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APPLICATION OF MATHEMATICAL MODELS IN OVERCOMING THE CRISIS STATE OF ECONOMICALLY UNSTABLE ENTERPRISES

ЗАСТОСУВАННЯ МАТЕМАТИЧНИХ МОДЕЛЕЙ ПРИ ВИХОДІ ІЗ КРИЗОВОГО СТАНУ ЕКОНОМІЧНО НЕСТІЙКИХ ПІДПРИЄМСТВ

Summary. The article proves that all economic crises are unique in their own way. This not only raises a serious problem of correct forecasting of the main parameters of the crisis on the basis of previous experience of economic development, but also emphasizes that the economic situation in which the crisis occurs is also unique. Obviously, if we imagine the onset of the same crisis in different time epochs, the development of the crisis situation may differ significantly, determining a high degree of stochasticity of this process. It is recognized that decision-making under conditions of uncertainty is a rather complex task. In this aspect, the probabilistic nature of the output variable is an attempt to obtain some simple integral characteristic of the enterprise crisis resistance under the accepted assumptions (optimal management) on the basis of the available experience. This assessment in its numerical expression (in the case of bringing it to clarity) cannot be considered as an exact parameter. Forming a ranked list of such assessments, we can come to a linguistic variable of output with a basic term set: high crisis resistance; moderate crisis resistance; low crisis resistance. On the one hand, it is a direct mathematical analysis, which consists in predicting the value of one linguistic variable (output variable) through other variables (including linguistic ones) by analyzing a fuzzy relation with some restrictions (fuzzy criterion of non-dynamicity), the difficulties of which are pointed out by the authors. In this case, as it was shown above, the expert system is formed in accordance with the course of human reasoning, without taking into account which its correctness and efficiency will be extremely low. However, on the other hand, a linguistic variable, which does not pretend to high accuracy in case of its reduction to clarity, at least because this clarity value essentially depends on the chosen method of reduction to clarity, in the authors' opinion, removes the very principle of "economy" associated with "elegance" of mathematical solutions, which is unacceptable and is a hindrance. At the same time, the problem of correct ranking of enterprises according to their crisis-resistance from the point of view of the peculiarities of the production process associated with a high degree of non-dynamism is solved. Thus, a compromise between the possibility of direct mathematical analysis and the absence of interference in decision-making has been found, which makes it possible to achieve the goal set in this article.

Key words: economic sustainability, crisis period, indicators, mathematical modelling, development.

Formulation of the problem. The estimated integral indicator of the company's lack of dynamism should be correlated with the main parameters of the impending crisis to determine the degree of reorganization of the enterprise's production process, the final result of which should be a reduction of lack of dynamism to such a level that will allow the company to successfully overcome the crisis, preserving key production and personnel potential. To achieve this goal, it is necessary to form a criterion for the non-dynamism of the enterprise, which would determine the critical value of the non-dynamic indicator, above which the enterprise will almost inevitably suffer irreparable significant losses in a crisis or even cease its activities due to a high degree of non-dynamism. At the same time, as already noted above, the quality of management decisions in this paper is not analyzed and is considered close to optimal.

Analysis of recent achievements and publications. The first works of foreign and domestic scientists [1-8] used mainly linear regression methods in assessing the financial and economic state of an enterprise before and after the crisis. However, the linear function has limitations even with small changes in parameters. For example, the weights and threshold intervals in the Altman model vary greatly depending on the country and year of the study; therefore, this model is not stable. In addition, linear regression equations do not allow taking into account the uniqueness and specificity of each of the surveyed enterprises, do not allow correctly analysing the state of enterprises in border zones.

Therefore, the **purpose** of the article is to analize the problems of economic stability of enterprices with weak dinamics during a crisis period and to propose measures to improve the situation.

Presentation of the main material. In [8] the crisis is modelled as a catastrophic phenomenon characterised by a sharp, discontinuous transition, sudden qualitative changes in the state of non-linear dynamic systems, which are enterprises. At the same time, it is noted that the enterprise is a complex system, the abrupt changes of which are poorly analysed and predicted by classical mathematical methods. The analysis of crises in enterprises allowed the authors of [6] to propose the following classification of the types of crises in the enterprise:

– prolonged;
– protracted;
– unexpected and abrupt;
– intense and rapid;
– leading to an insurmountable catastrophe.

