





“Model for preventing bankruptcy of Ukrainian enterprises in force majeure circumstances”

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ARTICLE INFO	Rodion Poliakov and Ivan Zayukov (2022). Model for preventing bankruptcy of Ukrainian enterprises in force majeure circumstances. <i>Problems and Perspectives in Management</i> , 20(4), 365-381. doi: 10.21511/ppm.20(4).2022.28
DOI	http://dx.doi.org/10.21511/ppm.20(4).2022.28
RELEASED ON	Friday, 09 December 2022
RECEIVED ON	Monday, 26 September 2022
ACCEPTED ON	Tuesday, 29 November 2022
LICENSE	 This work is licensed under a Creative Commons Attribution 4.0 International License
JOURNAL	"Problems and Perspectives in Management"
ISSN PRINT	1727-7051
ISSN ONLINE	1810-5467
PUBLISHER	LLC “Consulting Publishing Company “Business Perspectives”
FOUNDER	LLC “Consulting Publishing Company “Business Perspectives”



NUMBER OF REFERENCES

54



NUMBER OF FIGURES

5



NUMBER OF TABLES

3

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BUSINESS PERSPECTIVES


LLC "CPC "Business Perspectives"
Hryhorii Skovoroda lane, 10,
Sumy, 40022, Ukraine
www.businessperspectives.org

Received on: 26th of September, 2022

Accepted on: 29th of November, 2022

Published on: 9th of December, 2022

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Conflict of interest statement:

Author(s) reported no conflict of interest

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MODEL FOR PREVENTING BANKRUPTCY OF UKRAINIAN ENTERPRISES IN FORCE MAJEURE CIRCUMSTANCES

Abstract

Given rapid changes in global financial and economic processes caused by rapid transformations in the institutional environment and the onset of force majeure circumstances, there is a need to develop new approaches to assessing the level of bankruptcy. Most models that estimate the probability of enterprise bankruptcy are based on internal information, while external information is used to a limited extent. The growing threat of force majeure requires using not only the existing discrete models but also those that consider the external environment of enterprises when assessing the probability of bankruptcy. The purpose of this study is to develop a model for preventing bankruptcy of Ukrainian enterprises in force majeure conditions based on the use of artificial intelligence methods – the theory of fuzzy logic – which allows for a comprehensive assessment of bankruptcy prevention. The paper uses analytical data from the World Bank. The model consists of interrelated groups of factors: organizational, informational and legal, and economic. As a result, a comprehensive indicator of prevention of corporate bankruptcies (D) was calculated on a neurolinguistic scale from 0 to 10; the indicator was estimated for Ukraine (5.644) and Romania (4.520) (as countries close in terms of economic and geopolitical development). The simulation results show that the level of prevention of enterprises' bankruptcy in Ukraine falls into the average interval.

Keywords

bankruptcy, management, enterprise, measures, model,
theory of fuzzy logic

JEL Classification

G33, C45, M11

INTRODUCTION

Managing enterprises in force majeure circumstances requires new approaches to minimize bankruptcy risks. Nowadays, regardless of the geographical location, the economic development of the country, and various uncertainties, business is highly dependent on circumstances that cannot be fully predicted (force majeure). In particular, they include war, the COVID-19 pandemic, and natural, manufactured, and political disasters (earthquakes, floods, droughts, explosions, radiation, chemical hazards, strikes, revolutions, coups, etc.). These and other risks have a negative impact on business development around the world, in particular, in Ukraine.

Force majeure circumstances must be considered by every entrepreneur when concluding legal agreements (contracts). In the event of force majeure, enterprises objectively cannot fully fulfill the requirements specified in the agreements (contracts). This leads to a decrease in solvency, a drop in image, and may eventually lead to bankruptcy. Therefore, it is essential to focus on specific aspects of bankruptcy

procedures to prevent the bankruptcy of enterprises in force majeure circumstances. For this purpose, this study emphasizes the experience of such countries as Ukraine, the UK, Germany, the USA, and France. Thus, regulations of bankruptcy procedures taking into account force majeure circumstances are considered. For example, Ukraine is following the Code of Ukraine on Bankruptcy Procedures (The Verkhovna Rada of Ukraine, 2018), Germany uses the provisions of the German Insolvency Statute (Bundesministerium der Justiz, 1994), and France – the Commercial Code of France (Legifrance, 2000).

The effectiveness of preventing the bankruptcy of enterprises in force majeure circumstances should involve studying the experience of countries on bankruptcy issues. Force majeure is a legal basis for the protection of entrepreneurs from non-fulfillment of their obligations until they are resolved. In conditions of low liquidity and significant deterioration of solvency, an enterprise may find itself in a bankruptcy situation. Therefore, the court needs to determine the optimal procedures for the debtor and the creditor: reorganization, absorption, or liquidation. This is crucial because in building a bankruptcy prevention model, there is such an element as the quality of judicial processes index. Thus, in the Commercial Code of France, the legislator regulates the bankruptcy procedure (Legifrance, 2000). The quality of the judicial system within the framework of bankruptcy proceedings is determined by the ability of the judicial body to rationally choose procedures for the enterprise. For example, the Provisions of the Commercial Code of France, the Insolvency Act of England, and the Statute of Insolvency of Germany do not provide for the existence of a classical sanation procedure in contrast to the provisions of the Code of Ukraine on bankruptcy procedures. Therefore, the described problem of the lack of sanation procedure represents a considerable risk for enterprises and the economies of these countries in general. This determines the need to build a bankruptcy prevention model based on modern international experience as an essential component of the decision-making support system for relevant state bodies in developing and implementing effective management measures.

There are many approaches and models for predicting bankruptcy, for example, the Altman model (Altman, 1968), IN01 and IN05 indices (Gavurova et al., 2017), non-deflated and deflated ratios, and many others. For example, when checking the bankruptcy forecasting models (Altman model, Olson model, IN01 and IN05 indices) to assess the accuracy of forecasting on a sample of 700 Slovak companies, it was found that in the relevant crisis conditions, the most accurate method of forecasting the probability of bankruptcy was the use of the IN05 index (Gavurova et al., 2017). Yu and He (2018) proposed a two-period model to study which bankruptcy procedure is more suitable for both the debtor and the creditor in case of insolvency. Applying this model, it was concluded that larger enterprises are more likely to undergo reorganization than smaller ones. However, it becomes clear that the use of the specified models and coefficients, the calculation of which is based solely on financial statements, needs to be revised.

All this prompted the search for ways to an interdisciplinary approach to the study of corporate bankruptcy problems. The search for approaches to the simultaneous consideration of economic, legal, and organizational factors influencing the possibility of bankruptcy of enterprises is crucial. It is possible to implement this approach only based on modern economic and mathematical methods, namely, artificial intelligence methods, which include the theory of fuzzy logic. This approach will make it possible to take into account both qualitative and quantitative factors influencing the bankruptcy of an enterprise in the form of a linguistic assessment (or conditional scale). This study is devoted to implementing this approach to building a model to prevent an enterprise's bankruptcy.

