Neural Network Technologies of Investment Risk Estimation Taking into Account the Legislative Aspect

Anzhelika Azarova[1[0000-0003-3340-5701]], Larysa Azarova[1[0000-0002-2631-8151]], Liliia Nikiforova[1[0000-0002-7034-607X]], Veronika Azarova[1[0000-0001-7441-5725]], Olena Teplova[2[0000-0001-8763-891X]], Natalia Kryvinska[3[0000-0003-3678-9229]]

[1]Vinnytsia National Technical University, Vinnytsia, Khmelnytske shose 95, Ukraine

azarova.angelika@gmail.com, azarova.larusa@gmail.com, nikiforovalilia@gmail.com,nikolazarova14@gmail.com

[2]Vinnytsia Mykhailo Kotsiubynskyi State Pedagogical University, Vinnytsia, Ukraine

Teple@yandex.ua

[3]Comenius University in Bratislava, Bratislava, Slovakia

Natalia.Kryvinska@fm.uniba.sk

Abstract. The article proposes conceptual bases of formalization of the investment risk estimation process by means of mathematical and computer modeling on the basis of neural network technologies. The methodological approach to investment risk estimation has been improved. It allows identifying project risk and investment feasibility with using of Hamming neural network accurately and reasonably, reducing the cost of investment making decision and allows self-learning specialized network. The structural hierarchical model of the investment risk estimation process has been improved. It allows decomposing and simplifying the formalization procedure as well as allows simultaneous estimation of the financial ratio of the enterprise and its proposed investment project. The proposed mathematical model was verified and its adequacy was checked by comparing the results obtained on the basis of the application of existing methods and the approach developed by the authors of the article. This revealed the significant advantages of the method proposed in the article. The proposed approach was successfully implemented to estimate the investment risk of 20 domestic enterprises and projects.

Keywords: Investment risk, investment project, neural network technologies, Hamming neural network, Beaver's coefficient, Z-Score model, Lis's model, Taffler's model, Fulmer's model, Springgate's model, Chesser's model, Depalyan's model.

1 Introduction

Any field of human activity especially the economy and entrepreneurship is burdened by the risk posed by uncertainty, conflicts, variability of goals over time. The problem of risk and conflict is inherent in the economy. This is due, in particular, to the fact that the economic process is future-oriented. The external environment in which business organizations of various forms operate becomes qualitatively different: new risk factors appear, the degree of its risk increases. Scientifically based methods of risk estimation and consequently economic feasibility of investment projects (IP), their selection from existing alternatives are becoming increasingly significant. The lack of reliable information base poses a risk to investment decisions. There is always the possibility that a project which was considered attractive will be unprofitable in practice or will not bring the expected profits. This is, in particular, as a result of deviation of the actual values of indicators from those planned in the investment project, inaccurate structure of the investment model, the absence of significant and the presence of insignificant evaluation parameters.

The analysis of the state of real investment processes in Ukraine revealed a number of unresolved practical problems among which the main ones are: the focus of investors on obtaining a one-time fast profit; outflow of national capital; banks' disinterest in long-term crediting; low efficiency of the investment market; insufficient activity of public administration in financing business proposals; imperfection of legislation.

Since the beginning of Volodymyr Zelensky's presidency a lot of changes have been made in the legislation of Ukraine, in particular in the field of investments, both foreign and domestic. On October 3, 2019, the parliament passed a number of laws to stimulate investment: the law on concessions and the law on the lease of state and municipal property (new version) [1, 2]. Also, before January 1 of this year, the law on amendments to some legislative acts of Ukraine to stimulate investment activity in our country came into force. In addition, a law on the principles of government support of new investments in Ukraine was adopted [3]. It defines the principles of government support of new investments, determines the status of the State agency for support of these investments. The purpose of this law is to strengthen Ukraine's economic attractiveness for domestic and foreign investors, increase employment and improve the quality of ukrainian citizens' life. However, it should be noted that since 2014 Ukraine has become less attractive for investment due to the state of undeclared war in Donbas, not to mention the dangerous coronavirus which contributed to the suspension of normal economic activity in many sectors of the economy which significantly reduces investment in our country.

These problems negatively represent Ukraine in the world investment market and are obstacles to the use of developed investment mechanisms used in countries with post-industrial economies.

Thus, there is an objective need for scientific and theoretical substantiation of the concept and methodological principles of building mathematical methods and models of investment which will take into account the legislative, socio-economic aspect, strategic direction and provide an opportunity to increase investment activity and efficiency results. The generation of modern methodological principles requires the development of a qualitatively new methodological support for the implementation and stimulation of the investment process, i.e. the development of the concept of strategic investment of enterprises in an external environment that is not permanent.

Thus, the development of information tools for investment risk estimation based on modern intellectual technologies is extremely relevant at the present stage of development of Ukraine's economy.

2 Literature analyses

At the present stage of market economy development investment activity in Ukraine, despite some recovery in recent years, cannot be considered satisfactory. One of the reasons for this phenomenon is the difficulty of taking risks into account when evaluating investment projects. This causes inaccuracies in investment decisions which, in turn, can not only deprive the investor of the expected return, but also cause him significant losses.

