# Neural fuzzy models of estimation of the financial condition of corporate systems

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**Abstract.** The article is devoted to the problem of assessing the financial condition of corporate systems. For this purpose, models of estimation of the threat of forming financial crises in corporate systems are developed on the basis of method of neural networks and fuzzy logic. The realization of neural fuzzy models was approbated in Ukrainian agricultural corporations.

**Keywords**: analysis, bankruptcy, crisis, estimation, neural fuzzy model.

## 1. Introduction

Under market economy conditions one of the most important problems is a problem of preventing the forming of financial crises on enterprises and therefore of preventing insolvency and bankruptcy as an extreme degree of crisis. A large number of cases of bankruptcy and enterprises' liquidation is carried out every year in Ukraine. In addition, approximately every second domestic company operates at a loss and is in a financial crisis that could lead to their bankruptcy in the future. Such enterprises are in each region, both small businesses and large corporations become bankrupt. Now more than 50% of Ukrainian economy consists of corporate type enterprises, moreover, there is an exact tendency of incorporation of small businesses by large enterprises which are the part of corporations. So, for modern economy of Ukraine the problem of corporate bankruptcies is of considerable interest. That is why implementation of modern technologies of economic and mathematical modelling into domestic corporate systems for timely threat assessments of crisis forming and for its prevention is of particular importance.

## 2. Analysis of recent researches

The development of such models of estimation of the threat of bankruptcy and researches about general problems of crisis management were started only in the second half of the 20th century. The works of domestic and foreign scientists are devoted to these issues such as works of E. Altman, V. Beaver, V. Vitlynskyi, V. Zabrodskyi, Y. Zaichenko, G. Kadykov, A. Matviychuk, A. Morozevich, A. Nedosekin, D. Olhson, R. Sayfulin, G. Springate, M. Suvorov, R. Taffler, A. Tereshchenko, D. Chesser, etc. In particular, such aspects of bankruptcy problem were investigated, as the choice of the most significant factors affecting the probability of bankruptcy, an analysis of the most appropriate methods of estimation of the threat crises forming in enterprises, different approaches to anti-crisis policy of enterprises, implementation of econometric modelling into the process of financial analysis, dynamic assessment of financial stability of different entities depending on various external and internal factors and so on.

But these works paid less attention to assessing the impact of financial crisis at subsidiaries on bankruptcy of the corporations at the whole. In addition, the most current models of estimation of bankruptcy threat are the models of "pattern recognition", i.e. they definitely characterize enterprise's financial condition to an exact class of crisis. But companies are often in transition from one phase of crisis to another, and it is impossible to accurately describe his financial condition. Also still unresolved problem is the possibility of using such models for corporate enterprises of all sizes and of various industries; as well, currently not enough attention is paid to the development and making of anti-crisis management decisions and to the assessment of their effectiveness in these enterprises [3, 6-7, 9].

The goal of this study is to develop economic and mathematical models of estimation the financial condition of corporate systems based on neural fuzzy approach. To achieve this goal, it's needed to perform a number of tasks:

- to explore and to analyze the results of current domestic and foreign researches according to the chosen themes;

- to develop the model of estimation of the threat of financial crises forming in corporate systems based on hybrid neural networks and fuzzy logic mathematical tools;

- to test built models and to perform their approbation on domestic corporations.

## 3. Methodical approach to the estimation of crises threat in corporate systems

The financial system of any enterprise of corporate type has a subsystem of crisis management. In modern conditions of uncertainty and risks the task of crisis management is not only about prevention the crisis, but also about the early indication of this bifurcation point, about forecasting, which would prevent irreversible negative changes and about reaching a new level of development with minimal negative effects. So, now the main focus of modern improvements in corporate crisis management system is management based on proactive technology [1].