1. THEORETICAL BACKGROUND

In the conditions of globalization, enterprises face many problems that negatively affect their

financial situation and prospects for their future existence. Thus, according to the International Monetary Fund (2022), with the beginning of a full-scale war in Ukraine, more than 7 million citizens of Ukraine were forced to leave the coun-

try as of November 1, 2022. The number of unemployed people applying for the same job position increased from 6 to 12; the unemployment rate increased to 40%. As a result, the International Monetary Fund predicts that the Gross Domestic Product of Ukraine will decrease by about 35% in 2022, and inflation will reach 30%. These trends threaten stagflation in Ukraine and throughout the world (International Monetary Fund, 2022).

Since 2020, the world has witnessed increased global inflation, which led to the shutdown and bankruptcy of tens of thousands of enterprises. A study of 30 countries regarding the impact of force majeure circumstances showed that under the “soft” scenario of the forecast, as a result of the pandemic, the median decrease in GDP ranged from 3 to 6% (Fernandes, 2020). In fact, on average, in these countries, the median GDP decline in 2020 was 2.8%. In more pessimistic scenarios, it was predicted that GDP could decrease by more than 10%. In some countries, i.e., Greece, Portugal, and Spain (countries dependent on tourism), GDP was predicted to decrease by more than 15%.

Global crises have an extremely powerful impact on the activities of enterprises, but this impact is not the same for individual enterprises (Ritter & Pedersen, 2020). All this confirms the need to develop effective management solutions and build business models for their development. In addition to low profitability, insufficient income (rev-

enue), and low solvency ratio, the correctness of management decisions by bank management is essential, in particular, in the system “interest on loan – risk of loan repayment” (Serrano-Cinca et al., 2014).

Such force majeure circumstances as war and the COVID-19 pandemic have had a negative impact on the world economy. As a result, there are reductions in production volumes and employment and the threat of insolvency, which is a prerequisite for the increase in the number of bankruptcies. Figure 1 shows the percentage of increase in the number of bankruptcies in the fourth quarter of 2020 by individual countries of the world (2007 is taken as 100%).

Compared to 2007, in the fourth quarter of 2020, these countries had an increase in bankruptcies. The smallest increase was recorded in Canada – 32.09%, and the largest in Spain – 475.87%. The most significant contribution to the increase in the number of bankruptcies was caused by the COVID-19 pandemic, especially in the tourism business, cultural sphere, or service provision, where companies were in direct contact with consumers (Deloitte, 2021; Msomi & Nzama, 2022; Susanti et al., 2022; Martaleni et al., 2022; Lantara et al., 2022; Budiarto & Pontoh, 2022; Rittigul & Jindabot, 2022). The war in Ukraine since 2014 only exacerbates this problem (Belitski et al., 2021; O’Sullivan, 2021; Banerjee & Rai, 2020; Korneyev

Source: Organization for Economic Cooperation and Development (2020).

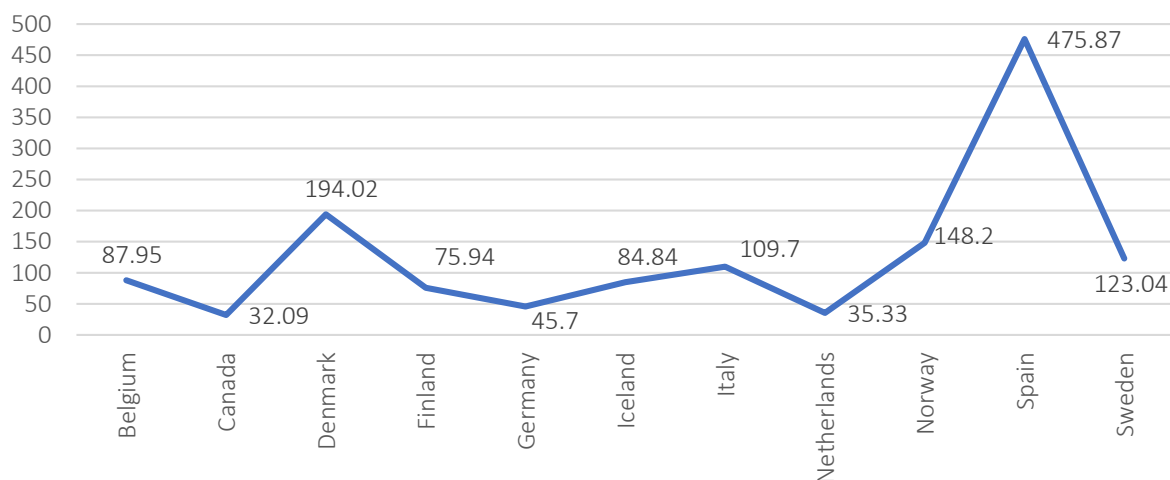


Figure 1. Increase in the number of bankruptcies in certain countries, % (the percentage of increase in the number of bankruptcies in the fourth quarter of 2020 by individual countries of the world (2007 is taken as 100%))

et al., 2022; Lopushniak et al., 2022). Some enterprises' bankruptcy can lead to others' bankruptcy, that is, create the risk of a powerful wave of bankruptcies (Polinkevych et al., 2021; Ritter & Pedersen, 2020).

Factors that affect the probability of bankruptcy (the level of coverage of the adult population by credit institutions, access to obtaining information from financial institutions, financial indicators of the development of enterprises (indicators of liquidity, business activity, the use of bankruptcy forecasting models, etc.), the level of protection of the rights of business owners, the level of corporate transparency, the level of responsibility of business directors, the level of the tax burden, the effectiveness of the judicial system in the area of decision-making in the field of bankruptcy) are given sufficient attention in the scientific literature (Barsotti et al., 2016; Gavurova et al., 2017).

The problem of using private and court-controlled mechanisms to settle default mechanisms and reorganize enterprises is extremely relevant. This concerns issues of out-of-court restructuring, corporate governance related to enterprise restructuring, judicial and extrajudicial costs, and the effectiveness of reorganization of companies undergoing bankruptcy proceedings (Hotchkiss et al., 2008). The procedure for bankruptcy of enterprises (economically efficient and economically inefficient) can be ineffective. That is, everything depends on the correctness of management decisions in court proceedings (White, 1994). White (1994) proposed a game-theoretic model of bankruptcy that can be applied in an out-of-court restructuring procedure, which will make it possible to avoid mistakes as much as possible. Moreover, those enterprises subject to judicial liquidation can be restructured and returned to normal operational activities. An integral factor in the prevention of bankruptcy is implementing the methodology of learning by doing, which involves quickly developing and implementing new knowledge on business methods as prerequisites for survival in crisis conditions (Chystal, 2019).

Dou et al. (2020) studied the effectiveness of corporate bankruptcy in the USA. As a result, it was found that there is a contradiction between asymmetric information and a conflict of inter-

ests between creditors, which can lead to wrong decisions, in particular, to bankruptcy and liquidation of an enterprise. For example, eliminating the relevant conflict of interest resulted in accelerated consideration of bankruptcy cases by 14%, while the term of consideration of court cases decreased by 73%. Due to the COVID-19 pandemic, cases of ineffective bankruptcies have been recorded. For example, individual enterprises that should be reorganized are liquidated instead. Other enterprises that should be liquidated are being reorganized. This indicates the ineffectiveness of the judicial system in matters of bankruptcy, as a result of which costs arise, including legal, indirect (loss of customers, suppliers, or employees), and costs associated with delayed court cases. This forced US legislators to adopt the Bankruptcy Abuse Prevention and Consumer Protection Act, which had a positive effect on the efficiency of bankruptcy procedures. This should also be taken into account in the legislation on bankruptcy in Ukraine.