Moreover, according to the authors [8], classical methods of analysis allow us to sufficiently study only the first two types of crises. At the same time, the catastrophe theory provides an opportunity to study sharp, jump-like transitions, sudden qualitative changes. However, these data have a significant dependence on the accuracy of estimation of the crisis parameters and the degree of non-dynamism of the enterprise, which has already been mentioned above. If a number of scenarios can be used to estimate parameters of the crisis can be used a number of scenarios: «optimistic», «neutral» and «pessimistic», thus removing the uncertainty of the real parameters of the crisis, the overlap of errors in the assessment of the degree of non-dynamicity of the enterprise, as well as its ability to reduce non-dynamicity makes this approach too cumbersome for the development of a set of measures to reduce non-dynamicity.

The authors [8] note the practical significance of work using the theory of catastrophes as the possibility of timely anticipation of the emerging discrepancy in the structure of the enterprise, determining the moment of entering the critical area. However, if the crisis comes suddenly and abruptly, ensuring timeliness is quite problematic. On the other hand, without considering the impact of the accuracy of estimating the real crisis parameters of the enterprise on the timeliness of anticipating mismatches, the practical significance is reduced. Different models of catastrophes will also give different results, which will be observed in fuzzy sets when applying different algorithms. sets at application of different algorithms of fuzzy inference, as well as the methods of fuzzification. methods of reduction to fuzziness. The inconsistencies in the structure themselves can be quite can be interpreted as a suboptimal value of the non-dynamicity index due to the inefficient organisation of production processes at the enterprise. inefficient organisation of production processes at the enterprise.

The disadvantages of such models are considered [6]:

– insufficient validity of the choice of a set of financial and economic indicators of the enterprise's activity, the values of which determine the distance of its current position from the «bankrupt» position;

– failure to take into account organisational-technical and financial-resource differences between enterprises of the same industry, and even more so between different industries in the formation of a certain «average» benchmark, for which at the first stage the system of weights of indicators in Z-survey is determined, and at the second stage – the range [Z1; Z2];

– «static» nature of the model, which consists in the deterministic nature of the procedures of forming a set of indicator weights, and, most importantly, the range [Z1, Z2], which does not correspond to the realities of enterprises' activity in the conditions of a highly dynamic market environment.

Some researchers come to the conclusion that the practice of analysing real phenomena has shown that in modern conditions for the economy with its instability and financial crises, the classical economic theory and statistics based on linear models proved to be unproductive [7].

Parallel to the linear models, «qualitative» models were also built, based on the study of characteristics inherent in enterprises on the way to bankruptcy and the assignment of appropriate scores. For example, the well-known Argentine model [8] allows predicting the management crisis as one of the factors affecting the possible bankruptcy of the enterprise, using the Argentine indicator (A-score). Bankruptcy forecasting by the method of financial flow analysis by J. K. Van Horn [6] is widely used. However, it should be noted that the correct construction of such models within the economy is still problematic due to the lack of mandatory consideration of a number of factors affecting the financial stability of enterprises. As a rule, these models are built on the basis of the discriminant method on the basis of statistical data of enterprises of one country and their use is limited to the limits of this country or, at best, countries that are close in terms of accounting system, taxes, etc. The applicability of these models for the economy should be checked statistically, because for all their merits they were built on the basis of studying the behaviour of firms in the conditions of Western economic development, which may not correspond significantly to the conditions of economic development of our country.

Fractal models of crisis phenomena are reduced to the study of financial and economic indicators of the enterprise from the parameters of the crisis by approximating the time series of data dynamics of these indicators by fractal functions [7]. Within the framework of the fractal approach the indicators are considered to be dependent on the fractal dimension of the approximating function [1]. However, in the fractal theory it is not easy to define the concept of fractal dimension [2]. The use of Hausdorff-Bezikovitch dimension, Minkowski dimension, generalised Renyi dimension, etc. as a fractal dimension essentially turns the fractal dimension into a fuzzy variable, since the values of the above fractal dimensions are generally different. The very proof of the fractal market hypothesis [3] also does not look trivial in a concrete situation, since the fractal is a fine structure from a mathematical point of view. The correctness of application of fractals should be investigated and justified separately and based not only on good local coincidence of particular results of modelling and real situation. of modelling and real situation.

To make decisions about reorganisation of production in crisis for enterprises with weak dynamics, it is worthwhile to briefly discuss the methods of decision-making. They are divided into axiomatic, heuristic and verbal. Verbal analysis allows:

– to check the received information for contradictions;

– to present contradictory information to the decision maker for its verification;

– establish ways of analysing and eliminating contradictions.