With technological, innovative progress in recent years, more attention is paid to methods of artificial intelligence. Thus, using developed software packages recently researchers use neural networks for crises threat assessment in enterprises, the accuracy of which is higher than of other methods [2, 7, 10]. And, regarding the results of previous studies [4-6], we can conclude that in the present conditions of uncertainty and risks as a tool for modelling the estimation of the threat of financial crises forming for corporations it would be best to use a method based on the use of neural networks and mathematical fuzzy logic. Because this method combines the most positive signs used in other methods and its application coincides with the essence of the implementation of proactive crisis management in the corporation.

But in corporate systems for estimating the crises threat there should be implemented a new, improved approach which, considering the elimination of detected shortcomings in the above analysis, must be based on a synthesis of economic and mathematical models of estimation the crises threat in corporate management systems. Implementing this approach will allow to diagnose the possibility of financial crisis in the particular company (subsidiary) and in the corporation at whole, to determine crisis' depth, and to develop and to make appropriate crisis management decisions.

This approach was proposed in studies [5-6] and consists of 5 modules: 1) analysis of the current financial condition of the corporation; 2) analysis of current financial condition of subsidiaries; 3) assessment of the impact of financial crisis on the subsidiary to the threat of bankruptcy of the corporation; 4) Forecasting the threat of crisis; 5) crisis management.

In the proposed approach there are such used methods as econometric methods, complex of methods of decision theory and modern economic and mathematical methods, such as neural fuzzy modelling and forecasting method "caterpillar". Its use will allow implementing the technology of proactive crisis management in the activities of corporations, analyzing the financial condition of both the subsidiary and the entire corporation adequately, assessing the impact of financial crisis on the subsidiaries to the threat of bankruptcy of the whole organization and implementing the necessary range of measures for its prevention.

## 4. Neural fuzzy models of assessment of the financial condition of corporate enterprises

Developed in accordance with this proposed approach model basis of estimation of the threat of financial crises forming in corporate systems was tested on the example of domestic agricultural corporations. According to the algorithms of neuro-fuzzy networks [10] for building the models of estimation of crisis threat in the head office of the corporation (realization of module 1) training sample was used which consists of 36 non-governmental head enterprises of corporations of agricultural sector of Ukraine, among which there are 12 of them that became bankrupt, and 24 normal functioning corporations.

According to the structure of the model it was used the following system indicators as an information space, forming and justification of which was carried out in previous studies [8]:

X1 - coefficient of suitability of fixed assets;

X2 – coefficient of quick liquidity;

X3 - coefficient of financial autonomy;

X4 - asset turnover ratio;

X5 - profitability of activity.

Formed system of indicators characterizes the financial condition of the corporation from the point of view of all areas of its activity, so it allows to estimate it adequately.

As a result, variable Y in the neuro-fuzzy model value of the threat of financial crisis forming is taken. And in the training sample Y acquired two values: 1 - if the company became insolvent, and 0 - if it is not bankrupt. To classify the values of Y obtained as a result of the implementation of this model, cluster analysis was conducted. The effectiveness of partitioning of the scale of Y values into 3, 4, 5 and 6 clusters was compared by the method of k-means. Number of classified objects in each cluster for all variants and appropriate values of total variance within groups are presented in Table 1.

*Table 1*

**Partitioning of Y values into clusters**

| Characteristic | Partitioning into | | | |
|---|---|---|---|---|
| | 3 clusters | 4 clusters | 5 clusters | 6 clusters |
| The number of objects in clusters | cluster 1 – 5 objects<br>cluster 2 – 13 objects<br>cluster 3 – 59 objects | cluster 1 – 5 objects<br>cluster 2 – 12 objects<br>cluster 3 – 10 objects<br>cluster 4 – 50 objects | cluster 1 – 4 objects<br>cluster 2 – 4 objects<br>cluster 3 – 10 objects<br>cluster 4 – 32 objects<br>cluster 5 – 27 objects | cluster 1 – 10 objects<br>cluster 2 – 4 objects<br>cluster 3 – 1 objects<br>cluster 4 – 3 objects<br>cluster 5 – 32 objects<br>cluster 6 – 27 objects |
| The value of total variance within group | 47,39 | 43,36 | 41,23 | 43,20 |

Thus, by the criterion of minimization of total variance within group the best conducted partitioning is done into 5 clusters. Thus, formed scale of interpretation of Y values is presented in Table 2.