Antill (2022) examined the experience of bankruptcy in the USA, where the courts, as a result of the bankruptcy procedure, can make three decisions: phased liquidation (bankrupt companies are sold and repurposed), takeover (bankrupt companies are bought in order to continue their activities as a "continuation of their own activities"), and reorganization (bankrupt companies continue their activities). 15% of bankruptcy cases end in liquidation and 6% of cases end in takeover, which is inefficient compared to reorganization. In addition, Antill (2022) conducted a study among 503 large US public companies undergoing bankruptcy. The study emphasizes that the efficiency of choosing one or another bankruptcy model depends on the judge. For example, if the reorganization model is chosen, the level of compensation to creditors increases by 52 cents for every dollar of debt claim. Thus, the quality of the judicial system plays a vital role in improving the efficiency of enterprise bankruptcy management.

Armstrong et al. (2013) investigated the problems of corporate management of economic and financial activities. The relationship between the motivation of managerial activities and the provision of false information (e.g., fraud with financial reporting) was investigated.

Globalization transformations and the war in Ukraine have led to severe consequences in the area of demand and a decrease in the level of operating capital, which are factors that will increase the likelihood of financial fraud in the future (Karpoff, 2021). Thus, the theory uses a bankruptcy prediction model (the “distorted facts model”) (Alawadhi et al., 2020). This model made it possible to conclude that, on average, 22.3% of companies annually falsify financial information, for which state financial authorities hold them accountable. Furthermore, it found that the average period of violations is 3.1 years, which shows that 7.2% of firms initiate new programs of financial malfeasance each year, of which about 3.5% are eventually prosecuted. Therefore, fraud with financial statements and other forms of illegal actions with financial statements represent a considerable threat to enterprises’ general existence (Amiram et al., 2018).

Bergstresser and Philippon (2006) focused on contradictions in corporate governance. They emphasized the conflict of interests between owners-investors of firms and managers. It was concluded that those managers whose personal interest does not depend on the value of the company they manage might act in a way that may be beneficial in a personal aspect. However, these actions reduce the demands of investors. In this aspect, the structural model of credit risk with tax reserves built by Barsotti et al. (2016) is gaining relevance. Thus, the optimality of financial decision management is influenced by tax payments and asymmetry. In addition, CEOs and CFOs in a relatively weak control environment are more likely to engage in fraudulent activities, including deliberate errors in financial and statistical reporting (Davidson et al., 2015).

The use of accounting information, compiled by considering all legislative and regulatory requirements, provides a reliable platform for solving financial problems related to bankruptcy (Ata, 2019). In the conditions of a financial crisis, it is more rational to liquidate a company during the bankruptcy procedure, which is more expedient in economic shocks. The problem of ownership and efficiency of company management is no less critical in the corporate

governance system. Jensen and Meckling (1976) claimed that managers are not as scrupulous about the property issues of the enterprises they lead as they are about their own private property. Thus, negligence and wastefulness can often be seen in their activities.

A qualitative assessment of the bankruptcy of enterprises is possible if artificial intelligence methods are used (Kozlovskiy et al., 2022). In particular, the fuzzy set method allows the inclusion of quantitative and qualitative indicators in the mathematical model (Kozlovskiy et al., 2019). This approach suggests using the indicators of the International Financial Reporting Standards when assessing the bankruptcy of enterprises. These indicators comprise the current liquidity ratio, accounts payable turnover ratio, equity turnover ratio, profitability of assets, and ratio of equity to debts. When predicting bankruptcy, models based on financial ratios are used. However, these models do not view many other factors, i.e., the structure of corporate governance and management methods (Aziz & Dar, 2006). In addition, Aziz and Dar (2006) established that models based on financial ratios are relatively accurate.

On the contrary, models based on artificial intelligence are much better than statistical and theoretical models. The theory also distinguishes a methodical approach to conducting a comprehensive analysis of the company’s financial condition using fuzzy logic methods, which made it possible to build a model for diagnosing the company’s bankruptcy (Matviychuk, 2013). During the experiment on applying discriminant models of bankruptcy forecasting, on the example of Ukrainian enterprises, it was concluded that the most accurate model for forecasting the probability of bankruptcy is based on artificial intelligence – the theory of fuzzy logic.

Therefore, the purpose of the study is to develop a model for preventing the bankruptcy of enterprises under conditions of force majeure based on the use of artificial intelligence methods – the theory of fuzzy logic, which makes it possible to comprehensively assess, based on partial indices, not only the probability of bankruptcy, but the level of its prevention.

2. METHODS

2.1. Algorithm for building a model for preventing the bankruptcy of enterprises

The development of a model for preventing the bankruptcy of enterprises should solve many issues:

- substantiation of indicators to be included in the relevant model should be carried out based on expert and sociological surveys and studies of scientific literature on the issues of assessing bankruptcy in wartime;
- assessment of compliance of actual indicators with current regulations;
- comparison with model indicators, which can be considered standards recommended by specialists, in particular the World Bank, the International Bank for Reconstruction and Development, the International Monetary Fund, etc. The assessment of compliance with the indicators of developed countries can be done by comparing such indicators as the index of the level of protection of credit operations, the index of legal responsibility, the general tax rate, the index of the quality of the judicial system concerning the conduct of bankruptcy proceedings, the ratio of refunds, etc. The elements of the business bankruptcy prevention model are based on indicators of the DoingBusiness index, which is compiled annually by the World Bank. In general, the DoingBusiness index consists of the following general indicators:

- Starting a Business;
- Dealing with Construction Permits;
- Getting Electricity;
- Registering Property;
- Getting Credit;
- Protecting Minority Investors;
- Paying Taxes;
- Trading across Borders;
- Enforcing Contracts;
- Resolving Insolvency.

The above general indicators consist of partial indicators, for example, for the general indica-

tor “Enforcing Contracts” the partial indicators are “Time” (days), “Cost” (% of claim value), and “Quality of judicial processes index.” The model for preventing bankruptcy of enterprises includes those partial indicators on which the financial condition of the enterprise, its solvency, which indirectly affect the probability of bankruptcy, mostly depend.

When developing a model for the prevention of corporate bankruptcy, a number of values are inaccessible for accurate quantitative measurement, a subjective component is introduced, which is expressed by vague assessments of the type “low,” “below average,” “average,” “above average,” and “high.” What appears is what is known in science as a “linguistic description” and is represented by functions of the fuzzy set factor.

To create an expert modeling system for the multifactorial analysis of the level of threats of bankruptcy for enterprises (D), a mathematical apparatus based on artificial intelligence – the theory of fuzzy logic – is used. The founder of fuzzy logic – Zadeh (1965) – substantiated the definition of a “fuzzy set,” which means a class of objects with a continuum of degrees of belonging and a “function of belonging.” Such a set of fuzzy sets is in the range from zero to one (Zadeh, 1965). The algorithm for building a model for preventing the bankruptcy of enterprises is shown in Figure 2.

