DEVELOPMENT OF A METHODOLOGY FOR FORMALIZING THE INVESTMENT DECISION-MAKING PROCESS BASED ON THE HOPFIELD NEURAL NETWORK

The article presents a methodological approach to assessing the investment attractiveness of an enterprise based on the Hopfield neural network mathematical apparatus. An extended set of evaluation parameters of the investment process has been compiled. An algorithm for formalizing the decision-making process regarding the investment attractiveness of the enterprise based on the mathematical apparatus of neural networks has been developed. The proposed approach allows taking into account the constantly changing sets of quantitative and qualitative parameters, identifying the appropriate level of investment attractiveness of the enterprise with minimal money and time expenses – one of the standards of the Hopfield network, which is most similar to the one that characterizes the activity of the enterprise. Developed complex formalization of the investment process allows you to make investment decisions in the context of incompleteness and heterogeneity of information, based on the methodological tools of neural networks.

Key words: Hopfield neural network, investing, estimation parameters, modeling, formalization, output parameters.

Tabl.: 3. Fig.: 1. Lit.: 12.

© RUZAKOVA O., KIPORENKO S., 2019
Оценивание инвестиционной привлекательности предприятия на базе нейронной сети Хопфилда

РУЗАКОВА О.В.,
кандидат экономических наук,
doцент кафедры компьютерных наук и экономической кибернетики

КИПОРЕНКО С.С.,
assistant кафедры компьютерных наук и экономической кибернетики
Винницкий национальный аграрный университет
(г. Винница)

В статье представлен методологический подход к оценке инвестиционной привлекательности предприятия на базе математического аппарата нейронной сети Хопфилда. Составлено расширенное множество оценочных параметров процесса инвестирования. Разработан алгоритм формализации процесса принятия решений по инвестиционной привлекательности предприятия на базе математического аппарата нейронных сетей. Предложенный подход позволяет учесть постоянно изменяющиеся со временем множества количественных и качественных параметров, с минимальными денежными и временными затратами идентифицировать соответствующий уровень инвестиционной привлекательности предприятия - один из эталонов сети Хопфилда, являющийся наиболее схожим с тем, который характеризует деятельность предприятия. Разработанный комплекс формализации процесса инвестирования позволяет принимать инвестиционные решения в условиях неполноты и неоднородности информации, опираясь на методологический инструментарий нейронных сетей.

Ключевые слова: нейронная сеть Хопфилда, инвестирование, оценочные параметры, моделирование, формализация, выходные параметры.

Problem statement. In recent years a growing interest in mathematical economic models that are based on the latest computer technology provide new opportunities to solve complex problems, there is a strong development of artificial intelligence technologies in various fields of human activity. Today mathematical technologies for solving financial problems, such as fuzzy set theory, threshold elements, genetic algorithms, etc., are quite effective. However, the use of each of the above devices is not without its disadvantages. For example, the field of fuzzy logic requires the definition and justification of the type and form of membership functions; threshold element apparatus – for processing large arrays of expert data; genetic algorithm technologies require sophisticated setup.

Neural networks are becoming more and more popular today. The first commercial realizations based on them appeared in the 1980s and were widespread in developed countries. Neural networks are constructed by analogy of organization and activity of biological neural networks – networks of nerve cells of a living organism. The concept of neural networks has emerged from the study of processes occurring in the brain and when trying to simulate these processes. After the development of appropriate training models and algorithms, the resulting artificial neural networks began to be used for practical purposes: in prediction tasks, image recognition, control tasks, etc.

Intellectual economic systems based on artificial neural networks can successfully solve problems of classification of economic objects, optimization of associative memory and management of business entities. The traditional approaches to solving these problems do not always have the necessary flexibility. However, the use of neural networks for specific management tasks poses certain requirements to the speed and complexity of the process of creating and learning a neural network. Assessing approaches and
describing systems and specific examples of using network models in the rationing process is of particular scientific interest and identifies ways to further use neural networks for management purposes. In doing so, a wide range of economic challenges benefit from the use of neural networks because their specificity is the need to take into account incomplete or distorted information.

