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BASIC APPROACHES TO INVESTMENT RISKS MODELING

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Abstract. *The paper highlights the need for analysis and assessment of enterprise investment risks in conditions of uncertainty and suggests the use of a neuro-fuzzy investment risk assessment model.*

Keywords: *investment risks, evaluation, evaluation methods, fuzzy logic, neural networks.*

Introduction.

The investment activity of the enterprise should be considered in two directions, as internal and as external. Considering the economic situation, the consideration of domestic investment activities is the most relevant. This direction involves real investment in the reproduction of fixed assets, as well as the creation of new types of products and the reduction of production costs.

Given that industrial enterprises lose part of their assets during crisis, risk management of their activities is a primary task. This requires an investment risk management system adequate to economic conditions. The uncertainty of the environment in which the enterprise has to carry out its activities is the most important reason for the existence of investment risk, its integral and significant characteristic.

Main text.

As a rule, the risks of investment projects mean the possible deterioration of the final performance indicators of the project, which arises under the influence of uncertainty. In quantitative terms, risk is usually defined as a change in numerical indicators of the project: net present value, internal rate of return and payback period. It is possible to distinguish the main investment risks: marketing risk, risk of non-compliance with the project schedule, risk of exceeding the project budget, as well as general economic risks.

Risk management involves the analysis of conditions for decision-making. The information used in this analysis is not completely accurate and reliable. This is due to both the complexity of the projects and the incompleteness of the information, as well as the unsuitability of the chosen methods for its analysis.

When evaluating investment projects in conditions of uncertainty, two tasks can be distinguished: uncertainty must be minimized by clarifying information, both quantitatively and qualitatively; uncertainty needs to be formalized and taken into account when assessing the risks and cost of projects. The reliability of the assessment depends on the quality of the information and the correct choice of the mathematical apparatus.

Risk analysis is aimed at achieving the following main goals [1]: formation of a holistic picture of risks threatening the interests of the enterprise; ranking of risks by degree of influence and identification of the most dangerous among them; comparison of alternative options; creation of databases and knowledge bases for expert systems; justification of risk reduction measures.

Risk assessment methods such as risk adjustment, analytical and expert assessments can be defined. When adjusting the amendment, the discount rate is used, which is considered risk-free or minimally acceptable. In the future, a risk premium is added to it and criteria such as NPV, IRR, PI are calculated. The most famous adjustment method is the Cumulative Capital Model (CCM) method.

The analytical group includes statistical and probabilistic risk assessment methods. Statistical ones are based on the study of the statistics of the losses that have taken place, the determination of the frequency of occurrence of losses and the prediction of their probability. Probabilistic methods are based on mathematical approaches. The main drawback of these methods is the dependence of the results on the quality of the forecast model.

The scenario method is reduced to the study of the dependence of the resulting indicator on the variation of the values of the indicators used. It allows to get a visual picture for various project implementation options, and also provides information about sensitivity and possible deviations. To use this method, the expert needs to determine the most probable, pessimistic and optimistic scenario, however, if the project implementation environment is very mobile, then it is very difficult to predict the results [2].

The main types of expert evaluations include quantitative evaluation, point evaluation, and ranking. Special so-called verbal-numerical scales are used for analysis. Harrington's verbal-numerical scale is common, i.e. the scale of correspondence of verbal assessments with numerical ones [3].

The method of obtaining an expert assessment in most cases includes the following points:

1. Formation of the purpose of the examination;
2. Formation of survey rules; formation of groups of experts;
3. Choosing a method of assessing the competence of experts;
4. Formation of rules for processing experts' opinions;
5. Conducting a survey and determining group assessments;
6. Determination of the degree of consistency of experts' assessments.

The main drawback of expert evaluations is subjectivity.

Analysis of the application of traditional methods of risk assessment shows their limitations, insufficient reliability of the results, which is connected with the lack of precise numerical characteristics. In these conditions, it is possible to use methods of fuzzy logic, which are closer in spirit to human thinking than traditional logical systems.

The main advantages of fuzzy logic in solving economic problems are [4]:

1. The ability to operate with input data given vaguely: for example, values that change continuously over time (dynamic problems), values that cannot be set unambiguously (results of statistical surveys, etc.);
2. The possibility of unclear formalization of assessment and comparison criteria;
3. The possibility of qualitative assessment of both input data and output results;
4. The possibility of rapid modeling of complex dynamic systems and their comparative analysis with a given degree of accuracy: operating on the principles of system behavior described by fuzzy methods, firstly, not much time is spent on finding out the exact values of variables and ordering the equations that describe them, and secondly, it is possible to evaluate different variants of the initial values.

Fuzzy-multiple methods of analysis make it possible to process heterogeneous, imprecise, qualitatively presented information related to the objects under study. When used together with the theory of artificial neural networks, it is possible to largely get rid of the general shortcomings of all methods associated with obtaining expert evaluations due to the use of information obtained as a result of statistical data processing.

Neural networks are models of biological neural networks of the brain, in which neurons are simulated by relatively simple, often identical, elements (artificial neurons) [5]. A neural network can be represented as a directed graph with weighted connections, in which artificial neurons are vertices and synaptic connections are edges.