2.2. Conceptual basis of model construction

Linguistic statements should correspond to the obtained fuzzy logical equations at the appropriate hierarchical level: the system and the proposed factors that connect the membership functions of the input and output variables due to the use of “max” and “min” operations in their construction. That is, logical operations “AND” (\wedge) and “OR” (\vee) over membership functions are replaced by operations “max” and “min” (Zadeh, 1965; Matviychuk, 2013; Kozlovskiy, 2001; Kozlovskiy et al., 2019, 2021, 2020, 2022):

$$\mu_{(a)} \wedge \mu_{(b)} = \min[\mu_{(a)}, \mu_{(b)}], \quad (1)$$

$$\mu_{(a)} \vee \mu_{(b)} = \max[\mu_{(a)}, \mu_{(b)}]. \quad (2)$$

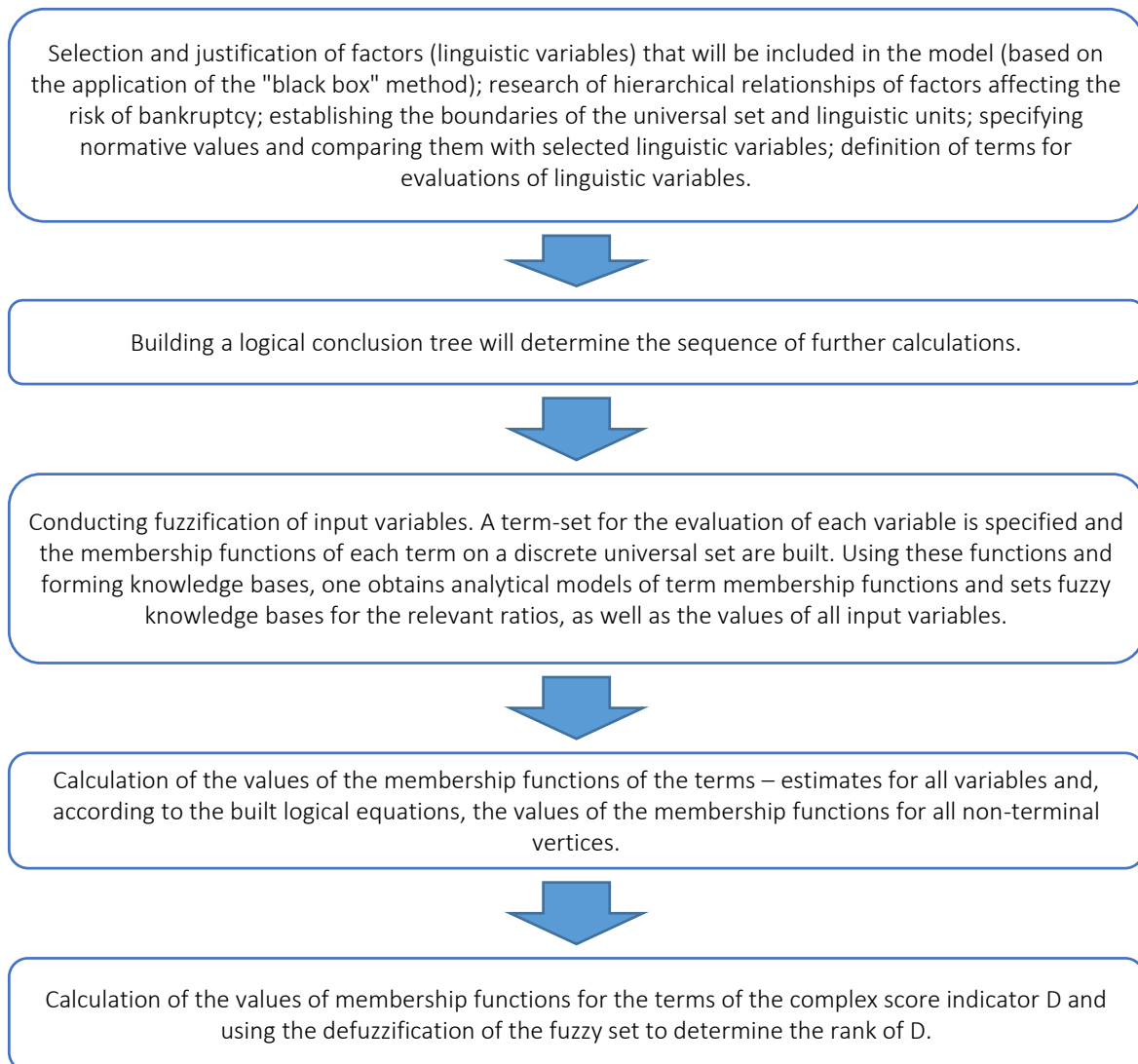


Figure 2. Stages of building a model for preventing the bankruptcy of enterprises

The considered approach identifies a linguistic term by the maximum of the membership function and generalizes it. Based on the use of membership functions and corresponding formulas, analytical models of membership functions of estimates of input variables for all terms were built. Since there are cases when the maximum membership functions are the same for two adjacent terms, and this complicates the ranking of projects, for greater clarity, it is suggested to consider the interval of changes of the input parameter – D – as continuous and to rank the projects according to the given scale $[D^1: D_2]$. In order to obtain a precise number corresponding to the rank of the project, the defuzzification operation should be applied in this interval, i.e., the operation of trans-

forming unclear information into clear or quantitative information.

According to the principle of the center of mass, the defuzzification of the fuzzy set gives a quantitative estimate D^* – the rank of the indicator of the complex estimate D with the given input factors (Zadeh, 1965; Matviychuk, 2013; Kozlovskiy et al., 2019):

$$D^* = (R^*) = \frac{\sum \left[D_2 + (i-1) \frac{D^1 - D_2}{m-1} \right] \mu^{ui}(D)}{\sum_{i=1}^m \mu^{ui}(D)}, \quad (3)$$

where m – the number of terms of variable D ; D^1 , D_2 – lower and upper limits of the range of vari-

able D ; $\mu^{ui}(D)$ – the function of membership of variable D to the fuzzy term U_i .

The source of the formation of the knowledge base, which models the relationship between the output and input indicators for assessing the level of preventing the bankruptcy of enterprises (D), are the opinions of experts who specialize in this field. The peculiarity of expressions like “IF - THEN, OTHERWISE,” which are formulated in natural language, is that their adequacy, unlike quantitative models, does not change with slight fluctuations of the input estimates in one direction or another. The set of similar statements is a set of points in the space “individual criteria - integral criterion.” The integral criterion is evaluated based on the fixed linguistic evaluations of individual criteria D .

2.3. Characteristics of the model’s elements

The initial indicator D (dependency 4) depends on the input factors of influence X, Y, Z (dependencies 5-7). The influence factors were selected based on the partial indicators of the DoingBusiness index, which are given in the following dependencies:

$$D = f_d(X, Y, Z), \tag{4}$$

where D – linguistic variable that characterizes a comprehensive assessment of the level of prevention of corporate bankruptcies; X – linguistic variable that characterizes organizational factors; Y – linguistic variable that characterizes informational and legal factors; Z – linguistic variable that characterizes economic factors.

