes the following integrated blocks: a block of cash flow modelling for operating, investment and financial activities; block of assessment of the level of financial security of the business structure. A fragment of the causal relationship diagram of this model, implemented in the Vensim PLE package, is shown on Fig. 5.

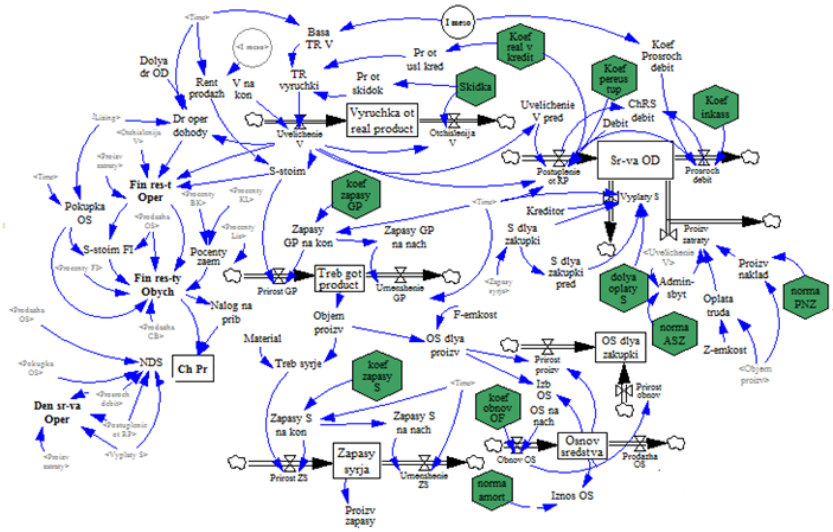


Fig. 5. Diagram of the cause-and-effect relationships of the system-dynamic model (fragment)

Alternative strategies for ensuring the financial security of the business structure (strategic financial alternatives) are considered as a set of strategic measures to ensure an acceptable level of financial security in the forecast period: SFA={Pr_1, Pr_2, Pr_3, …, Pr_n}. The formation of a set of strategic financial alternatives is carried out on the basis of an expert analysis of a portfolio of preventive measures, which is formed using the methods of experts, which reflects their effectiveness and priority of implementation in each of the possible security situations. A fragment of the list of controlled variables

of the system-dynamic model, allowing parameterization and assessment of the effectiveness of preventive measures, is given in Table 5.

Table 5

Identification of controlled variables of system-dynamic model (fragment)

Symbol	The name of the strategic event	Controlled variable (symbol)
Pr_1	Attraction of long-term capital in the form of financial leasing	The size of the loan for leasing (Lizing)
Pr_2	The use of various forms of refinancing receivables	Receivables transfer ratio (Koef pereustup)
Pr_3	Acceleration collection of receivables	Receivables collection ratio (Koef inkass)
Pr_4	Reducing the amount of fixed costs	The standard administrative costs for 1 unit of sold products (norma ASZ)
Pr_5	Increase in insurance reserves	Deductions to the reserve fund (Dolya rezerv)
Pr_6	Changing the conditions of a commodity loan	Coefficient of product sales on credit (Koef real v kredit)
Pr_7	The increase in investment in the growth of current assets	Reinvestment Profit Ratio (Koef reinvest)

The formation of a strategy to ensure the financial security of the corporate structure is carried out according to the following formalized procedure.:

$$G_i\left(SFA_n^i\right) = G_i\left(\bigwedge_{k=1}^{T} Pr_k^i\right), i = \overline{1,n}, k = \overline{1,T},$$

$$p\left(G_i\left(SFA_n^i\right)\right) \geq \alpha$$

$$R\left(Pr_k^i\right) > R\left(Pr_{k+1}^i\right)$$

$$n \rightarrow \min$$

In accordance with the procedure proposed above, at the initial step, using the simulation model (*model M5*), the consequences of implementing the first priority preventive measure are assessed. ($Pr_i|FS_i$, $i = \overline{1,N}$). Next, an assessment of the financial security level of the business structure takes place. If the predicted value is at an unacceptable level, the next preventive measure is selected and evaluated ($Pr_j|FS_i$, $j = \overline{1,N-i}$). The addition of measures to the strategic financial alternative (SFA) is carried out until an acceptable level of financial security of the business structure is reached.

The proposed set of models is implemented on a number of business structures. In particular, the adjustment of the basic security strategy, based on the assessment of the effectiveness of the complex of strategic measures SFA={Pr_{11_1}, Pr_{11_2}, Pr_{20}, Pr_{19}, Pr_3, Pr_5, Pr_4} with the help of the system-dynamic model, it was possible to prevent the transition of one of the studied enterprises to a class with a critical level of financial security. The results of testing have shown the feasibility of using the obtained set of models in the information analytical system of security of corporate business structures.

6 Summary and Concluding Remarks

The conducted researches allowed to conclude the following:

the structure of the model basis of the information-analytical security system of corporate business structures is proposed, the implementation of which in the financial activities of corporations will allow early diagnosis of crisis trends in the development of individual subsidiaries and corporations as a whole, preventing catastrophic financial risks, conducting adequate assessments of the reserves for financial stability of the corporate structure; developing preventive measures aimed at financial stabilization;

the possibilities of using a neuro-fuzzy approach to estimate the threat of the forming of a financial crisis at subsidiaries and the corporation as a whole are explored. The obtained results showed high predictive accuracy of the developed neuro-fuzzy models and the expediency of their application in the financial activity of the corporation under study;

the possibilities of using the methods of fuzzy logic theory to evaluate the impact of the financial crisis at the subsidiaries on the financial condition of the corporation as a whole are explored. The system of variables is grounded, the rules of fuzzy inference are developed. Approbation of the model on the data of the corporation under investigation shows the effectiveness of the proposed approach, which allows to obtain a quantitative and qualitative evaluation of the impact of the threat of the forming of local crises on the stability of the corporate structure as a whole;

models for forecasting financial indicators of enterprises of the corporate system based on the "Caterpillar" method have been developed. This method allows making better reconstruction of the time series, providing higher forecast accuracy in a complex data structure;

developed on the basis of fuzzy logic methods, neural networks, the "Caterpillar" method set of models for estimation the financial condition of corporate systems allows to use the fuzzy rules to estimate the threat of financial crisis forming at the parent and subsidiary enterprises of the corporation, not only in the current but also in the prospective period. The obtained results indicate the increased threat of bankruptcy at a number of subsidiaries in the prospective period and the strong impact of local crises on the financial condition of the corporation as a whole. This led to the need to optimize the parameters of the financial activity of SEs based on system-dynamic models. The parameters found ensured an acceptable level of security and stable operation of the corporate structure.

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