Neural networks technologies, such as the Hopfield Network, allow solve the task of classifying and reproducing images with incomplete and distorted information effectively and easily. The low capacity of the networks is explained by the fact, that networks not only memorize images, but also allow them to be generalized according to the maximum likelihood criterion. The ease of building software and hardware models makes these networks attractive to many practical applications, including financial management.

**Analysis of recent research and publications.** The problems of investment project risk assessment and investment rationale are in the focus of many researchers. In particular, the work of such authors as W. Sharp, J. Bailey [1], L. Hitman, M. Johnk [2], Melnichenko O. [3], Kaletnik G. [4]. The most essential achievement in the field of neurophysiology include Warren McCulloch and Walter Pitts [5] - the work of artificial neurons and models of neural networks on electrical circuits; Donald Hebb [6] - subject of synaptic connections tuning; John von Neumann [7], who proposed the simulation of simple functions of these neurons using vacuum tubes; John Hopfield [8] – works on restoring the distorted image of the nearest standard using neural networks.

These works provide an initial understanding of the natural thinking mechanism, where information is stored in the form of images.

For many economic problems, the choice of the optimal method of decision-making should be made according to the essence of the problem, since no other dominant approaches are justified. Efforts should be made to understand the possibilities, prerequisites and scope of the various approaches and to maximize their additional benefits for the further development of intellectual systems.

**Goals setting.** The purpose of the article is to evaluate the effectiveness of using neural networks to decide on the expediency of risk-based investing.

**Presentation of the main material of the research.** The idea to use fuzzy sets in investment analysis emerged as a way of dealing with uncertainty not only statistical but also linguistic, that is, the uncertainty of natural language expressions. The blurry multiple approach is more flexible and allows the investor or expert to come up with a model that will clearly meet all the requirements and give specific answers to all the questions.

The theory of neural networks is a generalization and rethinking of the most important areas of classical mathematics. It is an attempt to combine both formalized and non-formalized methods of analysis. Neural networks ideally describe the subjective activity of a decision-maker in risk and uncertainty [9].

Most economic object classification problems can be represented and solved as neural network problems that do not apply the paradigm of teaching with or without a teacher. In these networks, the weight components of the synopsis are calculated once before the network starts operating on the basis of standard information. All network training should be down to this calculation. On the one hand, the provision of a priori information is regarded as "teacher" assistance, and on the other hand, the network actually remembers samples of standards before the input of information about a real object and cannot change its behavior. Therefore, it is not possible to confirm the presence of feedback from the "teacher". The most famous network with such similar logic is the Hopfield network used to organize associative memory.

Thus, it is proposed to classify investment objects by different division criteria using the Hopfield neural network. To do this, we will build an appropriate decision support system, the structure of which is considered as a neural network with outputs representing different investment strategies \( O_j, (j = 1,3) \) and input neurons \( x_i, (i = 1,10) \), that are the parameters that evaluate the investment process. As presented DSS (Decision Support System) (Fig. 1) were used the following parameters to evaluate the investment object: Beaver Ratio \( x_1 \), Altman’s Model \( x_2 \), Lis’s Model \( x_3 \), Taffler’s Model \( x_4 \), which are designed to bankruptcy probability prediction for the enterprise. Also included qualitative indicators of the entity’s valuation: the level of professionalism \( x_5 \) and the decency of the entity \( x_6 \), whose values are measured using expert data.

Simultaneously with the valuation of the investment entity, the investment project itself is evaluated using the following indicators: Net Present Value (NPV) \( x_7 \), internal rate of return (IRR) \( x_8 \), Profitability Index (PI) \( x_9 \) and payback period (PP) \( x_{10} \) of this investment project. Thus, this system has 10 evaluation parameters that differ in nature (quantitative and qualitative indicators) (Fig. 1). However, neural networks are used only for systems with quantitative indicators, which implies the need to transform qualitative indicators in quantitative, as suggested in [10].
It is suggested to use the Hopfield neural network to formalize the built system, which will allow to map the image of the input vector $X = (x_i)$, $(i = 1,10)$, which evaluates investment project, with the closest reference vector that describes a specific investment strategy $O_j$, $(j = 1,3)$.