Organizational factors of influence are presented by:

$$X = f_x(x_1, x_2, x_3, x_4), \tag{5}$$

where x_1 – Extent of ownership and control index; x_2 – Extent of corporate transparency index; x_3 – Credit registry coverage, % of adults; x_4 – Credit bureau coverage, % of adults.

Informational and legal factors of influence are presented by:

$$Y = f_y(y_1, y_2, y_3, y_4, y_5, y_6, y_7), \tag{6}$$

where y_1 – Strength of legal rights index; y_2 – Extent of director liability index; y_3 – Extent of shareholder rights index; y_4 – Quality of judicial processes index; y_5 – Depth of credit information index; y_6 – Postfiling index; y_7 – Strength of insolvency framework index.

Economic factors of influence are presented by:

$$Z = f_z(z_1, z_2, z_3, z_4), \tag{7}$$

where z_1 – Total tax and contribution rate, % of profit; z_2 – Recovery rate (cents on the dollar); z_3 – Cost, % of estate; z_4 – Time, years.

2.4. Formation of knowledge base and system of fuzzy logical equations

The values of linguistic variables in the relationships (4-7) are evaluated based on the use of the corresponding terms. The number of terms in modeling the prevention of bankruptcy of enterprises (D) may differ for the proposed variables (factors). The next step of modeling is the construction of fuzzy logic equations. These equations connect membership functions of different levels, given input and output variables. To compile fuzzy logical equations, knowledge bases are set in the form of expert statements “IF” – “THEN” about the relations of fuzzy terms of input and output linguistic variables taking into account the constructed dependencies (4-7). An example of knowledge base formation for dependency 4 is given in Table 1.

An example of forming a system of fuzzy logic equations for dependence (4):

$$\begin{aligned} \mu(d1) &= \mu_{(H)} X \wedge \mu_{(H)} Y \wedge \mu_{(H)} Z \vee \\ &\vee \mu_{(H)} X \wedge \mu_{(Hc)} Y \wedge \mu_{(H)} Z \vee \mu_{(H)} X \wedge \mu_{(Hc)} Y \wedge \mu_{(H)} Z, \end{aligned} \tag{8}$$

$$\begin{aligned} \mu(d2) &= \mu_{(C)} X \wedge \mu_{(C)} Y \wedge \mu_{(C)} Z \vee \\ &\vee \mu_{(C)} X \wedge \mu_{(Bc)} Y \wedge \mu_{(C)} Z \vee \mu_{(C)} X \wedge \mu_{(Bc)} Y \wedge \mu_{(C)} Z, \end{aligned} \tag{9}$$

$$\begin{aligned} \mu(d3) &= \mu_{(B)} X \wedge \mu_{(Bc)} Y \wedge \mu_{(B)} Z \vee \\ &\vee \mu_{(B)} X \wedge \mu_{(B)} Y \wedge \mu_{(B)} Z \vee \mu_{(B)} X \wedge \mu_{(B)} Y \wedge \mu_{(B)} Z. \end{aligned} \tag{10}$$

Table 1. Knowledge bases and systems of fuzzy logic equations for dependence (4)

Source: Authors' elaboration.

IF			THEN
Organizational factors of influence (X)	Informational and legal factors of influence (Y)	Economic factors of influence (Z)	The level of threats of bankruptcy of enterprises (D)
Low (L)	Low (L)	Low (L)	d ₁ - The level of threats of bankruptcy of enterprises is high [1-4]
Low (L)	Below average (Ba)	Low (L)	
Low (L)	Below average (Ba)	Low (L)	
Average (A)	Average (A)	Average (A)	d ₂ - The level of threats of bankruptcy of enterprises is average [4-7]
Average (A)	Above average (Aa)	Average (A)	
Average (A)	Above average (Aa)	Average (A)	
High (H)	Above average (Aa)	High (H)	d ₃ - The level of threats of bankruptcy of enterprises is low [4-7]
High (H)	High (H)	High (H)	
High (H)	High (H)	High (H)	

3. RESULTS

3.1. Calculation of degrees of belonging of elements to terms

The evaluation of the values of linguistic variables is given in relations (4-7) based on the appropriate terms. The number of terms in modeling the D indicator can be different for the proposed variables (factors). Thus, the terms for evaluating such a variable as, for example, “y₂ – Extent of director liability index” are as follows: “Low (L); “Below average” (Ba); “Average” (A); “Above average” (Aa); “High” (H), with a universal set [0-12]. The calculation of the degrees of belonging of elements to terms on the example of - μ_h for the factor y₂ is:

$$\mu_{low1} = \frac{0.36}{0.36} = 1.00,$$

$$\mu_{low2} = \frac{0.28}{0.36} = 0.78,$$

$$\mu_{low3} = \frac{0.20}{0.36} = 0.56, \tag{11}$$

$$\mu_{low4} = \frac{0.12}{0.36} = 0.33,$$

$$\mu_{low5} = \frac{0.04}{0.36} = 0.11.$$

An example of the calculated membership function for (μ_{low}(u_i)) with a universal set [0-12]:

$$\left(\frac{1}{0}; \frac{0,78}{3}; \frac{0,56}{6}; \frac{0,33}{9}; \frac{0,11}{12} \right). \tag{12}$$

An example of the function of dependency of the parameter for factor y₂ is shown in Figure 3.

Source: Authors' elaboration.

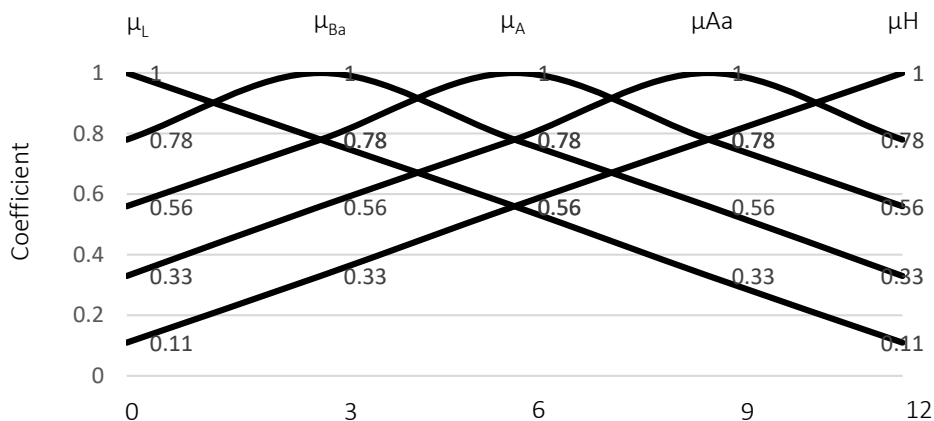


Figure 3. Membership functions of “y₂ – index of legal responsibility of management”

3.2. Construction of a tree of logical conclusion for hierarchical relationships of factors

The tree of logical conclusions for the hierarchical relationships of factors that make it possible to assess the level of prevention of enterprises' bankruptcy is shown in Figure 4. The root of the tree is the level of threats of bankruptcy of enterprises (D), and the leaves, respectively, are organizational, informational and legal, economic factors that have an impact on this state.

3.3. Systematization of factors for the proposed model

Systematization of factors for the proposed model (D) is given in Table 2.