Thus, the problem of investment risk management is one of the most of current interest. The processes of economic development in the crisis under the influence of the coronavirus in the world and in Ukraine have been exacerbated by uncertainty (demand, prices) and competition. To survive in such conditions, business leaders need to introduce new technologies and technical innovations, make bold and unconventional decisions and this increases the degree of economic risk. Therefore, you should learn to predict events, estimate the level and do not go beyond acceptable risk. Business inaction caused by coronavirus quarantine restrictions around the world is also associated with the risk of untapped opportunities.

The risk of both internal and external investors is acceptable and the investment is effective if the enterprise or project in which the investment can be made is profitable. Thus, we first analyze the models that predict the bankruptcy of enterprises that may be potentially investment objects. It allows to identify a potential threat to the timely formation of a system of measures to neutralize the negative trends in the financial situation in the enterprise.

Modern economics has many different techniques and methods for forecasting financial performance including the estimation of possible bankruptcy [4-8]. Most of them are focused on early diagnosis and prevention of signs of insolvency or bankruptcy.

For example, the paper [4] presents the results of intelligent information system development for enterprise bankruptcy risk estimation on the basis of fuzzy logic and neural network technologies synthesis. The developed information system allows making the current estimation of risk of bankruptcy of the enterprise and gives the chance to trace how it impacts to separate indicators' changes.

The paper [5] develops a genetic bankrupt ratio analysis tool using a genetic algorithm to identify influencing ratios from different bankruptcy models and their influences in a quantitative form.

The article [6] discusses the bankruptcy prediction model using random forest based on the most influential ratios needed to predict bankruptcy. These coefficients are selected based on a genetic algorithm that filters out the most important of the various existing bankruptcy models.

The article [7] proves that the traditional practice of using a singular performance metric for classifier evaluation is not sufficient for imbalanced classification credit and bankruptcy risk. This paper proposes a multi-criteria decision making (MCDM)-based approach to evaluate imbalanced classifiers in credit and bankruptcy risk prediction by considering multiple performance metrics simultaneously.

Note that the estimation of crisis symptoms of the enterprise and diagnosing the possibility of a financial crisis is carried out long before the detection of its obvious signs [8]. The key point of anti-crisis indicative planning of any organization is to determine the inclination of the enterprise as a whole as well as its structural units to bankruptcy. To do this, use the following basic mathematical models [9-16]: 2-factors model [9]. It is designed for the US economy. In Ukraine there are high inflation rates, other cycles of macroeconomics and microeconomics, levels of capital intensity, energy intensity and labor intensity of production, other taxation do not allow for a comprehensive estimation of the financial condition of enterprises and therefore significant deviations in estimates in the model.

Beaver’s coefficient [9, 10]. It has a number of disadvantages. First, the normative values of financial indicators do not take into account the industry specifics of enterprises. Secondly, the efficiency of capital use in enterprises (turnover, profitability) is not taken into account. Third, the calculation of the Beaver coefficient is carried out in statics, not taking into account the transient external and internal environment of enterprise valuation.

Altman’s Z-Score model [9, 11, 12]. In Ukrainian practice, numerous attempts have been made to use the Altman’s index to estimate solvency and diagnose bankruptcy. However, differences in external factors that affect the functioning of the enterprise, significantly distort the probability estimates. The experience of using this model in some countries (USA, Canada, Brazil, Japan) has shown that to predict the probability of bankruptcy using a 5-factor model for 1 year can be accurate to 90%, for 2 years − up to 70%, for 3 years − up to 50%.

Roman Lis’s model [7, 13]. External factors (the level of development of market relations, including the stock market, tax legislation, accounting regulations, economic stability) do not allow this method to fully reflect the situation for Ukrainian enterprises and be used to predict the probability of bankruptcy.

Taffler’s model [14, 15]. It does not reflect the situation at ukrainian enterprises because compared to foreign counterparts the parameters reflecting the state of the economy are fundamentally different, in particular, the parameters of exchange activity. It does not allow productive using of Taffler's model to predict the probability of bankruptcy of Ukrainian companies.

Fulmer's model [16]. According to the results of the model the following forecast can be obtained: the company is insolvent if $H < 0$; if $H \geq 0$, it functions normally. Unfortunately, such estimates of the result are rather rough and cannot be reasonably used in the comparative analysis of bankruptcies of different enterprises.

Springgate’s model, Chesser’s model, Depalian’s model. The models of Springgate, Cheser and Depalyan are characterized by regression estimates of parameters that have other values in Ukraine which causes a significant limitation in the application of these approaches in our country [13, 17, 18]. These models show fair results only in the conditions of foreign economies for which they were developed. The use of such models in Ukraine is not possible as there are significant differences between domestic accounting, financial and tax accounting and their international counterparts. In addition, the unstable activity of domestic enterprises leads to other estimates of the values of the studied multifactor models which significantly affects the results of calculations and the correctness of the conclusions about the financial condition of the enterprise [19, 20, 21].

An extremely important task of investment projects risk estimation is the calculation of future cash flows that arise from the sale of manufactured products. This is due to the fact that only the incoming cash flows are able to ensure the payback of the investment project. Therefore, they, not profit, are a central factor in valuation. In other words, the investment decisions risk estimation should be based on the study of income and expenses in the form of cash flows [22, 23, 24].