*Table 2*

**Interpretation of Y values**

| Y value | Threat of crises forming |
|---|---|
| $Y \le 0$ | Very low |
| $Y \in (0;0.25]$ | Low |
| $Y \in (0.25;0.75]$ | Medium |
| $Y \in (0.75;1)$ | High |
| $Y \ge 1$ | Very high |

The development of neuro-fuzzy model of the threat of financial crisis forming on the main enterprise of corporation was conducted in MatLab program. Model's input parameters are five selected indicators X1-X5, the output parameter is a resulting variable Y.

The structure of the fuzzy inference system (FIS) was generated in the program by selected type (Sugeno). The results of analysis of previous studies [6] showed that for achieving the best results of model development (for getting the slightest error) by the method of selection number number of specified linguistic terms (for all 5 inputs) and type of membership functions were chosen. Thus, there were set 3 linguistic terms for each input variable X1-X5; the triangular type was chosen as the type of membership functions. The rules of fuzzy productions were formed automatically by the program; Each fuzzy rule has been checked for logical and theoretical economic content and for the lack of controversy. So, all generated rules were proved 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 of input variables (3 terms for each input), 243 fuzzy rules, 1 output variable Y, 243 therms of output. To carry out the process of learning of the hybrid network the following steps were held:

1. Selection of a hybrid learning method of a hybrid network that is a combination of the method of least squares and of the method of reduction of reverse gradient.

2. Setting the level of training error (Error Tolerance) - value 0 (as by default).

3. Setting the number of cycles (Epochs) - value 40 (by default - 3).

Thus, we can say about the high adequacy of built neuro-fuzzy model (error - less than 0.11%).

Testing of built neuro-fuzzy system, which was conducted using Matlab program, showed that as the result neural network adequately built the system: by testing results the average error is equal to 0.10985%, errors values depend only on the first six cycles, after which they all are equal to about 0.0011. Thus, the built model can and should be used in future research.

Built neuro-fuzzy model was used to assess the financial condition of agricultural corporation "Biscuit-Chocolate", which is the largest producer of confectionery in Kharkov region and is part of the top 5 producers in Ukraine. The corporation includes 5 subsidiaries, which provide all the basic technological stages of

production. The significance of this corporation for Ukraine's economy is underlined by the fact that it employs more than 3,000 workers, and that 30% of corporation sales is accounted for export.

So, it was determined that at the time of the study (01/01/2015) the value of resulting variable Y (value of the crisis threat) for the corporation is -0.541, i.e. the probability of bankruptcy for this company in the near future is very low.

Likewise, Y values for the corporation "Biscuit-Chocolate" were calculated for years 2002-2015. The dynamics of changing the values of the threat of financial crises forming in the corporation is shown on Fig. 1.