First, ranges $j$ of values $x_i$ are estimated, the number of which $j = 3$ corresponds to the number of investment strategies at the exit. This leads to a sufficient level of precision in the economic decision-making process. The proposed decision-making system allows to classify the object investment attractiveness by three investment strategies, to which the following output parameters correspond $O_j$: $O_1$ – investment is advisable; $O_2$ – investment is possible if risk mitigation techniques are applied; $O_3$ – investment is inappropriate. Using Saati’s expert method of paired comparisons by conducting a questionnaire survey of employees from credit analysis departments of banking institutions in Vinnitsa, the limit values of the estimation parameters were substantiated, according to which it is possible to break the interval of each from ten parameters values into three ranges: $L$ – low, $M$ – medium and $H$ – high characteristic level (Tabl. 1).
Based on expert data and spectral data processing method [12], 18 reference images for the neural network were substantiated, which reflects the specifics of the three investment strategies (Table 2).

**Table 2**

| Parameter | The name of the parameter | Range | The characteristic level of the indicator |
|-----------|---------------------------|-------|-------------------------------------------|
| \(x_1\)   | Beaver Ratio              | to 0.2, 0.21-0.4, 0.41 or more | High, Medium, Low |
| \(x_2\)   | Altman’s Model            | to 1.8, 1.8-2.99, 3.0 or more | High, Medium, Low |
| \(x_3\)   | Lis’s Model               | to 0.037, 0.038-0.057, 0.058 or more | High, Medium, Low |
| \(x_4\)   | Tuffler's Model           | to 0.2, 0.21-2.99, 3.0 or more | High, Medium, Low |
| \(x_5\)   | Level of professionalism  | 9-12, 5-8, 0-4 | High, Medium, Low |
| \(x_6\)   | The decency of the entity | 9-12, 5-8, 0-4 | High, Medium, Low |
| \(x_7\)   | Net present value (NPV)   | 9-12, 5-8, 0-4 | High, Medium, Low |
| \(x_8\)   | Internal Rate of Return (IRR) | 9-12, 5-8, 0-4 | High, Medium, Low |
| \(x_9\)   | Profitability Index (IP)  | 9-12, 5-8, 0-4 | High, Medium, Low |
| \(x_{10}\)| Payback period (PP)       | 9-12, 5-8, 0-4 | H - short-lived, M - medium duration, L - long-lasting |

Source: calculated according to data [10]

**Table 1**

| Parameter | The name of the parameter | Range | The characteristic level of the indicator |
|-----------|---------------------------|-------|-------------------------------------------|
| \(O_1\)  |                           |       |                                           |
| \(O_2\)  |                           |       |                                           |
The research conducted in this paper can be continued to develop an apparatus for analyzing some other aspects of economic systems, which would allow the simultaneous analysis of many indicators at different levels. This would allow for more flexible policies for managing economic systems and, accordingly, ensure their profitability and functioning at a higher level.
The use of such systems on the basis of effective mathematical models will help to obtain appropriate recommendations for the formation of an optimal strategy for managing economic systems, which allows expecting to intensify and improve the efficiency of investment activities and achieve the most important goals of social policy.

