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ULRICHSWEB

- **Application of Neural Networks in Prediction of Enterprise Development in Global Environment**
  Nataliia Parkhomenko, Iryna Otenko, Nataly Martynovych and Vasyl Otenko
- **Auditors' Competence, Audit Fee, Quality Control, and Audit Quality**
  Hera Khairunnisa, Ayatullah Michael Musyaffi, Christian Wradendi Widar and Hafifah Nasution
- **Exploring Catalysts that Support Employee's Transformation for Unlearning and Innovation by Challenging the Irreversibility of Absorptive Capacity: The Case of Commercial Banks in Egypt**
  Said Abdo and David Edgar
- **Extrinsic Cues on Websites-Content Analysis on Natural and Organic Skin Care Products**
  Dr. Ritu Narang and Dr. Radhika Sharma
- **The Reverse Mortgage Conundrum: Perspectives of Households in India**
  Dr. Shruti Ashok and Dr. Madhu Vij
- **Household Coping Strategies under Covid 19 Economic Shocks: The Nigerian Experience**
  Uwa Ijim Agbor, Immaculata Ofu Ohaja-Akpet, Pius Otu Abang, Otu Offiong Duke and Felix Owen Eteng
- **The Relationship of Emotional Intelligence with Personality: A Systematic Review**
  Rutba Riyaz, Prof. (Dr.) Mushtaq Ahmad Darzi, Yusra Showkat Bukvla and Syed Shaista
- **Exploring the role of Modern Human Resource Practices in SMEs Productivity: Structural Model Analysis**
  Dr. Shobha Bhardwaj and Dr. Ajay Jain
- **Demography of Investors and Behavioral Biases – An Empirical Study**
  Bushra Khurshood, Dr. Shalini Srivastav and Dr. Ashwani Pandey
- **Impact of Intellectual Capital Efficiency on the Financial Performance of the Indian Banks: The Role of Diversification as a Moderator**
  Ms. Meena Rani and Prof. Meena Sharma

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Contents

January - March 2023, Vol. XX, Issue No. 1

Articles

5 **Application of Neural Networks in Prediction of Enterprise Development in Global Environment**
Nataliia Parkhomenko, Iryna Otenko, Nataly Martynovych and Vasyl Otenko

20 **Auditors' Competence, Audit Fee, Quality Control, and Audit Quality**
Hera Khairunnisa, Ayatulloh Michael Musyaffi, Christian Wiradendi Wolor and Hafifah Nasution

33 **Exploring Catalysts that Support Employee's Transformation for Unlearning and Innovation by Challenging the Irreversibility of Absorptive Capacity: The Case of Commercial Banks in Egypt**
Said Abdo and David Edgar

49 **Extrinsic Cues on Websites-Content Analysis on Natural and Organic Skin Care Products**
Dr. Ritu Narang and Dr. Radhika Sharma

65 **The Reverse Mortgage Conundrum: Perspectives of Households in India**
Dr. Shruti Ashok and Dr. Madhu Vij

79 **Household Coping Strategies under Covid 19 Economic Shocks: The Nigerian Experience**
Uno Ijim Agbor, Immmaculata Ofu Obaji-Akpet, Pius Otu Abang, Otu Offiong Duke and Felix Onen Eteng

92 **The Relationship of Emotional Intelligence with Personality: A Systematic Review**
Ratiba Riyaz, Prof. (Dr.) Mushtaq Ahmad Darzi, Yasra Showkat Bakshi and Syed Shaista

109 **Exploring the role of Modern Human Resource Practices in SMEs Productivity: Structural Model Analysis**
Dr. Shobha Bhardwaj and Dr. Ajay Jain

126 **Demography of Investors and Behavioral Biases – An Empirical Study**
Bushra Khursheed, Dr. Shalini Srivastav and Dr. Asheesh Pandey

140 **Impact of Intellectual Capital Efficiency on the Financial Performance of the Indian Banks: The Role of Diversification as a Moderator**
Ms. Meena Rani and Prof. Meena Sharma

Application of Neural Networks in Prediction of Enterprise Development in Global Environment

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Abstract

This paper deals with the issue of prediction models of enterprise development in the global environment and the development strategy formation of the enterprise. The paper aims at using neural networks to assess the current and forecast the future state of enterprises and to propose the optimum development strategy for a different area of business. The research also used the methods of multiple regression to evaluate the correlation between initial features and general factors, which in our case are global and national development indicators. The results of the analysis were used for building a model of business systems development in Statistica 13.5 program. The model, based on selected indicators, identifies the current state of the enterprise and future development strategies and designs the optimum scenario and proposes its development for the long-term progress of the enterprise. This approach to prediction is applicable to global and domestic companies.

Keywords: *prediction, enterprise development, global environment, neural networks, development strategy, global and national development indicators*

1. Introduction

The development of the enterprise depends on many factors, such as current financial and economic indicators, inflation, exchange rates, cooperation with suppliers and consumers, competition policy and more. The task of predicting indicators of enterprise development is among the poorly formalized and partially unaware. The development of an unambiguous algorithm for determining the parameters of the state of development of the enterprise based on the values of influencing factors is a difficult task.

The research aims to form an intelligent technology for the prediction of enterprise development indicators based on modelling, taking into account the internal state of financial and economic parameters of development and the external influence of the global environment, which will allow management to make informed decisions about business activities. In accordance with the purpose of the scientific task, it is advisable to use a mathematical apparatus that will implement the technology of enterprise development management and be able to adapt to changing conditions. The developed automated technology for enterprise development management will use the accumulated base for rapid and adequate response to unforeseen events. We are talking about creating an expert system. One of the modern mathematical methods, which to some extent meets all the previously defined requirements, is the method of artificial neural networks. Artificial neural networks are used to improve the accuracy of forecasting the development of enterprises in a changing global environment.