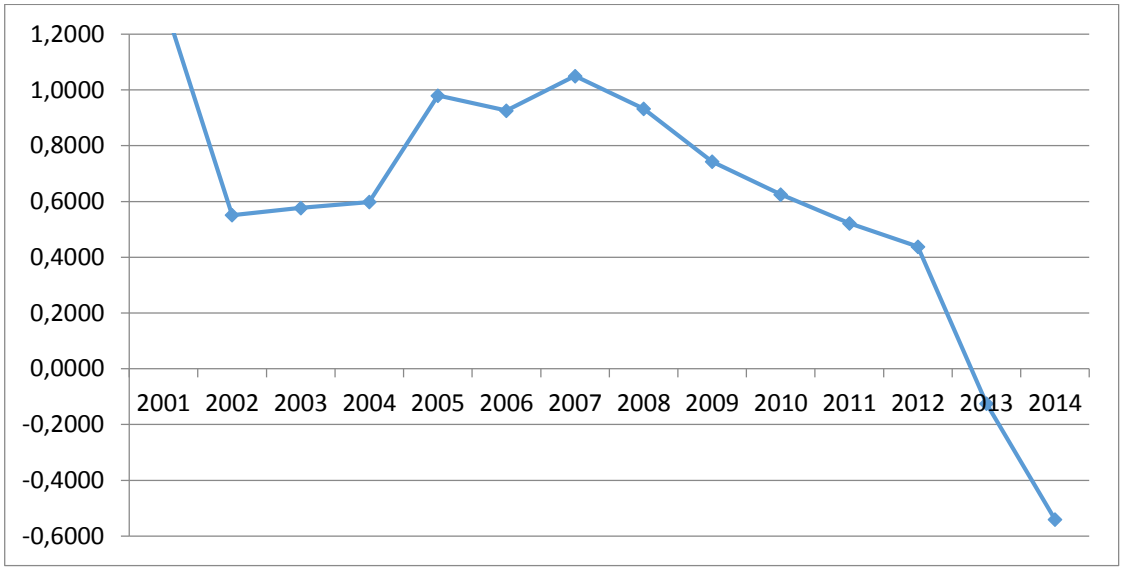


Fig. 1. The dynamics of Y values

As can be seen on Fig. 1, in general, for analyzed period the trend of decreasing of Y value of crises threat is noticeable, i.e., using a scale of interpretation of values of crisis threat (Table 2), we can conclude that there is a tendency of improvement of the financial condition of the corporation. In general, it can be concluded that the results of implementation of developed model of the estimation of fthe threat of financial crises forming on the example of the corporation "Biscuit-Chocolate" adequately describe the financial condition of the corporation throughout the period analyzed.

However, the functioning of such complex financial and industrial systems, as a corporation, is explained by many factors, among which the most important is the financial condition of subsidiaries, because the corporation well-being depends exactly on their activity. Therefore, despite the fact that the results of modelling the probability of bankruptcy of the corporation "Biscuit-Chocolate" is very low, it is advisable to assess the threat of financial crises forming on subsidiaries, as the crisis on these enterprises can lead to catastrophic consequences in the whole organization in the future. That must implement module 2 of proposed approach.

The model of estimation of the threat of financial crises forming on subsidiaries (module 2) was built on a sample of 40 non-government subsidiaries of Ukrainian agricultural sector, and among them 24 are normally operating companies and 16 – which had become bankrupt. As while developing the neuro-fuzzy model in module 1, the same information space of 5 indicators was used. To generate fuzzy inference system, unlike the first model, trapezoidal membership function of input factors and linear input type membership function of output variable Y were used. Testing of neuro-fuzzy model showed high adequacy of constructed system, because of low level of error model made (0.00115%).

This model was approbated on 5 subsidiaries of the corporation "Biscuit-Chocolate": Enterprise "Kharkiv biscuit factory", "Kharkovchanka", "Agricultural Firm named after G.S. Skovoroda"," Pervuhinskyy sugar plant"and "Sloboda". It should be noted that first two enterprises produce and sell prepared pastries, and the latter - provide the necessary raw materials to them.

The dynamics of the values of estimation of crises threat on corporation’s subsidiaries is presented on Fig. 2.