To estimate the effectiveness of investment projects most often are used such indicators as net present value (NPV), internal rate of return (IRR), profitability index (PI) and payback period of the project (PP) [19, 20]. They use a measure of cash flow, not net income; the factor of change of money cost in time is considered. If NPV is correctly calculated, it allows choosing the project which maximizes the capital of the enterprise and its market value. However, this indicator has certain disadvantages:

- the difficulty of estimating future cash flows for the long term;
- incorrect estimating of future cash flows may, as a consequence, lead to the wrong investment decision;
- it provides for a constant level of discount rate throughout the project implementation period which, in turn, increases the risk;
- difficulties in setting the optimal discount rate.

The main disadvantages of the IRR are that it sometimes gives unrealistic income rates and incorrect answers to the question of which of the two alternative projects should be chosen, especially if they differ in scale and duration of implementation. The significant disadvantages of the PP method are that it does not take into account the cost of invested capital [25, 26].

It is necessary to distinguish between the financial attractiveness of an individual project and the financial attractiveness of the enterprise that aims to implement this project, if it is an existing enterprise, and compare all the key points of such an enterprise with the key points of the investment project [27, 28, 29].

The complexity of the calculation of indicators and the need to take into account a large number of evaluation parameters requires the creation of an appropriate mathematical model and method of its formalization to estimate the level of investment risk. This approach allows a combination of the most accurate models for assessing the probability of bankruptcy of the investment object and the effectiveness of the investment project [30, 31, 32].

3 Formal problem statement

To estimate the investment $X^* \xrightarrow{F_1} R$ risk it is necessary to take into account a large set of input parameters *X**, output parameters *R* and their mapping function. The authors propose to decompose a complex investment problem into a sequence of simpler problems so that the solution of any lower-level problem determines certain parameters in the higher-level problem. The solution of the complex problem of investment risk estimation becomes possible when the solutions of all lower-level subtasks are obtained.

4 Building the structural and mathematical models of investment risk assessment

The peculiarity of the investment making decision process is the consistent implementation of the functional *F*. The task of the investment project risk estimation is to choose an adequate solution *R* from a set of decisions − possible levels of risk of the *IP* – R_j, $j=\overline{1,n}$. The authors propose to make a choice based on the classification of investment objects according to investment strategies on the basis of a set of *X* evaluation parameters X_i, $i=\overline{1,l}$.

Taking into account all the above factors we offer the following general mathematical model for investment risk estimation: $R = \{X^*, X, Y, F_1, F_2, F_3\}$,where $X^*=\{x^*b\}$ – is the set of primary input parameters, $b=\overline{1,k}$; $X=\{X_i\}$ – set of evaluation parameters, $i=\overline{1,l}$; $Y=\{Y_j\}$ – generalized set of investment decisions, $j=\overline{1,n}$; $R=\{R_j\}$ – generalized set of investment decisions $j=\overline{1,n}$; $F_1 : X^* \to X$ – function of transformation of primary input parameters into evaluation parameters of model; $F_2 : X \to Y$ – generalization function; $F_3 : Y \to R$ – function of classification of investment objects according to investment strategies.

To obtain the final result − risk level − *R* based on the set of primary input parameters X^* it is necessary to implement the above functions in the following sequence $X^* \xrightarrow{F_1} X \xrightarrow{F_2} Y \xrightarrow{F_3} R$.

Thus, the authors propose such a structural model of the process of estimation the level of investment risk which is shown in Fig. 1.

The proposed structural model allows classifying IP according to three investment strategies which correspond to the following values of risks R_j: R_1 − minimum level of risk: investment is appropriate; R_2 − medium level of risk: investment is possible in case of application of risk reduction methods; R_3 − high level of risk: investing is impractical.

The proposed structural model allows classifying IP according to three investment strategies which correspond to the following values of risks R_j: R_1 − minimum level of risk: investment is appropriate; R_2 − medium level of risk: investment is possible in

case of application of risk reduction methods; R_3 − high level of risk: investing is impractical.