The sudden onset of a crisis situation leaves minimal time for detailed analyses and checks, so, according to the authors [5], verbal methods are poorly suited. In such situations, many researchers see the advantages of axiomatic and heuristic methods, such as multicriteria utility theory, analytical hierarchy method, fuzzy sets theory.

The author of [5] considers heuristic methods more suitable for decision-making under uncertainty, because the heuristic approach itself corresponds to repetitive complex situations that at first glance do not lend themselves well to direct mathematical analysis. The decision selection process is modelled in such a way that the human reasoning process is reproduced, and the very principle of 'economy' associated with the «elegance» of mathematical solutions is unacceptable and is a hindrance [7]. However, these statements do not seem to apply to the apparatus of fuzzy sets. Repetition of complex situations is provided by the expert system, the direct mathematical analysis of which is the algorithm of implementation of fuzzy inference. The choice of the method of fuzzification is closely connected with the course of reasoning, which is described in [7].

Thus, the use of the apparatus of fuzzy sets for the construction of the criterion of non-dynamicity, related as in the criterion of non-dynamicity, related both to the estimation of the current degree of non-dynamicity of the enterprise, as well as the forecast of its criticality in relation to the impending crisis. impending crisis, as well as the development of a set of measures for the reorganisation of production activity. reorganisation of production activities during the crisis period in order to reduction of non-dynamicity, seems to be the most justified and

in line with the conclusions of many researchers concerning the correctness of application of the mathematical apparatus for modelling the crisis. mathematical apparatus for modelling the crisis dynamics of an enterprise.

Conclusions. If there are no changes in the initial data or knowledge base, it is necessary to form a fuzzy conclusion in the form of evaluation of the belonging functions of the investigated enterprises to the fuzzy subsets describing the basic term-multiplicity of the fuzzy criterion of non-dynamicity. Thus, a classical expert system has been constructed, which allows solving the problem of assessing the crisis resistance of the enterprise as an analysis of the criticality of the degree of their non-dynamicity in the aspect of the main parameters of the impending crisis. Significant criticality means the necessity to increase the efficiency of production organization during the crisis period by reducing the non-dynamism. On the basis of the output variable obtained with the help of the expert system, taking into account the constraints, a fuzzy criterion of non-dynamicity will be formed in the next section of the chapter.

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Анотація. У статті доведено, що всі економічні кризи по-своєму унікальні. Це не тільки висуває серйозну проблему коректного прогнозування основних параметрів кризи на основі попереднього досвіду розвитку економіки, а й акцентує увагу на тому, що унікальною є і сама економічна ситуація, в яку настає криза. Очевидно, що якщо уявити собі настання однієї й тієї самої кризи в різні часові епохи, то розвиток кризової ситуації може істотно відрізнятися, визначаючи високий ступінь стохастичності цього процесу. Визначено, що ухвалення рішень в умовах невизначеності є досить складним завданням. У цьому аспекті ймовірнісний характер змінної виходу – це спроба отримати якусь просту інтегральну характеристику кризостійкості підприємства за прийнятих припущень (оптимального менеджменту) на основі наявного досвіду. Цю оцінку в числовому її вираженні (у разі приведення до чіткості) не можна розглядати як точний параметр. Формуючи

ранжований список таких оцінок, можна дійти до лінгвістичної змінної виходу з базовою множиною: висока кризової стійкість; помірна кризової стійкість; низька кризової стійкість. З одного боку, це – безпосередній математичний аналіз, який полягає у прогнозуванні значення однієї лінгвістичної змінної (змінної виходу) через інші (зокрема, лінгвістичні) шляхом аналізу нечіткого відношення з деякими обмеженнями (нечіткий критерій нединамічності), на складність якого вказують автори. При цьому, як це було показано вище, експертна система формується відповідно до перебігу міркування людини, без урахування якого її коректність і ефективність будуть вкрай низькими. Однак, з іншого боку, лінгвістична змінна, що не претендує на високу точність у разі її приведення до чіткості, хоча б тому, що це чітке значення істотно залежить від обраного методу приведення до чіткості, на думку авторів, знімає той самий принцип «економії», пов'язаної з «вишуканістю» математичних рішень, який є неприйнятним і є перешкодою. При цьому розв'язується завдання коректного ранжування підприємств за їхньою кризостійкістю з погляду особливостей виробничого процесу, пов'язаних із високим ступенем нединамічності. Таким чином, знайдено компроміс між можливістю безпосереднього математичного аналізу і відсутністю перешкод під час ухвалення рішень, що дає змогу досягти мети, поставленої в цій статті.

Ключові слова: економічна стійкість, кризовий період, показники, математичне моделювання, розвиток.