To effectively diagnose the state of the enterprise, it is often necessary to reflect on the nonlinear relationships between many factors, in particular, indicators of the state of enterprise development. The basis for solving the problem of building a model of an intelligent automated control system for enterprise development is an artificial neural network. This approach to building a neural network allows for taking into account the background of the state of enterprise development and accumulating information to form an effective strategy for managing enterprise development in a global environment.

2. Literature Review

The principle of operation of the neuron is as follows: the input signals (x_a), having the appropriate weights (w_a), are added and passed through the transfer function, generate the result and at the final stage the output is obtained. In addition, all neurons are interconnected and form certain layers, which form an artificial neural network (Jencova et al., 2021).

The input layer receives information from the external environment and transmits it to the next level, where it is analyzed and processed. After that, from the intermediate layer, the already processed information enters the source layer, from which it goes directly to the external environment. The transfer of information from one neuron to another is an important aspect of neural networks.

To effectively diagnose the state of the enterprise, it is necessary to reflect on the nonlinear relationships between many factors, in particular, indicators of the state. The mathematical apparatus of artificial neural networks makes it possible to take into account this feature and effectively replace the classical discriminant models (Breiman, 1996).

Using neural network technology, the strategies of different enterprises are evaluated, calculated and optimized. The error between the final calculation and the actual result is relatively small (Zhao et al., 2022).

The artificial neural network is used to construct the prediction model of influencing factors of development behaviour adopted by enterprises (Li et al., 2022).

Today, artificial neural networks solve the following tasks: price and production management, cost planning, determining the relationships between advertising costs, sales, competitors' prices, product prices, etc.; selection of optimal financial, pricing, and marketing strategies in terms of maximizing profits or sales; identification of factors influencing the parameters of the enterprise; forecasting consumer behaviour when changing marketing policy; finding the optimal advertising strategy, determining the segment of the most promising consumers for this product; management of business processes; monitoring of production processes with continuous adjustment of control parameters; technical diagnostics; creditworthiness assessment, forecasting of financial time series, forecasting of stock prices; linguistic analysis, etc.

The use of programs based on artificial neural networks simplifies calculations. Thus, the MATLAB software package allows you to solve technical problems, the Gene Hunter software package uses genetic algorithms to solve

combinatorial and optimization problems, the Neuro Shell Trader system is designed to predict and find effective trading strategies in financial markets, the Neuro Shell Classifier program is designed to solve problems image recognition and their assignment to one or another category, the package Statistical Neural Networks is designed to solve regression and time series prediction, and the add-on Excel Neural Package, which implements the concept of neural networks and can solve a wide range of financial, economic, statistical and management problems, using networks based on single-layer and multilayer perceptron.

The mathematical basis of the model is an artificial neural network of counter propagation, built based on a combination of a layer of Kohonen neurons of the so-called self-organization map, which aims to highlight common characteristics in the studied objects by clustering, and the original Grossberg star, which interprets the clustering (Anyaeche & Ighravwe, 2013).

3. Data and Methodology

The methodical approach to predicting the development of the enterprise should be implemented by performing a certain sequence of steps (Figure 1).

At the first stage of construction of the model of prediction of development of the enterprise, we carry out a choice of factors, formation from them of educational examples and their representation on an entrance layer. In our problem, a set of the most informative indicators of financial and economic activity is a set of independent variables based on which the conclusion about a condition of the enterprise is carried out. There are many such factors in modern analysis, but it is advisable to choose the most significant of them.

The toolkit of artificial neural networks of counter-propagation makes it possible to include in the model as many informative indicators as possible and does not require for its functioning prerequisites for the stationary nature of the studied process or the absence of multicollinearity in the input data (Boritz & Kennedy, 1995; Režňáková et al., 2020). During the formation of a model, the task of selecting the most significant independent factors takes into account the degree of influence on the performance indicator. A large number of elements of the input vector increase the noise of the input signal. From a mathematical point of view, this task is reduced to the optimal compression of information about the state of the enterprise, i.e. the display of initial information with a minimum number of parameters at a given level of accuracy or minimization of information loss at a given number of generalized coordinates. The neural network consists of a competing layer, which is represented in this case by the Kohonen map, and the source layer is the source star of Grossberg. The Kohonen neuron layer learns "without a teacher" and does not need the desired network response to correctly adjust the synaptic weights. It is due to the implementation of this procedure in the search for hidden dependencies in the structure of indicators of the business system. This neural network learning algorithm provides a two-dimensional mapping of multidimensional input vectors, performing their clustering (Tumpach et al., 2020).

After forming all the examples to submit them to the inputs of the neural network in order to train it, we can choose the structure of the Kohonen map. The number of parameters