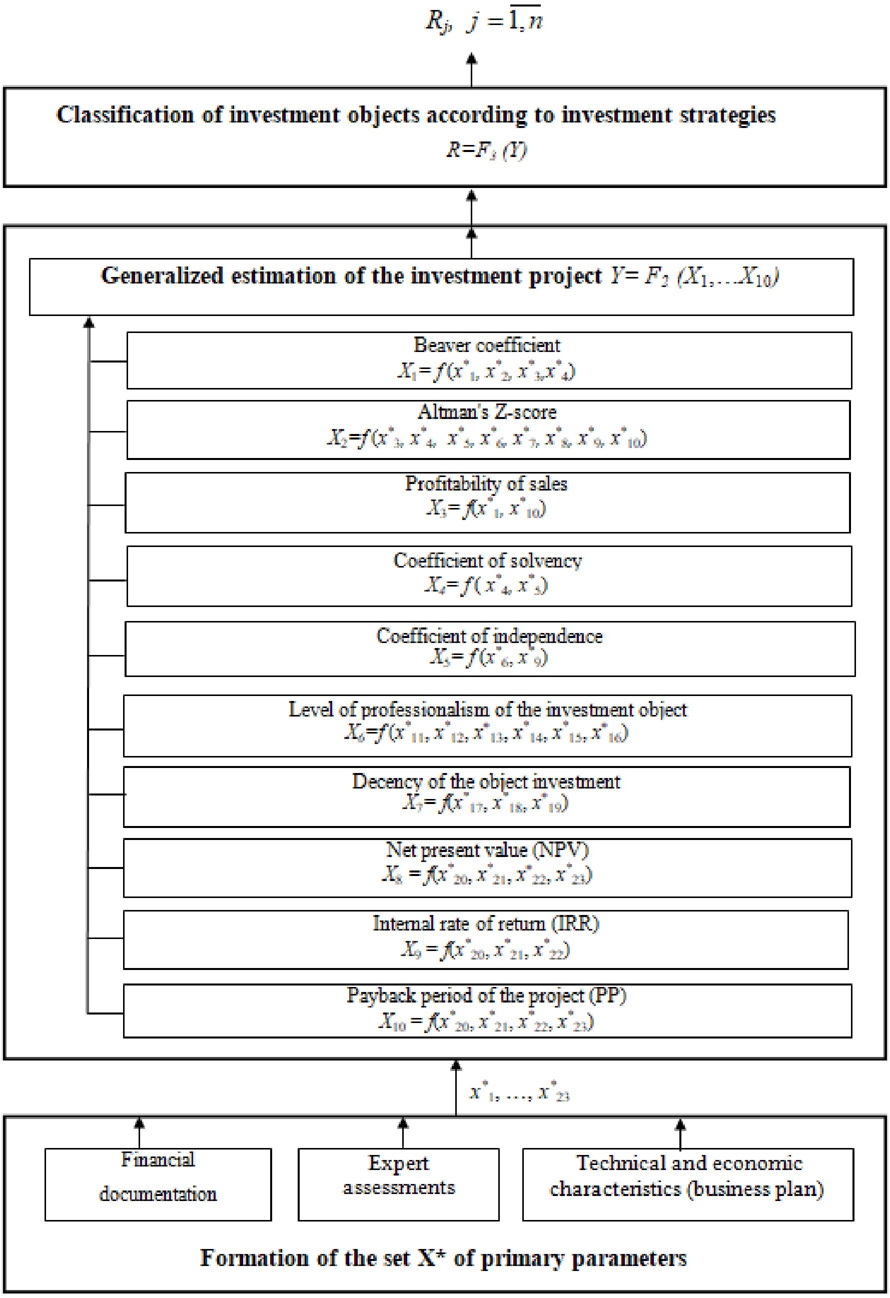

Fig. 1. Structural model of the investment risk estimation process

Using the method of pairwise comparisons Saati on the basis of questionnaires of employees of credit analysis departments of banking institutions in Vinnytsia was substantiated the limit values of evaluation indicators according to which you can divide the range of values of each of 10 evaluation parameters into three ranges: $L -$ low, $M -$ medium and $H -$ high characteristic level of the indicator (Table 1).

Table 1. Ranges of change of estimation parameters X_i

Param-eter	Name of parameter	Ranges of change of parameter	Characteristic level of parameter
X_1	Beaver's coefficient	< 0,2	Low
		[0,21 − 0,4]	Medium
		> 0,41	High
X_2	Altman's Z-Score	< 1,8	Low
		[1,8 − 2,99]	Medium
		> 3,0	High
X_3	Profitability of sales	(0 − 1,0]	Low
		[1,1 − 1,4]	Medium
		> 1,5	High
X_4	Coefficient of solvency	(0 − 1,0]	Low
		[1,1 − 2,0]	Medium
		> 2,1	High
X_5	Coefficient of independence	(0 − 0,3]	Low
		[0,31 − 0,7]	Medium
		0,71 і більше	High
X_6	Level of professionalism of the investment object	(0 − 4]	Low
		[5 − 8]	Medium
		[9 − 12]	High
X_7	Decency of the object in-vestment	(0 − 4]	Low
		[5 − 8]	Medium
		[9 − 12]	High
X_8	NPV	< 0	Low
		(0 − 500]	Medium
		> 501	High
X_9	IRR	(0 − 15]	Low
		[16 − 30]	Medium
		> 31	High
X_{10}	PP	> 7	Low
		[3 − 7]	Medium
		< 3	High

5 Formalization of the mathematical model of the investment risk estimation process

With the development of artificial intelligence systems and computerized information processing tools it becomes possible to productively solve the problem of investment risk estimation. Many experts in this field believe that neural network technologies are aimed at solving classification problems. Thus, the classification of investment entities and investment projects by level of risk is considered by the authors of the article as one of the successful applications of neural networks.

The most productive means of neural technology for investment risk estimation is the Hamming network. It was developed by Richard Lippman in the middle of 1980's [21-23]. The Hamming network implements a classifier based on the smallest error (Hamming distance) for binary input vectors which the authors of the article offer to describe the values of the evaluation parameters of the investment object. The Hamming distance is defined as the number of bits that differ between the two corresponding input vectors of fixed length. The first input vector is a quiet example − reference image − a training investment project, the other is a distorted image − any investment entity. The authors consider the vector of outputs of the educational set as a vector of classes − levels of risk which can be characterized by images − investment projects. In the process of learning the input vectors are divided into categories − the resulting solutions for which the distance between the sample input vectors and any input vector is minimal.

The choice of the Hamming network among other similar networks is due to its following advantages. It implements the optimal minimum error classifier if the input bit errors are random and independent. A smaller number of neurons is required for the Hamming network to function because the middle layer requires only one neuron per class, instead of a neuron for each input node. Finally, the Hamming network is free of incorrect classifications that may occur, in particular, in the Hopfield network. In general, the Hamming network is both faster and more accurate than the Hopfield network and many other classification networks.