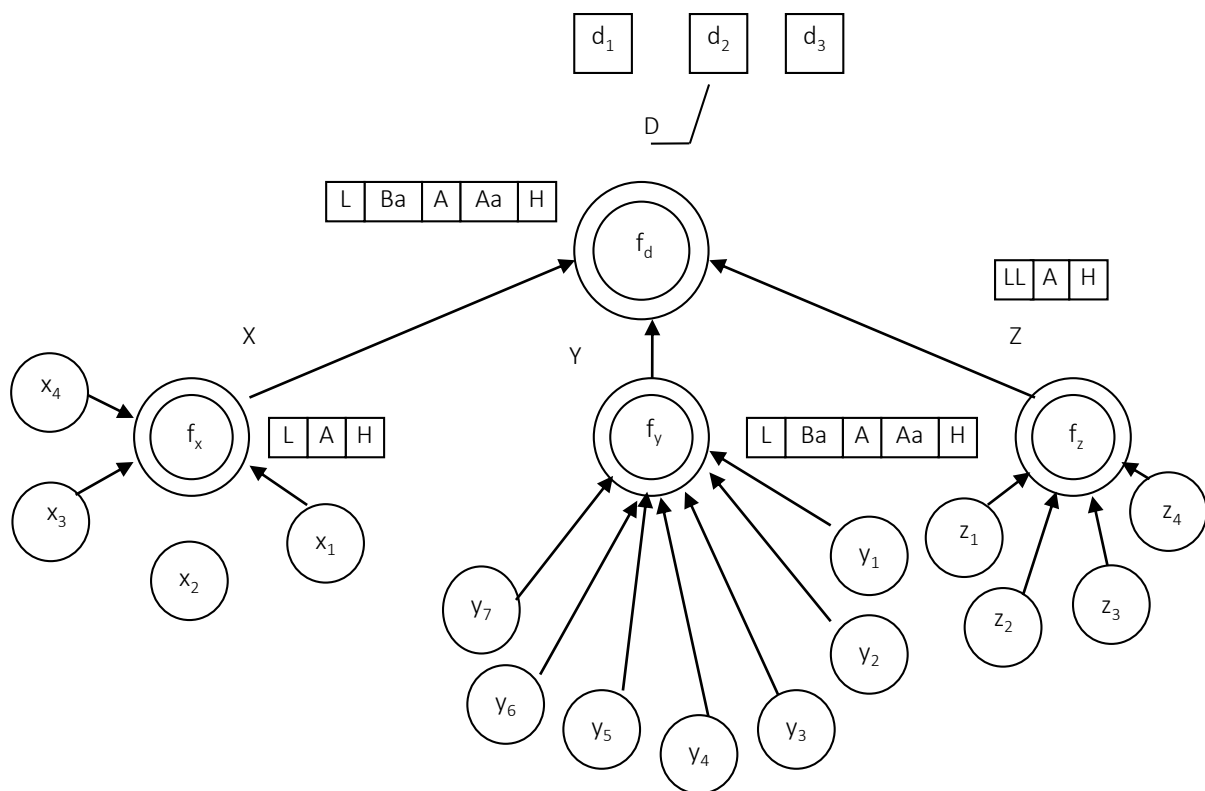
According to the constructed membership functions of each term on the discrete universal set, using logical equations (4-7) of the membership function values for all non-term vertices, the val-

ue of the membership functions of the term-estimates for all variables and the membership function values for all non-term vertices were obtained. The input data for modeling D and the justification of universal set intervals are shown in Table 3.

3.4. Systematization of input data and the result of modeling

The final stage in modeling the level of preventing the bankruptcy of enterprises is defuzzification (formula 3). This was preceded by the calculation of the values of membership functions for term-estimates for all variables and the values of membership functions for all non-term vertices (for example $(\mu(d_1-d_3))$) and the output data given in Table 3. Since Ukraine pays great attention to the development of socio-economic, political, and other relations with Romania as a neighboring state that fully supports the Euro-Atlantic and European integration of Ukraine. In addition, there is an in-depth cooperation between Ukraine and Romania in the energy and economic spheres,

Source: Authors' elaboration.



Note: L, Ba, A, Aa, H – terms of evaluation (respectively: L – low level; Ba – below average level; A – average level; Aa – above average level; H – high level).

Figure 4. The tree of logical conclusion for hierarchical relationships of factors

Table 2. Systematization of factors for the proposed model (D)

Source: Authors' elaboration.

Linguistic variables	Universal set, terms for evaluation
Organizational factors (X)	
Extent of ownership and control index, (x_1);	[0-8], "Low," "average," "high"
Extent of corporate transparency index, (x_2);	[0-8], "Low," "average," "high"
Credit registry coverage, % of adults, (x_3);	[0-100], "Low," "average," "high"
Credit bureau coverage, % of adults, (x_4).	[0-100], "Low," "average," "high"
Informational and legal factors (Y)	
Strength of legal rights index, (y_1);	[0-12], "Low," "below average," "above average," "high"
Extent of director liability index, (y_2);	[0-12], "Low," "below average," "average," "above average," "high"
Extent of shareholder rights index, (y_3);	[0-8], "Low," "below average," "above average," "high"
Quality of judicial processes index, (y_4);	[0-20], "Low," "below average," "above average," "high"
Depth of credit information index, (y_5);	[0-8], "Low," "average," "high"
Postfiling index, (y_6);	[0-100], "Low," "below average," "average," "above average," "high"
Strength of insolvency framework index (y_7).	[0-16], "Low," "below average," "average," "above average"
Economic factors (Y)	
Total tax and contribution rate, % of profit, (z_1);	[0-80], "Low," "average," "high"
Recovery rate (cents on the dollar), (z_2);	[0-100], "Low," "average," "high"
Cost, % of estate %, (z_3);	[0-60], "Low," "average," "high"
Time, years, (z_4).	[0-4], "Low," "average," "high"

Table 3. Output data for modeling the level of prevention of corporate bankruptcies (D)

Source: The World Bank (n.d.).