**References**

1. Sharp, U., Aleksander, H., & Beili, Dzh. (1998). *Investytsii [Investment]*. Moscow: INFRA-M [in Russian].
2. Hytman, L. Dzh., & Dzhonk, M. D. (1997). *Osnyv investuvannia [Fundamentals of investing]*. Moscow: Dilo [in Russian].
3. Melnychenkov, O.A. (2012). *Investytsiiniy klimat: sutnist ta napriamky yoho pokrashchennia v Ukraini [Investment climate: the essence and directions of its improvement in Ukraine]*. *Visnyk Skhidnoukrainskoho natsionalnoho universytetu imeni Volodymyra Dalia, 14*(185), 292-295 [in Ukrainian].
4. Kaletnik, H.M., & Tsikhanovska, V.M. (2010). *Finansovyi menedzhment [financial management]*. Kiev: *Khai-Tek Pres* [in Ukrainian].
5. Pitts, W., & MCCulloch, W. C. (1947). *How we know the universals: the perception of auditory and visual form*. *Bull. Math. Biophys*, 9, 127-147 [in USA].
6. Hebb, D.O. (1949). *The organization of behavior; a neuropsychological theory*. England: Wiley [in USA].
7. Monastyrskyi, M. I. (2006). Dzhon fon Neiman – matematyk i liudyna [I. von Neumann – mathematician and man]. *Istoryko-matematychni doslidzhennia, 46* (11), 240-266 [in Russian].
8. Hopfield, J. J. (1982). *Neural networks and physical systems with emergent collective computational abilities. Proceedings of the National Academy of the Sciences of the USA, 79*, 2554-2558 [in USA].
9. Matviychuk, A.V. (2010). *Modeliuvannia finansovoi stiklosi pidpriyemstv iz zastosuvanniam teorii nechitkoi lohiky, neironnykh merezh i dyskryminatnoho analizu [Modeling financial sustainability of enterprises using theories of fuzzy logic, neural networks and discriminatory analysis]. Visnyk Natsionalnoho akademii nauk Ukrainy – Bulletin of the National Academy of Sciences of Ukraine*, 9, 24-46 [in Ukrainian].
10. Azarova, A.O., & Bershov, D.M. (2008). *Rozrobka metodu formalizatsii DSS shchodo investuvannia na bazi neironnoi merezhi Khopfilda [Development of a method of formalization of the DSS for investing on the basis of Hopfield neural network]*. *Visnyk Vinnytskoho politekhnichnoho instytutu*, 2, 13-18 [in Ukrainian].
11. Horodnia, T.A. (2010). *Diahnostyka investytsiiniy pryablyvosti pidpriyemstv [Diagnosis of investment attractiveness of enterprises]. Torhivlia, komertsia, pidpryemnytstvo*, 11, 100-103 [in Ukrainian].
12. Totsenko, V.H. (2002). *Metody i sistema pidtrymky pryiniattia rishen [Decision Support Methods and Systems]*. Kiev: *Naukova dumka* [in Ukrainian].
ОСОБЛИВОСТІ РОЗВИТКУ FINTECH В СУЧАСНИХ УМОВАХ

У роботі розкрито особливості становлення та розвитку ринку FinTech в умовах цифровізації фінансового ринку. Доведено, що однією із тенденцій глобального ринку фінансових послуг, є активне впровадження FinTech-інновацій.

Дослідження дефініції FinTech, явило чотири підходи до виявлення сутності поняття: інституційний, галузевий, функціональний, операційний. Обґрунтовано, що FinTech передбачає взаємозв’язок двох складових – інновацій, що базуються на технологіях традиційного фінансово-банківського сектору і нових бізнес-моделей надання фінансових послуг.

Вивчено класифікаційні підходи до систематизації FinTech-послуг: для підтримки інновацій, за галузевими інноваціями.

Охарактеризовано принципи, на яких базується реалізація фінансових технологічних систем. Розглянуто потенційні переваги і недоліки FinTech-інновацій для економіки.

Здійснено аналіз світового ринку FinTech, який показує значне збільшення глобальних інвестицій у цю галузь, протягом останніх років. Український ринок FinTech слідить глобальним тенденціям та показує динамічне зростання. Вітчизняний ринок FinTech представлені такими напрямами, як: платежні і грошові перекази, мобільні гаманці, цифрові банки і необанки, блокчейн і криптовалята, технології і інфраструктура, консалтингові і аналітичні системи, особисте та споживче кредитування, кредитування бізнесу, іншуртех, кібербезпека, регтех, персональний фінансовий менеджмент, цифрові інструменти порівняння, юридичні технології.

Вмотивовано, що для створення та розвитку FinTech-стартапів необхідно інвестування і знання. Сьогодні інвестування є однією з ключових проблем розвитку українських FinTech-компаній. Проаналізовано джерела фінансування українських FinTech-компаній та описано їх особливості.