Therefore, to formalize the processes of mapping the set X^* to the set R of initial solutions − risk levels R_j the authors of the article propose to use the Hamming neural network. We implement the structural model of the investment risk estimation process built on the basis of the Hamming neural network as shown in Fig. 2.

With the help of expert data and the spectral method of processing expert information 5 reference images of E_p for the neural network were substantiated. They correspond to three levels of investment risk R_j (Table 2). Sets 1 and 2 describe an investment strategy with R_1 risk, sets 3 describe a strategy with R_2 risk and sets 4 and 5 describe a strategy with R_3 risk.

It's known that the Hamming network works with the numerical values «1» and «-1» [21−23], so after obtaining the levels of indicators (high, medium, low) the authors to apply the Hamming algorithm propose to encode the values of indicators in ordinary binary code. The code format should consist of two digits which allows you to encode 4 (22 = 4) possible values of the evaluation parameter. Note that the investment project is characterized by only three strategies $R_j\,(j=\overline{1,3})$ at the output of the model, i.e. there is a need to encode only three levels of indicators: low level of indicator *(-1-1)*, medium *(-1 1)*, high characteristic level of indicator *(1 1).*

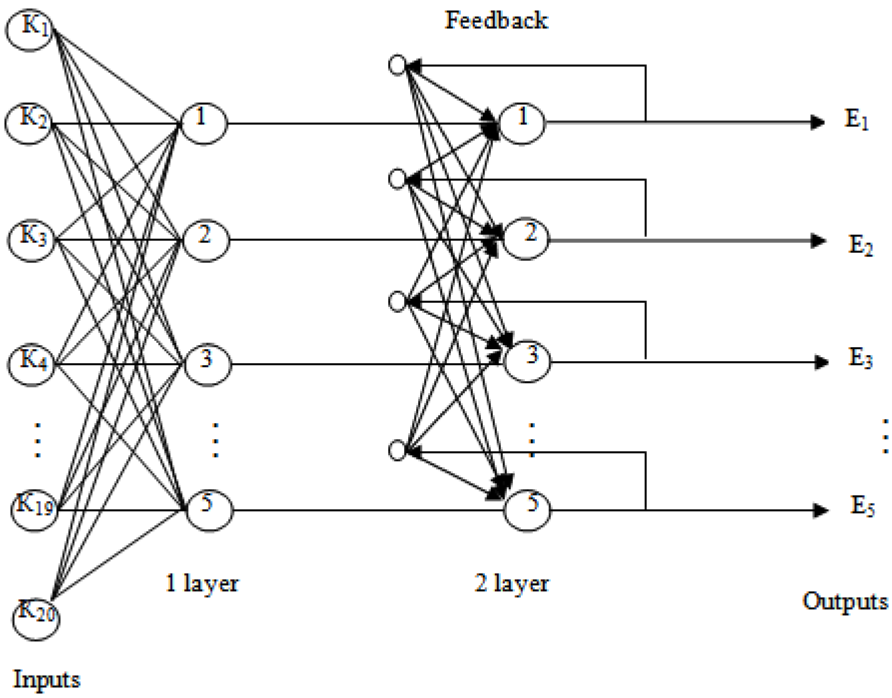

Fig. 2. Hamming network architecture for 24 input elements and 5 standards

Table 2. 5 reference images E_p for investment strategies $R_j\,(j=\overline{1,3})$

№ standard	X_1	X_2	X_3	X_4	X_5	X_6	X_7	X_8	X_9	X_{10}	R_j
1	-1-1	-1-1	-1-1	-1-1	-1-1	-1-1	-1-1	-1-1	-1-1	-1-1	1
2	-1-1	-1-1	-1-1	-1-1	-1-1	-1 1	-1 1	-1 1	-1 1	-1 1	
3	-1 1	-1 1	-1 1	-1 1	-1 1	-1 1	-1 1	-1 1	-1 1	-1 1	2
4	1 1	1 1	1 1	1 1	1 1	-1 1	-1 1	-1 1	-1 1	-1 1	3
5	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	1 1	

After the construction of the network a vector of coded 20 values of 10 evaluation parameters X_i (which characterize the investment attractiveness of a particular enterprise) is fed to its entrance.

The neural network identifies the standard that is closest to the vector fed to its input. The number of this standard E_p allows you to classify the resulting decision to assign the appropriate level of risk $R_j\,(j=\overline{1,3})$.

Therefore, the method of formalization of the proposed mathematical model for estimating the level of investment risk by means of the Hamming neural network is as follows:

1. The input is given the values of the primary indicators $X^{*}b(=\overline{1,23})$ which are used to calculate the evaluation parameters $X_i\,(i=\overline{1,10})$ based on the relevant dependencies.
2. The values of the evaluation parameters $X_1 \ldots X_{10}$, using the appropriate ranges of values presented in table 1, are described by a specific characteristic level (L − Low, M – Medium, H − High).
3. Each evaluation parameter described by a certain characteristic level is assigned a corresponding binary code.
4. The input vector of the Hamming network have to be formed (coded combination of 20 digits «1» and «-1»).
5. The Hamming neural network identifies the closest to the input vector standard among those described in table 2, the number of which is issued at the network output. In this case, each of the standards corresponds to a certain level of investment risk R_j.

Thus, with the help of the above method it becomes possible to unambiguously classify the object of investment, determine its investment strategy, level of risk and decide on the feasibility of investing.