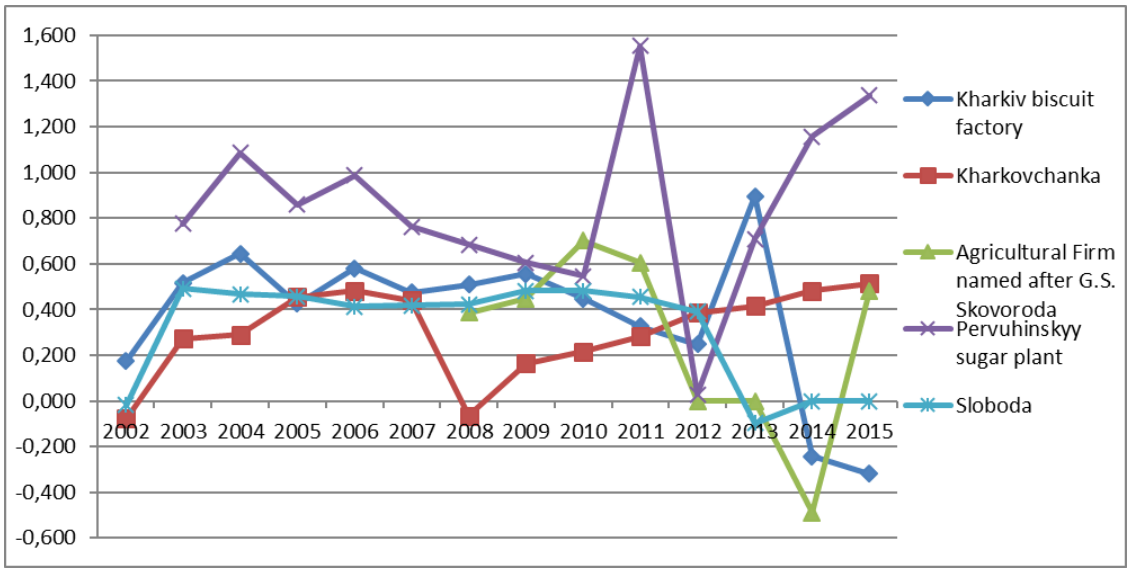

Fig. 2. Dynamics of the values of estimation of crises threat on corporation's subsidiaries

As can be seen on Fig. 2, during last 14 years financial position of these subsidiaries has different trends. Using the scale of interpretation of Y values (Table 2), we can conclude that the average threat of the crisis is at the enterprise "Kharkovchanka" (and it remains at this level since 2008, with a gradual deterioration) and at "Agricultural Firm named after G.S. Skovoroda "(and last year the threat increased significantly: from very low to high). At the moment very low threat of the financial crisis is at "Kharkiv Biscuit Factory" and at "Sloboda", and in the last 3 years there is a noticeable trend of improvement of their condition in the future.

The worst condition is at "Pervuhinskyy sugar factory", where the financial crisis could go to a catastrophic phase - bankruptcy; moreover, for the last 3 years, the value of the threat was only increasing. Therefore, the corporation management should pay the greatest attention to financial processes on this subsidiary, which provides sugar to two major corporate revenue factories.

Besides the verification of the adequacy of application results of built neuro-fuzzy models by the criterion of minimizing errors, also their adequacy was proved by the analysis of financial activity of subsidiaries and of the whole organization. For example, as can be seen on Fig. 1, in 2008 there was a significant "leap" of Y value, and the threat of crisis in the corporation was very high. And this is proved by relevant processes proceeded in the corporation during this period: a significant increase in accounts receivable without income growth, reducing of net income and of corporation's sales revenue, the accounts payable (especially, current) almost doubled, increasing operating costs by 50% etc. But that year the management implemented a complex of measures to leveling the crisis, which led to a significant improvement in the financial condition of the corporation.

Thus, according to the results of modelling we can conclude that the current financial condition of the corporation "Biscuit-Chocolate" is characterized by a very low risk of forming of the crisis, but on some of the subsidiaries of the corporation, there is even a significant threat of bankruptcy, i.e. the corporation already has serious threats of reduction of the solvency and of more acute crisis situations that can lead to catastrophic consequences for the entire corporation in the future. Therefore, it is expedient to realize the modules of crisis forecasting at subsidiaries and at corporation and to implement a complex of anti-crisis measures.

## 5. Conclusion

The review clearly shows the necessity of development the methods of estimation the threat of financial crises forming in corporate systems. Developed by using the methods of fuzzy logic and neural network models of estimation the financial condition of corporate systems allow, using fuzzy rules to determine the crises threat at head enterprise of the corporation and at its subsidiaries not only in the current but in the subsequent period as well, allowing the company to timely detect and prevent threat to the financial crisis and to implement a complex of anti-crisis measures.

That is why it can be considered as a promising area for future research.

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