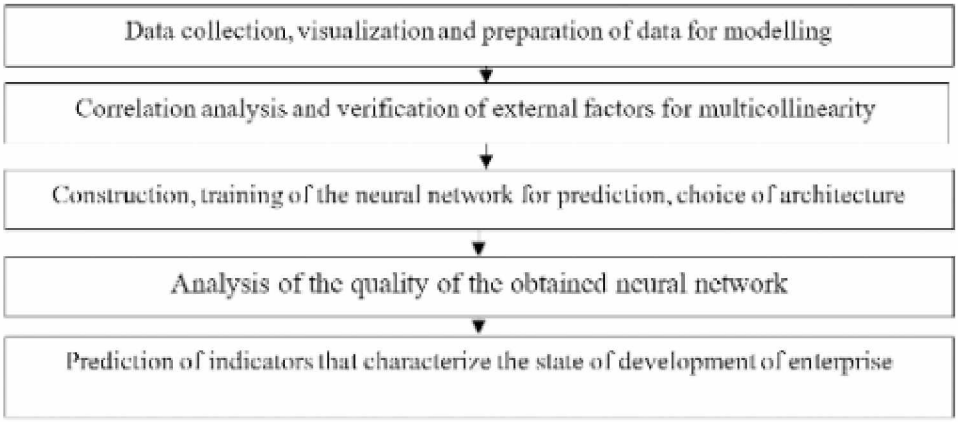
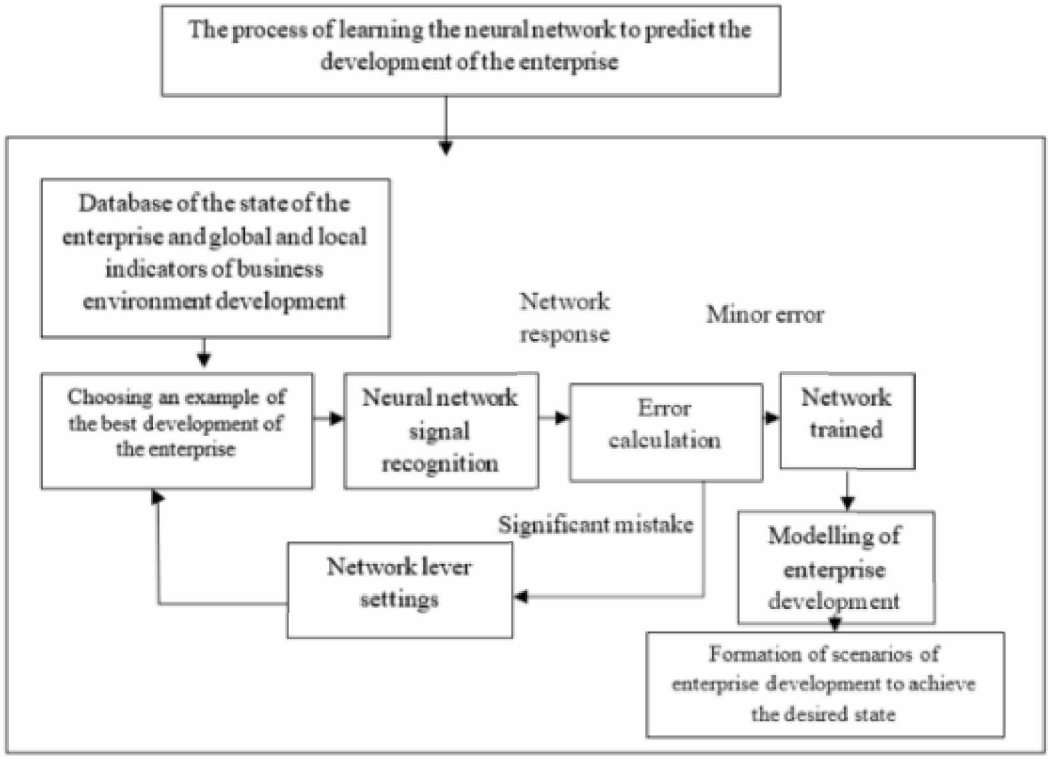


Figure 1. The process of predicting the development of the enterprise based on neural networks

Source: Author's approach



Source: Author's approach

Figure 2. Methodical approach to the formation of intelligent technology for prediction of the development of the enterprise based on the use of artificial neural networks

(connection weights) of each neuron in the Kohonen layer coincides with the number of indicators in the generated input examples, which for our model will be equal to eleven elements for global business systems and twenty-three elements for domestic enterprises.

The advantage of methods based on neural networks is the lack of need for strict mathematical specification of the model. Neural networks allow taking into account the influence of factors influencing the results. Neural networks should be used where there is a large amount of data. In this case, various nonlinear interactions between factors are automatically taken into account. It is advisable to use neural networks in problems with incomplete information, as well as in problems that are characterized by intuitive solutions.

The methodical approach presents the formation of intelligent technology for prediction and the development of the enterprise based on the use of artificial neural networks (Figure 2).

The main difference of this approach to modelling the development of enterprises in comparison with alternative approaches is to solve forecasting problems by recognizing pattern images in the structure of indicators and assigning recognizable images to clusters that characterize different classes of change of the studied indicator (Turdubaev et al., 2021).

The main idea of the study to assess the impact of global environmental factors on the parameters of enterprise development is that development trends can be assessed based on the properties of enterprises, namely adaptability, reliability, flexibility, mobility, and sufficiency (Stefko & Sojka, 2015; Vuković et al., 2020). This takes into account the main property of the potential which is the integrity, which is the result of the interaction of its components; priority of economic goals of the enterprise and economic results of its activity, which allows achieving long-term development goals due to the effective functioning of the enterprise; the maximum degree of adaptability to changing

conditions of the internal and external environment, which is determined by its sustainability and economic security.

The first and second provisions allow choosing among all indicators of activity the economic indicators characterizing profitability of the enterprise (intensity of use of resources, efficiency of economic activity and business activity of the enterprise). The third provision necessitates the use of liquidity and financial stability of the enterprise. Indicators of solvency, profitability and business activity are used to assess the financial and economic development of the enterprise. And although these characteristics are closely interrelated, they are independent areas of analysis.

In this research, we form a model for the prediction of the development of the enterprise, based on many indicators of their activities, namely, for global business systems: x1 – net sales, x2 – operating profit, x3 – net assets, x4 – current liquidity ratio, x5 – return on investment capital, x6 – return on assets, x7 – return on investment, x8 – financial leverage, x9 – return on operating activities, x10 – average share price, x11 – earnings per share, etc. The following performance indicators were used to study domestic business systems: x1 – assets, x2 – equity, x3 – net income, x4 – the cost of sales, x5 – net profit (loss), x6 – return on assets, x7 – return on equity, x8 – material consumption, x9 – labour intensity, x10 – average salary, x11 – profitability ratio.

Given the rather large volume of statistical data on the activities of enterprises as a method of modelling and evaluation of strategic priorities, factor analysis based on the model of multiple regressions was chosen. The description of business systems development processes is carried out with the help of a system of indicators that characterize the state of these processes (Boichenko et al., 2021; Valaskova et al., 2018). Determining the minimum number of factors that are sufficient to describe the initial system of indicators and their correlations is solved by the method of principal components (Malyarets et al., 2020). According to the standard procedure, a matrix of loadings of weight coefficients is obtained. Factor loads are characteristics of the stochastic relationship between the initial features and general factors, which in our case are global and national development indicators. The module Statistics, Advanced Models, Multiple Regression of the statistical package Statistica 13.5 is used to perform factor analysis calculations.