6 Implementation of the model

Consider the process of investment risk estimation in the mathematical model proposed by the authors, formalized using the apparatus of the Hamming network, on the example of «Enterprise №1».

For the computer implementation of the proposed Hamming network, the authors of the article have developed a corresponding software product «INVESTOR» based on which the value of the parameters X_i was calculated (as illustrated in Fig. 3) to estimate the level of investment risk of «Enterprise №1».

Based on the developed software product «INVESTOR», the values of the parameters X_i, the linguistic terms corresponding to them, as described in table 1, as well as the corresponding Hamming codes given in table 2, were evaluated. We reduce all these data to the table 3.

This input signal (20-digit Hamming code provided in table 3) was applied to the input of the Hamming neural network which on the basis of the compiled software product identified the nearest input vector standard (among those described in table 2), the number of which was obtained at the output.

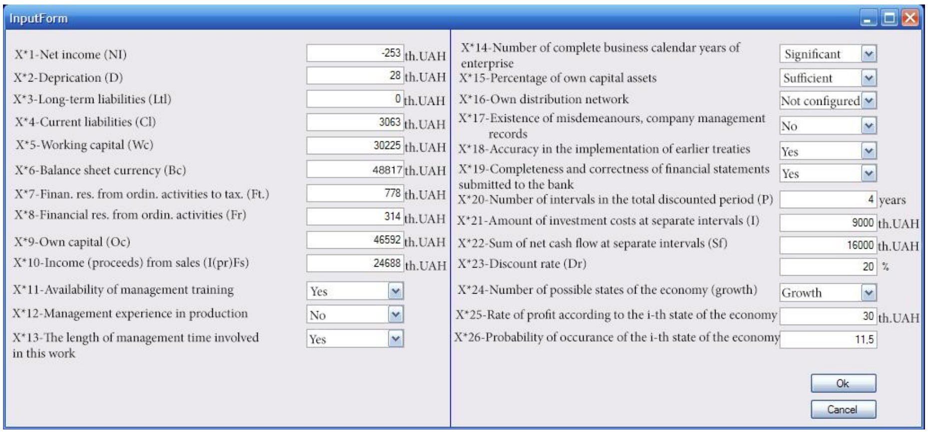

Fig. 3. Screen form «INVESTOR» for entering parameters x^*_b to evaluate parameters X_i

Table 3. Values and coding of parameters X_i for «Enterprise №1»

X_i	**Value**	**Term**	**Code of the Hamming network**
X_1	0,875	H	1 1
X_2	13,37	H	1 1
X_3	1,27	M	-1 1
X_4	16,8	H	1 1
X_5	0,95	H	1 1
X_6	10	H	1 1
X_7	High	H	1 1
X_8	1355	H	1 1
X_9	28	M	-1 1
X_{10}	3,3	M	-1 1

Thus, the level of investment risk of «Enterprise №1» which is described by a coded set of values − 20-digit code (see table 3) − using the software product «INVESTOR» is evaluated by the standard №4. That is, the level of investment risk of this business entity is minimal (see table 2).

Similarly for another 14 analyzed enterprises using the software product «INVESTOR» were formed input vectors of the Hamming network (coded combination of 20 digits «1» and «-1») as indicated in table 4. It was identified the closest to the input vector standard among those described in table 2, the number of which is issued at the network output. This number uniquely identifies the investment decision for a particular entity (Table 4).

Thus, each investment decision corresponds to a certain level of investor risk $R_j\,(j=\overline{1,3})$ for each of the analyzed companies. Reference numbers №1, №2 correspond to a high level of risk − R_3, therefore investing in such an object is impractical; standard №3 corresponds to R_2 − the average level of risk, investment is possible in the case of risk reduction methods; the numbers of standards №4, №5 correspond to

R_1 − the minimum level of risk which indicates the feasibility of investing in such an object.

Table 4. Coding of evaluation parameters X_i and determination of R_j solution based on Hamming neural network for 15 business entities

Business entities	Evaluation parameter											
	X1	***X2***	***X3***	***X4***	***X5***	***X6***	***X7***	***X8***	***X9***	***X10***	**№ standard**	**Level of risk**
	Hamming code	**Hamming code**	**Hamming code**	**Hamming code**	**Hamming code**	**Hamming code**	**Hamming code**	**Hamming code**	**Hamming code**	**Hamming code**		
Enterprise №1	1 1	1 1	-1 1	1 1	1 1	1 1	1 1	1 1	-1 1	-1 1	4	R1
Enterprise №2	-1 1	-1 1	-1-1	-1-1	-1-1	-1 1	-1 1	1 1	1 1	1 1	3	R2
Enterprise №3	-1-1	-1-1	-1-1	-1 1	-1 1	-1 1	1 1	-1 1	-1 1	-1 1	2	R3
Enterprise №4	-1 1	1 1	-1 1	-1 1	-1 1	1 1	1 1	-1 1	-1-1	-1-1	3	R2
Enterprise №5	-1 1	-1 1	-1 1	-1 1	-1-1	-1-1	-1-1	-1-1	-1-1	-1-1	1	R3
Enterprise №6	1 1	1 1	1 1	1 1	-1 1	-1 1	1 1	1 1	-1 1	1 1	5	R1
Enterprise №7	-1-1	-1-1	-1-1	-1-1	-1-1	1 1	-1 1	1 1	1 1	1 1	2	R3
Enterprise №8	1 1	1 1	1 1	1 1	1 1	1 1	1 1	-1-1	-1-1	-1-1	4	R1
Enterprise №9	-1 1	-1 1	-1 1	-1 1	-1-1	1 1	1 1	-1 1	-1-1	-1 1	3	R2
Enterprise №10	-1-1	-1 1	-1-1	-1-1	1 1	1 1	1 1	-1 1	-1 1	-1-1	4	R1
Enterprise №11	1 1	1 1	1 1	1 1	-1-1	-1-1	-1-1	1 1	1 1	-1-1	4	R1
Enterprise №12	1 1	1 1	-1 1	1 1	-1-1	-1 1	-1 1	1 1	-1 1	-1-1	3	R2
Enterprise №13	-1 1	-1 1	-1-1	-1 1	1 1	1 1	1 1	1 1	-1 1	-1 1	3	R2
Enterprise №14	1 1	1 1	-1-1	1 1	-1 1	-1 1	1 1	-1 1	-1-1	1 1	1	R3
Enterprise №15	1 1	1 1	1 1	1 1	-1 1	-1 1	-1 1	-1-1	-1-1	1 1	2	R3