Country	Factors														
	Organizational				Informational and legal							Economic			
	x_1	x_2	x_3	x_4	y_1	y_2	y_3	y_4	y_5	y_6	y_7	z_1	z_2	z_3	z_4
Austria	7	6	2.2	53.5	4	7	5	13	7	98.5	11	51.4	79.9	10	1.1
Belgium	3	6	95.6	0	8	7	4	8	5	83.5	11.5	55.4	89.4	3.5	0.9
Bulgaria	4	7	78	0	8	8	6	10.5	5	71.2	12	28.3	37.7	9	3.3
Hungary	5	5	0	91.1	9	7	4	12.5	6	87.5	10	37.9	44.2	14.5	2
Germany	5	6	1.8	100	6	5	5	12.5	8	97.7	15	48.8	79.8	8	1.2
Greece	6	6	0	69.9	2	5	5	12.5	7	76.7	11.5	51.9	32	9	3.5
Denmark	5	6	0	7.3	8	8	5	14	6	89.4	12	23.8	88.5	4	1
Ireland	3	6	94.4	100	7	9	5	8.5	7	93.4	10.5	26.1	86.1	9	0.4
Iceland	5	6	0	100	4	8	5	7.5	7	87.2	11.5	31.9	85.5	3.5	1
Spain	5	6	68.6	7.5	5	6	6	11.5	7	93.6	12	47	77.5	11	1.5
Italy	4	7	31.1	100	2	6	5	13	7	52.4	13.5	59.1	65.6	22	1.8
Latvia	5	6	96.9	48.1	9	9	5	13.5	8	98.1	12	38.1	41.4	10	1.5
Lithuania	6	7	53.7	100	6	7	4	15	8	97.5	8	42.6	40.3	15	2.5
Luxembourg	2	6	0	0	3	4	4	8.5	0	83.8	7	20.4	43.9	14.5	2
Malta	4	6	54.4	0	2	8	6	10.5	5	52.5	5.5	44	39.2	10	3
Poland	4	6	0	100	7	9	5	11	8	77.4	14	40.8	60.9	15	3
Portugal	4	6	100	7.9	2	7	3	13.5	7	92.7	14.5	39.8	64.8	9	3
Romania	3	5	19.4	54.5	9	5	5	14	7	76.8	13	20	34.4	10.5	3.3
Slovakia	5	4	2	85.4	7	7	5	13.5	7	87.2	13	49.7	46.1	18	4
Slovenia	6	5	100	0	3	8	6	11.5	6	80	11.5	31	90	4	0.8
Sweden	6	6	0	100	7	7	5	12	5	90.7	12	49.1	78.1	9	2
France	6	7	17	0	4	6	4	12	6	92.4	11	60.7	74.8	9	1.9
Ukraine	6	7	2.4	56.9	8	6	4	11.5	7	86	8.5	45.2	9	40.5	2.9

which has a tactical and strategic nature for both states. Based on the principles laid down in formulas 1-2, calculations of the values of membership functions for all non-term vertices, the constructed system of fuzzy logic equations (for d_1, d_2) of formulas 8-10 and the data in Table 2, the following results were obtained:

$$\mu(d1) = 0.402 \wedge 0.225 \wedge 0.183 \vee \quad (13)$$

$$\vee 0.402 \wedge 0.380 \wedge 0.183 \vee 0,402 \wedge 0.380 \wedge 0.183,$$

$$\mu(d2) = 0.691 \wedge 0.623 \wedge 0.605 \wedge \quad (14)$$

$$\wedge 0.691 \wedge 0.770 \wedge 0.605 \vee 0.691 \wedge 0.770 \wedge 0.605,$$

$$\mu(d3) = 0.215 \wedge 0.770 \wedge 0.259 \vee \quad (15)$$

$$\vee 0.215 \wedge 0.770 \wedge 0.259 \vee 0.215 \wedge 0.770 \wedge 0.259.$$

Thus, the level of prevention of enterprise bankruptcies in Ukraine and Romania is:

$$D_{Romania}^* = \frac{0.183 \cdot 1 + 0.605 \cdot 5.5 + 0.215 \cdot 10}{0.183 + 0.605 + 0.215} = \quad (16)$$

$$= 5.644,$$

$$D_{Ukraine}^* = \frac{0.380 \cdot 1 + 0.578 \cdot 5.5 + 0.141 \cdot 10}{0.380 + 0.578 + 0.141} = \quad (17)$$

$$= 4.520.$$

The conducted calculations show that the value of the complex indicator D (the level of prevention of enterprise bankruptcies) in 2020 in Romania was 5.644 and in Ukraine – 4.520, i.e., these values fell into the interval (d_2) – [4-7]), which makes it possible to conclude that the level of prevention of enterprise bankruptcies is estimated as average.

The model for preventing enterprise bankruptcies is considered an essential component of the management decision-making system, improving the situation in the reduction of risks related to the bankruptcy of enterprises, which involves the development of appropriate measures at the state level. This prompts the formation of management measures to prevent the bankruptcy of enterprises (in the example of Ukraine) under force majeure circumstances (Figure 5).

The central management measures to prevent the bankruptcy of Ukrainian enterprises in force majeure circumstances are normative-legal, economic, organizational-legal, social, production-techni-

cal, informational, and personnel. The effectiveness of the implementation of the above measures in the management decision-making system can also be evaluated by applying the proposed model of preventing the bankruptcy of enterprises. It will make it possible to compare the actual and basic simulation results and quickly take appropriate measures.

4. DISCUSSION

The approach proposed in this study has certain advantages over the existing ones. First, it is based on the application of the method of artificial intelligence, namely the theory of fuzzy logic. Second, it contains two groups of factors – internal and external – and focuses more on the quality of corporate governance: reducing the risk of abuse by management of their position, fraud and falsification of financial statements, etc. Internal factors (abstracted from financial indicators that are based on purely financial statements) include net profit, equity capital, working capital ratio to current liabilities, etc. External factors comprise the level of corporate transparency, the level of protection of credit operations, the level of legal responsibility, the level of shareholder rights, the level of quality of the judicial system, the level of effectiveness of the regulatory and legislative framework based on the experience of applying bankruptcy procedures in Germany, Italy, France, or the USA. The debatable issue of building a model to prevent the bankruptcy of enterprises is the abstraction from the financial indicators on which most bankruptcy forecasting models are based.

The proposed model for preventing corporate bankruptcies should be based on the following theoretical and methodological approaches. First, it should ensure the efficient operation of enterprises and protect the rights of shareholders and business owners to avoid fictitious bankruptcies (Antil, 2022; Dufrene, 1993; Mooradian, 1994; White, 1994; Dou et al., 2020). Second, reduce the risk of investing in risky and deliberately unprofitable business projects (Black & Scholes, 1973; Jensen & Meckling, 1976). Third, provide reliable, objective, and up-to-date information, including credit information (Dufrene, 1993; Mooradian, 1994; White, 1994; Dou et al., 2020). Forth, in-