To test the hypothesis of the impact on key performance indicators of global environmental factors, the following global indicators were selected for the study of global corporations: Vary 1 – consumer price index; Vary 2 – changing the current account balance; Vary 3 – GDP growth rate in constant prices; Vary 4 – change in GDP at purchasing power parity; Vary 5 – GDP growth rate per capita, %; Vary 6 – GDP deflator; Vary 7 – market capitalization, %; Vary 8 – the average world price of Brent oil; Vary 9 – change in quotation on the Dow Jones index, %; Vary 10 – change of quotations by index S&P, %; Vary 11 – change of quotations according to the FTSE index, %.

A representative amount of data for analysis and forecasting was a seven-year observation for 2013-2019. For the research of Ukrainian business systems (Ukrainian case), national indicators of economic development were added as parameters of influence, 23 indicators were selected as studied parameters, among which: Vary 1 – nominal GDP growth rates in hryvnia equivalent, %; Vary 2 – nominal GDP growth rates in dollar equivalent, %; Vary 3 – inflation index, %; Vary 4 – dynamics of external debt, %; Vary 5 – real wage index, %; Vary 6 – unemployment rate, %; Vary 7 – export coverage ratio by import, Vary 8 – index of industrial output,%; Vary 9 – volume of direct investments of the world countries in the economy of Ukraine, million USD; Vary 10 – balance of investment activity in Ukraine,%; Vary 11 – official exchange rate of hryvnia against the dollar (average for the period); Vary 12 – official exchange rate of hryvnia against the euro (average for the period); Vary 13 – hryvnia devaluation index; Vary 14 – the average world price of Brent oil; Vary 15 – producer price index; Vary 16 – the share of scientific and technical work performed in GDP, %; Vary 17 – the share of enterprises engaged in innovation, %; Vary 18 – the share of unprofitable enterprises in Ukraine, %; Vary 19 – return on assets of Ukrainian banks, %; Vary 20 – return on equity of Ukrainian banks, %; Vary 21 – change in quotation on the Dow Jones index, %; Vary 22 – change of quotations by index S&P, %; Vary 23 – change of quotations according to the FTSE index, %.

A sample with data from global and national indicators (Table 1) for 2013-2019, formed based on monitoring reporting and statistical data of international and domestic agencies, was used to train the network.

The list of initial data (Table 1), which characterizes the impact of exogenous factors on the development of global business systems, was based on the study of the global environment, separation of general parameters and indicators, analysis of global economic trends and trends in business systems in the global economic space. Indicators that characterize the impact of exogenous factors on the development of domestic business systems (in the case of Ukraine) change according to the current situation (Table 2).

Table 1. Initial data characterizing the influence of exogenous factors on the development of global business systems

Indicator	Year						
	2013	2014	2015	2016	2017	2018	2019
Consumer price index	*3,6*	*3,2*	*2,7*	*2,7*	*3,2*	*3,6*	*3,5*
Changing the current account balance	*6,43*	*2,93*	*-43,31*	*29,1*	*57,97*	*-29*	*16,05*
GDP growth rate in constant prices	*-20,27*	*-7,95*	*16,41*	*-5,1*	*-2,24*	*1,97*	*-2,32*
Change in GDP at purchasing power parity	*4,54*	*5,92*	*5,36*	*3,79*	*2,07*	*3,74*	*4,92*
GDP growth rate per capita, %	*1,3*	*1,9*	*2,1*	*1,4*	*1,7*	*1,7*	*1,5*
GDP deflator	*2,3*	*2,8*	*2,9*	*1,8*	*2,1*	*2*	*2,2*
Market capitalization, %	*91,1*	*91,9*	*111,2*	*97,1*	*94,7*	*91,6*	*89*
The average world price of Brent oil, USD per barrel	*112,3*	*110,91*	*56,29*	*37,35*	*65,47*	*66,57*	*54,91*
Change in quotation on the Dow Jones index, %	*26,5*	*7,52*	*-2,23*	*13,42*	*25,05*	*-5,63*	*13,94*
Change of quotations by index S&P, %	*29,6*	*11,39*	*-0,73*	*9,54*	*19,42*	*-6,24*	*17,31*
Change of quotations according to the FTSE index, %	*14,43*	*-2,71*	*-4,93*	*14,43*	*7,63*	*-12,4*	*10,8*

Source: World Bank's World Development Indicators

Table 2. Intial data characterizing the influence of exogenous factors on the development of domestic business systems (in the case of Ukraine)

Indicator	Year						
	2013	2014	2015	2016	2017	2018	2019
Nominal GDP growth rates in hryvnia equivalent, %	*3,3*	*7,7*	*26,3*	*20,4*	*25,2*	*19,3*	*11,7*
Nominal GDP growth rates in dollar equivalent,%	*4,3*	*-28,1*	*-31,3*	*2,9*	*20,2*	*16,7*	*17,5*
Inflation index, %	*100,5*	*124,9*	*143,3*	*112,4*	*113,7*	*109,8*	*104,1*
Dynamics of external debt, %	*-5,2*	*-11,1*	*-6*	*-4,4*	*2,7*	*-1,6*	*6,1*
Real wage index, %	*106,8*	*86,5*	*90,1*	*106,5*	*118,9*	*109,7*	*111,4*
Unemployment rate, %	*7,7*	*9,7*	*9,5*	*9,7*	*9,9*	*9,1*	*8,6*
Export coverage ratio by import	*0,9*	*1,06*	*1,01*	*0,93*	*1,08*	*1,08*	*0,97*
Index of industrial output, %	*95,3*	*89,3*	*86,6*	*102,4*	*101,1*	*103*	*99,5*
Volume of direct investments of the world countries in the economy of Ukraine, million USD	*51705,3*	*53704*	*40725,4*	*3615 4,5*	*31230,3*	*31606,4*	*32905,1*
Balance of investment activity in Ukraine, %	*-43,4*	*-92,7*	*907,4*	*8,5*	*-32,9*	*7,6*	*2,6*