The results obtained for the analyzed 15 enterprises on the basis of the author's approach were compared with the results obtained for these enterprises according to traditional approaches − models of Lis's and Taffler's bankruptcy forecasting as well as the method of «Raiffeisen Bank Aval». This allowed proving the adequacy and verifying the mathematical model built by the authors. In contrast to traditional approaches the approach proposed by the authors allows much more accurate and faster with the help of appropriate software to estimate investment risk.

7 Conclusions

The conceptual approach proposed by the authors has significant advantages over existing alternative methods:

(1) accuracy of estimation;
(2) taking into account a wide range of different evaluation parameters;
(3) speed;

(4) the ability of self-learning.

Using the proposed mathematical model of investment risk estimation (formalized using the Hamming network) allows to eliminate errors in evaluating the investment project, take into account a wide variety of different primary indicators, investor requirements for profitability and payback period project, conduct a simultaneous assessment of bankruptcy, reduce the time to make a final decision on the feasibility of investing.

The main scientific result of the study is the development of conceptual foundations for the formalization of the process of estimation the investment risk level by means of mathematical and computer modeling based on neural network technologies.

The methodological approach to investment risk estimation has been improved which, unlike existing approaches, allows using Hamming neural network to accurately and reasonably identify project risk and assess the feasibility of investing, reduce the cost of such process and allows self-learning specialized network.

The structural hierarchical model of the investment risk estimation process has been improved which carries out its decompositional division and simplifies the formalization on the basis of the mathematical apparatus of the Hamming neural network. It also allows to simultaneously assessing the financial ratio of the entity and its proposed investment project.

References

1. Law of Ukraine «On Concession» № 155-IX from 3.10.2019. URL: https://zakon.rada.gov.ua/laws/show/155-20#Text
2. Law of Ukraine «About rent of the state and municipal property» № 157-IX, from 3.10.2019. URL: https://zakon.rada.gov.ua/laws/show/157-20#Text
3. Project Law of Ukraine «On Principles of State Support for New Investments in Ukraine» from 12.03.2020. URL: http://w1.c1.rada.gov.ua/pls/zweb2/webproc4_1?id=&pf3511=68353
4. Telipenko, E., Sopova, S.: Software for Bankruptcy Risk Assessment of the Enterprise. In: Proc. of 2018 IEEE 3rd Russian-Pacific Conference on Computer Technology and Applications (RPC), pp. 1-4. Vladivostok (2018). DOI: 10.1109/RPC.2018.8482206.
5. Lakshmi, T., Martin, A., Venkatesan, V.: A Genetic Bankrupt Ratio Analysis Tool Using a Genetic Algorithm to Identify Influencing Financial Ratios. In IEEE Transactions on Evolutionary Computation, vol. 20, no. 1, pp. 38-51 (2016). DOI:10.1109/TEVC.2015.2424313
6. Joshi, S., Ramesh, R., Tahsildar, S.: A Bankruptcy Prediction Model Using Random Forest. In: Proc. of 2018 IEEE Second International Conference on Intelligent Computing and Control Systems (ICICCS), pp. 1-6. Madurai, India (2018). DOI: 10.1109/ICCONS.2018.8663128.
7. Song, Y., Peng, Y.: A MCDM-Based Evaluation Approach for Imbalanced Classification Methods in Financial Risk Prediction. In IEEE Access, vol. 7, pp. 84897-84906 (2019). DOI: 10.1109/ACCESS.2019.2924923.
8. Azarova, A., Zhytkevych, O.: Mathematical methods of identification of ukrainian enterprises competitiveness level by fuzzy logic using. Economic Annals-XXI 9-10 (2):59-62 (2013).