Neural networks are used in the processes of pattern recognition, forecasting, adaptive control, creation of expert systems, organization of associative memory, etc. The possibility of using neural networks is included in almost all known statistical packages. The most famous specialized packages are BrainMaker, NeuroOffice, NeuroPro, etc. Most neuropackages include: creation of a network (user selection of parameters or adoption of standard settings); network training; issuing a decision to the user.

Consider an approach to determining investment risks based on a neural fuzzy network (NFN). In order to develop and use NFN for investment risk analysis, it is necessary to determine the structure of the network. The input variables will be the values of three risk factors on the interval [0, 1], which are described by the linguistic term set (very low, low, medium, high, very high).

As a result, the system output will receive an estimate of the risk level on the interval [0;1], described by a linguistic term set (negligibly low, very low, low, below average, moderate, above average, high, very high, critical).

The risk level measurement scale will look like this:

1. Negligibly low (0) – the risk can be neglected;

2. Very low (0.125) – it is necessary to determine whether there is a need for corrective actions, or whether it is possible to accept this risk;

3. Low (0.250) – the level of risk allows work, but there are prerequisites for disruption of normal work;

4. Below the average (0.375) – it is necessary to develop and apply a plan of corrective actions within an acceptable period of time;

5. Moderate (0.500) – the level of risk does not allow stable work, there is an urgent need for corrective actions that change the mode of work in the direction of reducing risk;

6. Above average (0.625) – the enterprise can continue to work, but the corrective action plan must be implemented as soon as possible;

7. High (0.750) – the level of risk is such that business processes are in an unstable state;

8. Very high (0.875) – it is necessary to immediately take measures to reduce the risk;

9. Critical (1) – the level of risk is very high and is unacceptable for the enterprise, which requires the termination of investment activities and the adoption of radical measures to reduce risk.

After determining the structure of the NFN, the membership functions of the input variables should be set. In addition, it is necessary to set the parameters of the selected membership functions.

Specialized programs have been developed to perform these procedures. The most effective development tool is the FIS editor of the MATLAB software complex, which has a graphical interface and allows you to call all other editors and viewer programs for fuzzy output systems.

Let us give an example of a fuzzy model for which the following parameters are selected:

1. 3 input (threat, damage, vulnerability) and 1 output (risk) variables;

2. Type of fuzzy inference system – Sugeno;

3/ And method (logical conjunction method) – prod (algebraic product method);

4. Or method (logical disjunction method) – probor (method of algebraic sum);

5. Implication (conclusion method) – min (minimum value method);

6. Aggregation – max (maximum value method);

7. Defuzzification (method of defuzzification) – wtaver (weighted average method).

For 3 input variables, 5 fuzzy classes (very low, low, medium, high, very high) and a trapezoidal membership function are selected. For the output variable, 9 fuzzy classes (negligibly low, very low, low, below average, moderate, above average, high, very high, critical) are selected, which in the Sugeno-type fuzzy system take the above-mentioned fixed values on the interval [0, 1], so there is no membership function for the output variable.

The fuzzy investment risk analysis model contains 125 fuzzy inference rules for all possible combinations of fuzzy classes of input variables.

A fragment of the set of rules is presented below.

1. *If (Threat is Very Low) and (Damage is Very Low) and (Vulnerability is Very Low) then (Risk is Extremely Low)* (1)

2. *If (Threat is Very Low) and [Damage is Very Low) and (Vulnerability is Low) then (Risk is Extremely Low) (1)* and so on to point 125.

So, the fuzzy inference system contains 3 input variables with 5 terms, 125 fuzzy production rules, and 1 output variable with 9 terms. To create a NFN, it is necessary to create a file with training data (a file with the extension *.dat), which is an ordinary text file. At the same time, the training data is a numerical matrix of dimension *mx (n+1)*, in which the number of rows m corresponds to the volume of the sample, the first n columns – the values of the input variables of the model, and the last column – the value of the output variable.

Although there are no formal recommendations for the number of rows of the training data matrix, it is generally accepted that the training quality of the hybrid network and, therefore, the accuracy of the obtained results proportionally depends on the size of the training sample. As for the number of columns, in the case of NFN for investment risk analysis, it is 4.

The investment risk assessment algorithm based on the application of NFN consists of the following stages [6]:

1. Conducting an expert survey to obtain estimates of the strength of the threat (a_1), the amount of damage (a_2) and the degree of vulnerability (a_3) in the interval [0, 10];

2. Ensuring the adequacy of expert assessments through the calculation of the concordance coefficient: The concordance coefficient W lies within [0, 1]. The closer the value of the coefficient is to one, the higher the level of consistency of experts' opinions. Usually, the minimum permissible value of the concordance coefficient is 0.4. Therefore, with an agreed result, W>0.4;

3. According to the remaining estimates, the calculation of the input variables of the NFN – the maximum values of the probability of the realization of the threat (x_1), causing the most possible damage (x_2) and using the vulnerability of the system (x_3). Since the variables x_1, x_2, x_3 mean probabilities, their values should be in the interval [0, 1]. Submission of the received values of the variables x_1, x_2, x_3 to the input of the developed NFN;

5. Obtaining the value of the risk level, comparing it with a qualitative scale, analyzing the results and developing countermeasures based on the analysis.

Conclusions.

The neurofuzzy model can be used to: calculate the predictive value of the degree of risk; determining the ranges of change of each of the indicators of the investment project, under which the degree of difficulty remains high. The model can be used as a basis for creating decision support systems for investment risk management.

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