Official exchange rate of hryvnia against the dollar (average for the period)	*7,993*	*11,8867*	*21,8447*	*25,5513*	*26,5966*	*27,2005*	*25,8456*
Official hryvnia exchange rate against the euro (average for the period)	*10,61*	*15,7159*	*24,2287*	*28,2919*	*30,0042*	*32,1429*	*28,9518*
Hryvnia devaluation index	*100*	*197,3*	*150,8*	*112,2*	*104,5*	*99,3*	*85,5*
The average world price of Brent oil, USD per barrel	*112,3*	*110,91*	*56,29*	*37,35*	*65,47*	*66,57*	*54,91*
Producer price index	*101,7*	*131,7*	*125,5*	*135,8*	*116,6*	*114,3*	*92,5*
The share of scientific and technical work performed in GDP, %	*0,8*	*0,69*	*0,64*	*0,48*	*0,45*	*0,47*	*0.43*
The share of enterprises engaged in innovation, %	*13,6*	*16,1*	*17,36*	*18,9*	*16,2*	*16,4*	*15,8*
The share of unprofitable enterprises in Ukraine, %	*34,1*	*33,7*	*26,3*	*26,6*	*27,2*	*25,7*	*23,3*
Return on assets of Ukrainian banks, %	*0,12*	*-4,07*	*-5,46*	*-2,48*	*-1,94*	*1,65*	*4,35*
Return on equity of Ukrainian banks, %	*0,81*	*-30,46*	*-51,91*	*- 26,56*	*-15,96*	*10,73*	*34,18*
Change in quotation on the Dow Jones index, %	*26,5*	*7,52*	*-2,23*	*13,42*	*25,08*	*-5,63*	*13,94*
Change of quotations by index S&P, %	*29,6*	*11,39*	*-0,73*	*9,54*	*19,42*	*-6,24*	*17,31*
Change of quotations according to the FTSE index, %	*14,43*	*-2,71*	*-4,93*	*14,43*	*7,63*	*-12,48*	*10,8*

Source: Ukrstat

The fact of the non-linearity of the original data is beyond doubt. Let's analyze the importance of independent factors and the degree of their influence on the initial parameters, and determine the type of functional dependence.

4. Results and Discussion

Enterprises that have been among the top best corporations in the world in recent years have been selected as objects of diagnosing the relationship between the key parameters of business systems development on exogenous factors of global and national influence. We will present a study on the example of the activities of Arcelor Mittal International Metallurgical Company and its Ukrainian division Arcelor Mittal Kryvyi Rich.

Arcelor Mittal is one of the largest metallurgical companies in the world, controlling more than 10% of the global steel market. The company is registered in Luxembourg, has facilities in 18 countries, and sells products in 160 countries. According to Forbes Global, Arcelor Mittal ranks high in the ranking of large companies in terms of revenue, net profit, asset size and market capitalization. Arcelor Mittal Kryvyi Rich is a metallurgical plant, one of the largest mining and metallurgical enterprises in Ukraine. Arcelor Mittal Kryvyi Rich is a unique enterprise in terms of capabilities and scale, which includes an ore mining department, a mining and processing plant, agglomeration, coke and metallurgical production. The company specializes in the production of long products, namely fittings, rolled products, strips, and blanks. The company is a significant exporter of Ukraine.

The correlation analysis conducted in the STATISTICA package allowed us to assess the relationship between exogenous factors and key parameters of the enterprise. The

existence of a factor relationship was determined using pairwise correlation coefficients. The results of the analysis proved that not all selected exogenous factors correlate with the key parameters of the enterprise. Such factors were excluded from the list of exogenous variables in the construction of neuron models and, accordingly, forecasting the future state of enterprise development. The results of the multifactor regression analysis performed in the STATISTICA package for all key parameters and the correlation matrix of key Arcelor Mittal indicators and exogenous global indicators present relatively balanced results (Table 3).

The research confirmed the feasibility of including a number of exogenous factors in the forecast models. The results of a study of the relationship between the parameters of business systems development and global indicators by Arcelor Mittal show that the business system is weakly affected by changes in stock prices on the stock exchange. That is, in the future, when forming a model of development of this business system and forecasting its development, the impact of these parameters can be ignored. A high correlation has a value of [-1; -0.5] and [0.5, 1], with negative values indicating a negative correlation or inverse relationship, and a plus sign indicating a direct relationship.

Each of the parameters of the study of the business system correlates with these indicators. The correlation matrix of key indicators of Arcelor Mittal Kryvyi Rich and exogenous global to national indicators present different results as compared with the main company (Table 4). According to the studied objects, there is a correlation between financial leverage and the consumer price index, between earnings per share and the GDP deflator, and between net sales and market capitalization.

Table 3. Correlation matrix of Arcelor Mittal key indicators and exogenous global indicators