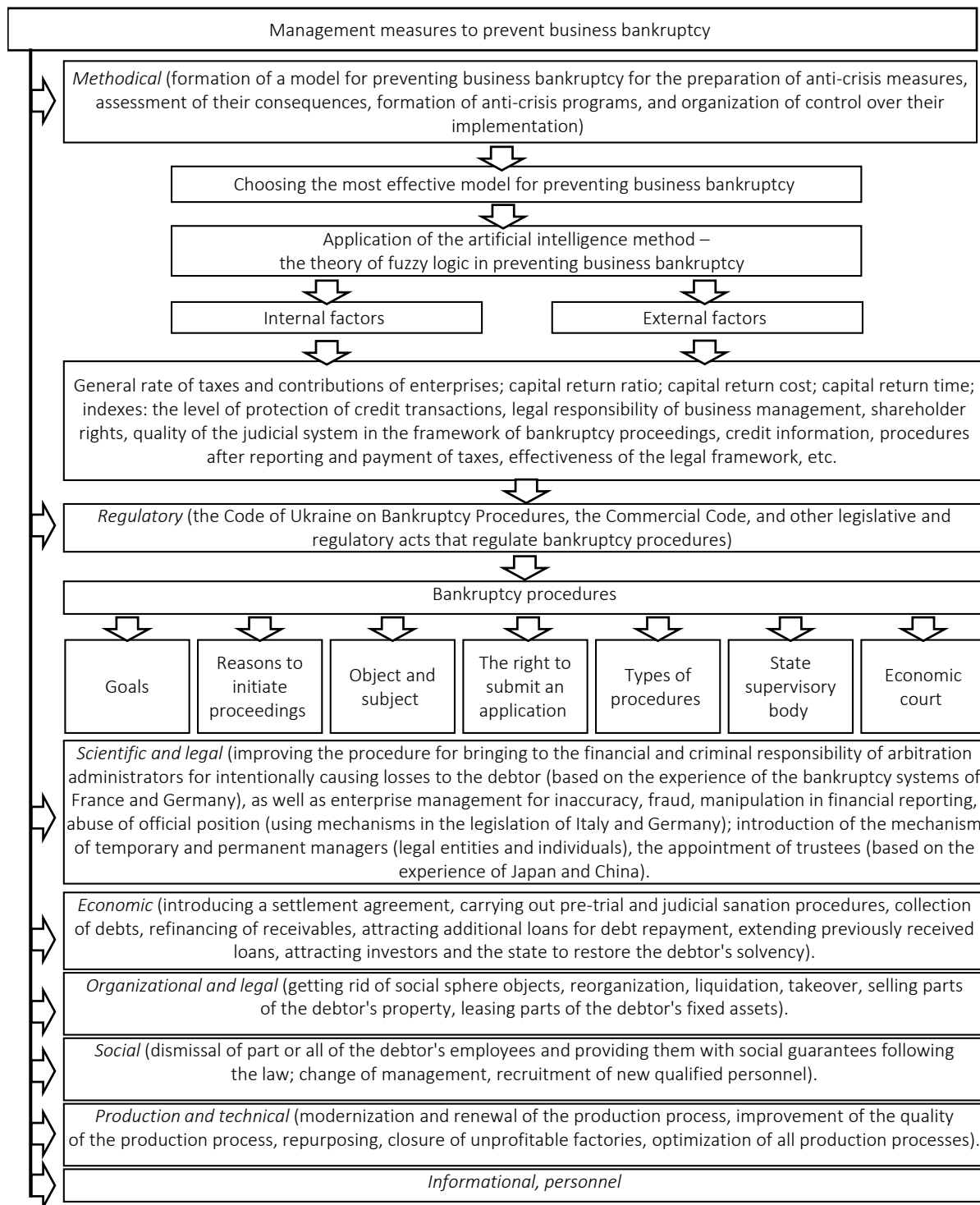


Figure 5. Management measures to prevent the bankruptcy of Ukrainian enterprises under the force majeure circumstances

crease the effectiveness of the structure and quality of management, ensuring corporate transparency (Bergstresser & Philippon, 2006; Armstrong et al., 2013; Jia et al., 2014; Davidson et al., 2015;

Ham et al., 2017). Finally, increase the efficiency of legal procedures for conducting bankruptcy procedures and the work of the judicial system within the framework of the implementation of bank-

ruptcy cases, and improve the legal framework that regulates the mechanism for implementing the bankruptcy procedure (Davidson et al., 2015).

A critical task for developing global business is to reduce the risk of insolvency of enterprises and their bankruptcy. This problem can be solved by building a model for preventing business bankruptcies. The existing models are based mainly on financial indicators (Aziz & Dar, 2006; Hotchkiss et al., 2008; Senbet & Wang, 2012). These models can be used at the enterprise level, but their application at the state level becomes problematic. Solving the problem of using legal, informational, and economic factors in the models, i.e., external factors, on which the probability of the deterioration of solvency and the onset of bankruptcy also strongly depends, is promising. The developed model for preventing the bankruptcy of enterprises is unique and is based on a promising method of artificial intelligence – the theory of fuzzy logic (Matviychuk, 2013; Kozlovskiy et al., 2019). Therefore, it is necessary to build a system for assessing the level of prevention of business bankruptcy, taking into account not only economic, but also legal factors (related to increasing the efficiency of enterprise management; protecting the rights of shareholders, covering the population with credit registers, protecting the rights of shareholders, and ensuring the transparency of business management). The use of economic, financial, and legal factors simultaneously and in the form of “linguistic” assessments determines a certain uniqueness of this development in comparison with existing bankruptcy forecasting models (models of Altman, Springate, Lees, Fulmer, Kadykov, Beaver, and many others).

From a theoretical point of view, it is promising not only to choose a method of assessing the level of prevention of business bankruptcies with the building of an appropriate model and the development of management measures but also to improve the approach to managing business bank-

ruptcies under the conditions of force majeure circumstances in Ukraine. The main components of this approach should be (Figure 5):

- setting goals (assessing the state of business development, forecasting and preventing the probability of bankruptcy);
- defining subjects (the main subjects are: shareholders, owners, managers, arbitration administrators, state bodies, associations, and judicial bodies);
- defining objects (the object of management is processes and phenomena (external and internal), which may threaten the financial position, solvency, and bankruptcy of businesses);
- establishing functions (diagnostic, planning, organizational, stabilizing, controlling, informative and cognitive, practical, motivational, protectionist, educational, and research);
- establishing principles (effectiveness and optimality of management decisions, dedication to work, timely response to changes in the internal and external environment, legality, responsibility, and comprehensiveness); and
- developing strategies and programs that should ultimately lead to a rational decision (phased liquidation, takeover, and reorganization).

At the same time, in Ukraine, as evidenced by the experience of developed countries, during the bankruptcy procedure, more decisions are made aimed at restructuring rather than the liquidation of enterprises, which, under the force majeure conditions (war or spread of COVID-19), is extremely important for the development of the economy.

CONCLUSION

This study developed the model for preventing enterprises' bankruptcy under force majeure. The implementation of the study goal is based on the search for effective methods of determining the level of prevention of business bankruptcies. The chosen method of the theory of fuzzy sets as a type of artificial intelligence method made it possible to take into account quantitative and qualitative factors in the modeling process and, as a result, obtain a comprehensive indicator of the level of prevention of business bankruptcies.

The obtained value of the complex indicator for the selected two countries among the group of 23 countries, Ukraine and Romania, shows that the level of prevention of enterprise bankruptcy is 4.520 and 5.644, respectively. The importance of the obtained values lies in the ability of the bodies responsible for the state of business development in their countries to make timely and quick decisions on preventing the bankruptcy of enterprises and to develop appropriate management measures. In addition, by performing annual calculations of the above complex indicator, it is possible to evaluate its dynamics and the management decisions taken to prevent the bankruptcy of enterprises. The proposed management measures (scientific-legal, economic, organizational-legal, social, production-technical) increase the efficiency of the decision-making system preventing the bankruptcy of enterprises.

AUTHOR CONTRIBUTIONS

Conceptualization: Rodion Poliakov, Ivan Zayukov.
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 Funding acquisition: Rodion Poliakov.
 Investigation: Rodion Poliakov.
 Methodology: Ivan Zayukov.
 Project administration: Ivan Zayukov.
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 Software: Rodion Poliakov.
 Validation: Rodion Poliakov, Ivan Zayukov.
 Visualization: Ivan Zayukov.
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 Writing – review & editing: Rodion Poliakov, Ivan Zayukov.

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