9. Horvathova, J., Mokrisova, M.: Risk of Bankruptcy, Its Determinants and Models. Risks 6:117. (2018). DOI: 10.3390/risks6040117.
10. Beaver, W.: Financial ratios as predictors of failures. Empirical Research in Accounting, Supplement to Journal of Accounting Research 71-111 (1966).
11. Altman, E.: Financial Ratios Discriminant Analysis and the Prediction of Corporate Bankruptcy. The Journal of Finance. DOI: 10.2307/2978933. URL: https://www.jstor.org/stable/2978933?seq=1.
12. Ashok, P.: Validity of Altman's «Z» Score Model in Predicting Financial Distress of Pharmaceutical Companies. Nmims Journal of Economics and Public Policy, vol. IV, no. 1 (2019).
13. Model bankruptcy Lis. URL: http://1-fin.ru/?id=281&t=967
14. Taffler, R.: The Assessment of Company Solvency and Performance Using a Statistical Model, Accounting and Business Research 13(52):295-308. DOI: 10.1080/00014788.1983.9729767.
15. Taffler, R.: The Use of the Z-score Approach in Practice. Centre for Empirical Research in Finance and Accounting, City University Business School Working Paper (1995).
16. Fulmer, J. et al.: A Bankruptcy Classification Model For Small Firms. Journal of Commercial Bank Lending, pp 25-3. Július (1984).
17. Springate, G.: Predicting the Possibility of failure in a Canadian Firm. Unpublished M.B.A. Research Project, Simon Fraser University. In. Insolvency prediction, E. Sands&Associates Inc. (1978).
18. Credit-men method, assessing the financial situation at the enterprise. URL: https: // afdanalyse.ru/publ/finansovyj_analiz/1/metod_credit_men_ocenki_finansovoj_situacii_na_predprijatii/13-1-0-121
19. Rad, M., Jamili, A., Tavakkoli-Moghaddam, R., Paknahad, M.: Resource Constraint Project Scheduling to meet Net Present Value and quality objectives of the program. In: Proc. of 2016 IEEE 12th International Conference on Industrial Engineering (ICIE), pp. 58-62, Tehran (2016). DOI: 10.1109/INDUSENG.2016.7519349. URL: https://ieeexplore.ieee.org/ document/7519349
20. Yin-Xiang, L.: The Rules and Models to Estimate IRR Conveniently and Effectively. In: Proc. of 2013 IEEE Third International Conference on Intelligent System Design and Engineering Applications, pp. 1530-1532, Hong Kong (2013). DOI: 10.1109/ISDEA.2012.367.
21. Hamming code. URL: https://en.wikipedia.org/wiki/Hamming_code
22. Sharma, M., Singh, G.: Hamming Encoding and Decoding Algorithms for TDCS and WDCS Design. In: Proc. of 2015 IEEE Fifth International Conference on Communication Systems and Network Technologies, pp. 393-396, Gwalior (2015). DOI: 10.1109/CSNT.2015.199.
23. Azarova, A., Royik, O., Kilymnyk, L.: Mathematical model and method of risk level estimation for capital structure by means of Hopfield neural network. Actual Problems of Economics. 1(103):245–253 (2010).
24. Azarova A., Zhelyuk N.: Selection, planning and realization of development strategy by an enterprise. Actual Problems of Economics. 12:91–100 (2010).
25. Azarova A., Hil, O.: Basic indices definition of product quality management by means of correlation-regressive modelling. Actual Problems of Economics. 12:186–191 (2008).
26. Wójcik, W., Smolarz, A.: Information Technology in Medical Diagnostics. London, July 11, 2017 by Taylor &Francis Group CRC Press Reference. 210 p. DOI:10.1201/9781315098050.

27. Vassilenko, V., Valtchev, S., Pamies-Teixeira, J., Pavlov, S.: Energy harvesting: an interesting topic for education programs in engineering specialities. Internet, Education, Science (IES-2016), 149-156 (2016).
28. Krak, Y., Barmak, A., Bagriy, R., Stelya, I.: Text entry system for alternative speech communications. Journal of Automation and Information Sciences, Vol. 49, 1:65–75 (2017).
29. Serkova, V., Pavlov, S., Romanava, V., Monastyrskiy, Yu., Ziepko, S., Kuzminova, N., Wójcik, W., Dzierżak, R., Kalizhanova, A., Kashaganova, G.: Medical expert system for assessment of coronary heart disease destabilization based on the analysis of the level of soluble vascular adhesion molecules. Proc. SPIE 10445, Photonics Applications in Astronomy, Communications, Industry and High Energy Physics Experiments (2017). DOI: 10.1117/12.2280984.
30. Kryvonos, Iu., Krak, Iu., Barmak, O., Bagriy, R.: Predictive text typing system for the Ukrainian language. Cybernetics and systems analysis, Vol. 53, 4:495–502 (2017). DOI: 10.1007/s10559-017-9951-5.
31. Timchenko, L., Pavlov, S., Kokriatskaia, N., Gertsiy, O., Stepaniuk D., Babiuk, N., Kashaganova, G., Harasim, D.: Precision measurement of coordinates of power center of extended laser path images. Proc. SPIE 10808, Photonics Applications in Astronomy, Communications, Industry and High-Energy Physics Experiments (2018). DOI: 10.1117/12.2501628.
32. Azarov, D., Pavlov, S., Chernyak, O., Ivasyuk, I., Wójcik, W., Syzdykpayeva, A.: Principles of fast count in modified Fibonacci numerical system. Proc. SPIE 10808, Photonics Applications in Astronomy, Communications, Industry and High-Energy Physics Experiments (2018). DOI: 10.1117/12.2501565.
33. Lurie, I., Podlevsky, A., Savina, N., Voronenko, M., Pashnina, A., Lytvynenko, V.: Inductive technology of the target clusterization of enterprise's economic indicators of Ukraine. Proceedings of the Second International Workshop on Computer Modeling and Intelligent Systems (CMIS-2019), pp.848-859, Zaporizhzhia (2019).