Indicators	Consumer price index	Changing the current account balance	GDP growth rate in constant prices	Change in GDP at purchasing power parity	GDP growth rate per capita,%	GDP deflator	Market capitalization, %	The average world price of Brent oil, USD per barrel	Change in quotation on the Dow Jones index, %	Change of quotations by index S&P, %	Change of quotations according to the FTSE index
Net sales	*0,818988*	*-0,16510*	*-0,4973*	*0,264298*	*-0,03219*	*0,2800*	*-0,5842*	*0,870875*	*0,078307*	*0,260102*	*-0,26821*
Operating profit	*0,308524*	*0,450254*	*-0,3746*	*-0,63353*	*-0,31595*	*-0,6624*	*-0,5737*	*0,043069*	*0,128137*	*-0,04429*	*-0,07504*
Net assets	*0,774645*	*-0,01621*	*-0,6789*	*0,278946*	*-0,18521*	*0,2173*	*-0,6668*	*0,920229*	*0,237506*	*0,418845*	*-0,07360*
Current ratio	*0,898304*	*-0,31398*	*-0,3825*	*0,243464*	*-0,22173*	*-0,0452*	*-0,6822*	*0,523787*	*-0,16934*	*0,002897*	*-0,31445*
Return on invested capital	*0,396579*	*0,595287*	*-0,4487*	*-0,68970*	*-0,47200*	*-0,7711*	*-0,6956*	*-0,02288*	*0,279274*	*0,110521*	*0,105350*
Return on assets	*0,388822*	*0,563131*	*-0,4056*	*-0,70592*	*-0,43441*	*-0,7648*	*-0,6650*	*-0,03879*	*0,239123*	*0,063629*	*0,056506*
Return on investment	*0,292909*	*0,518759*	*-0,3891*	*-0,67972*	*-0,38590*	*-0,7321*	*-0,5892*	*-0,02544*	*0,187058*	*0,002108*	*0,013551*
Financial leverage	*-0,674325*	*-0,54278*	*0,5157*	*0,558388*	*0,560673*	*0,7269*	*0,8777*	*-0,06229*	*-0,31833*	*-0,23198*	*-0,14508*
Profitability of operating activities	*0,238129*	*0,517358*	*-0,3924*	*-0,65998*	*-0,37717*	*-0,7190*	*-0,5590*	*-0,02447*	*0,181684*	*-0,00614*	*0,021819*
The average stock price	*0,430777*	*-0,21475*	*-0,5006*	*0,353145*	*0,098954*	*0,4760*	*-0,2521*	*0,971513*	*0,099115*	*0,255790*	*-0,23335*
Profit per share	*0,461564*	*0,548429*	*-0,4898*	*-0,73382*	*-0,54298*	*-0,8038*	*-0,6819*	*0,011976*	*0,316791*	*0,149284*	*0,128261*

Source: Authors' calculations based on Arcelor Mittal

The results of studying the correlation between global and national indicators and performance parameters of leading domestic companies that are part of global or national business systems show that almost all of these indicators affect the development of business systems in the global environment. It should be noted that each business system should be studied individually. According to this approach, it is possible to receive the most realistic forecasts for enterprise development. The results of an analysis by Arcelor Mittal Kryvyi Rich (Ukraine) showed a lack of correlation between key parameters of the company with indicators such as inflation, investment balance, and change in quotations on the Dow Jones index. In this case, the following high-level correlations are observed.

First, there is a relation between the net income parameter and the nominal GDP growth rates in the dollar equivalent. Secondly, there is a relationship between the parameters of net income, cost of sales and wage index. Third, the parameters of net income, cost of sales, rate of return, and earnings per share correlate with the index of industrial production. Fourth, the parameters of net income and earnings per share are related to the indicator of foreign direct investment in the economy. Fifth, the cost of sales depends on the devaluation index of the hryvnia. Sixth, the size of assets depends on the intensity of innovation of business systems. All identified dependencies will be used to form models of business systems development and forecast scenarios for their future activities.

Among the exogenous factors of global influence, the most important on the key parameters of global systems were: Vary 4 – change in GDP at purchasing power parity, Vary 6 – GDP deflator, Vary 7 – market capitalization, %, with the least impact had Vary 9 – change in quotations for Dow Jones index, % and Vary 11 – change in quotations on the FTSE index, %. Regarding exogenous factors of global and national influence on key parameters of national business systems had Vary 2 – nominal GDP growth rate in dollar, %, Vary 4 – external debt dynamics, %, Vary 5 – real wage index, %, Vary 8 – industrial production index, %, Vary 9 – volume of direct investments of the world in the economy of Ukraine, million dollars, Vary 12 – official hryvnia exchange rate against the euro (average for the period), Vary 13 – hryvnia devaluation index, Vary 15 – produce price index, Vary 17 – the share of enterprises engaged in innovation, %. Minimal impact was also provided by the parameters Vary 21 – change in quotations on the Dow Jones index, % and Vary 23 – change in quotations on the FTSE index, %.

The consequences of changes in the state of the enterprise are the likelihood of approaching a crisis or catastrophic situation, which may lead to loss of opportunity to purchase the necessary range of raw materials due to insolvency of suppliers, increasing the cost of material resources, which may adversely affect price competition; destruction of partnerships with stakeholders; depreciation of assets, which will increase costs and increase the percentage of marriage; increase production costs, reduce the number of orders and contracts for the sale of products; cost increase; increase in the amount of illiquid working capital; reduction of sales due to the lack of revenue from sales of products, etc. (Parkhomenko & Otenko, 2019).

Thus, the current factor system reflects not only the strategic priorities and the complete structure of the state of development processes, identifies the most important factors, but also determines the structure of each factor and the relationship between indicators that determine each factor. This research allows us to identify, systematize and classify the whole set of factors that determine the state of enterprise development processes in the global environment, to develop methods for measuring quantitative characteristics of the impact of these factors, forming on this basis tools for managing these processes. Therefore, determining the relationship between the key parameters of business systems development and exogenous global and national indicators requires further study to forecast the development of enterprises.

We present the results of experiments on forecasting the development of enterprises using economic and mathematical models built on neural networks of counter-propagation. For forecasting, we will use a methodical approach to modelling and forecasting using the Statistical application package.

The original time series was converted into input image vectors, each of which contains data for the last seven years. During the calculations, a number of economic and mathematical models based on neural networks of different configurations were built to determine the most adequate set of explanatory variables, the required number of neurons in

Table 4. Correlation matrix of key indicators of Arcelor Mittal Kryvyi Rich (Ukraine) and

Indicator	Nominal GDP growth rates in hryvnia equivalent, %	Nominal GDP growth rates in dollar equivalent %	Inflation index, %	Dynamics of external debt, %	Real wage index, %	Unemploymen t rate, %	Export coverage ratio by import	Index of industrial output, %	Volume of direct investmen ts of the world countries in the economy of Ukraine, million USD	Balance of investment activity in Ukraine, %
Assets	0,567662	0,343887	0,081306	0,560180	0,289756	0,5376	0,596804	0,430092	-0,80933	-0,001363
Equity	0,188383	0,094780	0,188364	0,303323	0,042944	0,1115	0,794363	-0,10419	-0,27355	0,121556
Net profit	0,634062	0,631731	-0,13939	0,742429	0,619314	0,4006	0,514953	0,670086	-0,95701	-0,084053
The cost of sales	0,559790	0,588867	-0,13321	0,845267	0,580560	0,2956	0,340955	0,573289	-0,93636	0,001039
Net profit (loss)	0,620412	0,380707	0,010575	0,161605	0,380644	0,3915	0,581480	0,526016	-0,61478	-0,014107
Return on assets	0,719503	0,346425	0,094397	0,198644	0,357085	0,5150	0,616361	0,513614	-0,68679	0,042053
Return on equity	0,448300	0,168644	-0,04395	-0,04474	0,202260	0,4548	-0,16519	0,518822	-0,39227	-0,091688
Material intensity	-0,22659	0,100970	-0,18763	0,444212	0,157665	-0,525	-0,65752	-0,13638	0,007250	0,204385
Labour intensity	-0,86517	-0,07351	-0,37149	-0,05179	-0,15342	-0,853	-0,55222	-0,31915	0,597907	-0,168500
Profitability ratio	0,458723	0,340708	-0,04289	0,038537	0,312460	0,5042	0,693957	0,518739	-0,46178	-0,267462
Average salary	0,132401	0,646723	-0,38836	0,853411	0,551278	-0,093	0,205425	0,546116	-0,73523	-0,192398
Profit per share	0,620744	0,380577	0,010696	0,161291	0,380878	0,3907	0,580234	0,525720	-0,61445	-0,013119

Source: Authors' calculations based on Arcelor Mittal

the Kohonen layer and the number of learning circuits for efficient operation of the model. As a result of using such a neural network, we obtain specific forecasts for the development of enterprises, depending on the values of key indicators (Narinder et al., 2021).

Thus, eleven factor models for the global business system and eleven factor models for the domestic business system for prediction were formed, which passed additional testing, namely, built a normal probabilistic graph of residuals (values were placed along the line), histogram of residual distribution balances had a normal distribution, scatter plot of predicted values and balances (there should be no pronounced trend).

Thus, with the help of the STATISTICA Neural Networks software package, neural networks were built for forecasting purposes. The construction of a mathematical model for a new set of initial data gave the resulting response with an accuracy of not less than 5%. This model reflects the relationship between exogenous factors (Vary 1-Vary N) as inputs of the model and key parameters of business systems as outputs of the model. In the future, the model can be used to predict the development of the enterprise for future periods. The Statistical Nonlinear Estimation module was used to build the model. We build a neural network that will select an adequate function that best approximates the original data.

exogenous global to national indicators

Official exchange rate of hryvnia against the dollar (average for the period)	Official hryvnia exchange rate against the euro (average for the period)	Hryvnia devaluation index	The average world price of Brent oil, USD per barrel	Producer price index	The share of scientific and technical work performed in GDP, %	The share of enterprises engaged in innovation, %	The share of unprofitable enterprises in Ukraine, %	Return on assets of Ukrainian banks, %	Return on equity of Ukrainian banks, %	Change of quotations by index S&P, %	Change of quotations by index S&P, %	Change of quotations according to the FTSE index, %
0,884322	0,910126	-0,18783	-0,66770	0,0125	-0,90861	0,522956	-0,82486	0,294994	0,262433	-0,46037	-0,57352	-0,385729
0,247071	0,303168	0,055517	0,126644	-0,329	-0,23063	-0,28124	-0,24750	0,209641	0,242661	-0,38433	-0,34023	-0,691964
0,945723	0,966230	-0,50014	-0,70487	-0,136	-0,95412	0,399618	-0,84688	0,414433	0,373114	-0,23993	-0,42178	-0,232501
0,926370	0,924066	-0,53367	-0,76274	-0,280	-0,95004	0,372554	-0,93001	0,491272	0,442180	-0,17442	-0,30557	-0,075971
0,607006	0,656752	-0,25651	-0,36788	0,2456	-0,49847	0,341104	-0,37346	0,019651	-0,01402	-0,40769	-0,61703	-0,536431
0,708112	0,750195	-0,21926	-0,48579	0,3098	-0,59772	0,471298	-0,47572	-0,02608	-0,06601	-0,44409	-0,66847	-0,532380
0,480333	0,461804	-0,16533	-0,64041	0,5893	-0,44284	0,791659	-0,30864	-0,17694	-0,24108	-0,09021	-0,30463	0,190524
-0,096686	-0,17375	-0,38036	-0,13068	-0,617	0,071188	-0,28291	-0,19753	0,330986	0,302934	0,445152	0,556026	0,642883
-0,707960	-0,71514	-0,05878	0,622071	-0,648	0,601033	-0,78288	0,45033	0,390633	0,430026	0,337684	0,597850	0,337937
0,478289	0,547034	-0,06697	-0,17897	0,3575	-0,45846	0,303949	-0,17407	-0,03065	-0,02660	-0,31413	-0,51508	-0,518192
0,676690	0,694194	-0,59340	-0,47559	-0,604	-0,77334	0,015131	-0,77634	0,800549	0,772472	-0,14602	-0,15480	-0,059295
0,606432	0,656039	-0,25714	-0,36788	0,2456	-0,49743	0,340758	-0,37300	0,019012	-0,01477	-0,40700	-0,61646	-0,535689

In the first stage of modelling, the network is trained on a test set, which assesses the significance of inputs, as not all exogenous factors affect the studied indicator Y. The share of influence of some factors may be so small that ignoring them will not lead to significant deviations. The modelling procedure is implemented in STATISTICA using three modes: automated and custom neural networks, as well as the method of multiple subsamples. In the mode of automated and custom neural networks, a multilayer perceptron (MLP) was used, and in the mode of multiple subsamples a radial basis function (RBF).

The network configuration is defined. The STATISTICA Neural Networks (SNN) add-on simplifies this process by using the Intelligent Problem Solver procedure, which automatically reduces the dimension of the designed network by highlighting the most significant external factors and searching for neural networks by analyzing networks of different typologies. The algorithm of such search involves the search of a number of neural network configurations and the selection of the best in terms of minimum errors at the output of the network and maximum performance. We can identify possible alternative options for enterprise development.

The most probable or inertial development of the enterprise is possible according to the basic variant. This option characterizes the management of enterprise development in

terms of retrospect, without significant changes in the components and the absence of significant changes in the global environment. Such a development scenario may lead to a decrease in competitiveness, a lack of positive changes in activities, and does not involve the implementation of innovative projects. The scenario of a pessimistic scenario of enterprise development is the worst-case scenario. The scenario of optimistic development envisages positive tendencies of change of state, acceleration of innovative changes, the introduction of new projects, restructuring of the enterprise, development of potential through the use of opportunities, the introduction of strategic tools of threat detection, the definition of development priorities, ways of solving problem situations (Drobyazko et al., 2020).

As a result, 15 neural networks were obtained for each key indicator of the enterprise. The quality of each of them is checked based on histograms of the distribution of residues (residues have a normal distribution), diagrams of scattering of the target and "yield" (the result of the architecture). Analysis of the control performance of models and graphs has identified a favourable architecture for predicting a multilayer perceptron with one hidden layer and seven hidden neurons. Forecasts for key indicators of enterprise development, taking into account global and national indicators, are based on neural network models, namely, trained and tested neural networks. In Table 5 we can present the final results of forecasting the development of Arcelor Mittal taking into account the influence of exogenous factors.

The developed forecast of key parameters of Arcelor Mittal's development under the condition of forecasts on exogenous global indicators shows rather positive dynamics of development of all companies.

Positive dynamics will be observed in terms of net sales, operating profit, and return on investment. Net assets and financial leverage will remain at about the same level. The current liquidity ratio will remain within the normative values, although it will decrease, which should be noted by management and preventive measures should be taken.

The value of return on invested capital, return on assets, and earnings per share over the next two forecast periods is a matter of concern and requires management decisions. There will be a negative trend in the reduction of the company's share price, which should be noted and determine the possible consequences of such changes.

The forecast results of the development of the Ukrainian division of the international company Arcelor Mittal Kryvyi Rich (Table 6) show positive trends in the company's development, namely the gradual increase in the company's assets, constant equity, doubling net income, rapid growth in net income.

Table 5. The most reliable forecast of key parameters of Arcelor Mittal's development, taking into account the impact of exogenous global indicators

Indicators of enterprise development	Forecast period				
	2021	2022	2023	2024	2025
Net sales	*72025,87*	*71992,88*	*72084,56*	*72081,44*	*72041,80*
Operating profit	*2125,431*	*2118,700*	*4193,067*	*5449,406*	*6500,510*
Net assets	*90444,86*	*90285,49*	*89657,33*	*90006,27*	*90213,60*
Current ratio	*1,361579*	*1,340751*	*1,208951*	*1,286119*	*1,286119*
Return on invested capital	*-4,95000*	*-2,19000*	*5,71000*	*12,22000*	*11,99000*
Return on assets	*-2,30000*	*-1,02000*	*2,36000*	*5,54000*	*5,85000*
Return on investment	*1,67054*	*4,50032*	*9,26973*	*11,42982*	*12,59987*
Financial leverage	*37,56833*	*37,66271*	*37,60252*	*37,58788*	*37,62490*
Profitability of operating activities	*1,510000*	*3,830000*	*7,300000*	*7,900000*	*8,600000*
The average stock price	*42,47247*	*44,72562*	*16,70215*	*27,43355*	*28,85213*
Profit per share	*0,18000*	*-2,00000*	*1,87000*	*4,48000*	*5,07000*

Source: Authors' calculations

Table 6. The most probable forecast of key parameters of Arcelor Mittal's development in Kryvyi Rich (Ukraine) taking into account the impact of exogenous global and national indicators

Indicators of enterprise development	Forecast period				
	2021	2022	2023	2024	2025
Assets	*51580477*	*65512989*	*86970044*	*89902488*	*91617964*
Equity	*46733853*	*46869198*	*46790197*	*47005866*	*46812509*
Net profit	*26557176*	*38471193*	*54003795*	*66783638*	*66645009*
The cost of sales	*31690005*	*29785350*	*54970633*	*56719505*	*56257098*
Net profit (loss)	*-1517018*	*-1180487*	*2704116*	*5061847*	*9509163*
Return on assets	*-3,64475*	*-1,58390*	*3,33975*	*5,68344*	*9,73558*
Return on equity	*-4,33935*	*-1,31771*	*4,87672*	*9,89805*	*10,64439*
Material intensity	*0,708283*	*0,660271*	*0,682095*	*0,680831*	*0,649023*
Labour intensity	*0,058747*	*0,058964*	*0,058349*	*0,058292*	*0,058228*
Profitability ratio	*0,999376*	*1,083519*	*1,105106*	*1,170145*	*1,243019*
Average salary	*6126,53*	*6900,96*	*8588,73*	*11113,19*	*14285,89*
Profit per share	*-0,39000*	*-0,310000*	*0,700000*	*1,310000*	*2,460000*

Source: Authors' calculations

Despite the unsatisfactory results of return on assets and return on equity during the two forecast periods, we continue to see a positive trend of increasing and increasing financial strength. The indicators of the average salary at the enterprise, which is a positive social component of the business system, also have a positive upward trend. It is clear that the high material consumption of the metallurgical enterprise, in the forecast period tends to decrease. The capacity of the business system is low, which will remain at about the same level during the forecast period. The profitability ratio also has positive dynamics, which indicates the strengthening of the business system's position in a competitive changing market in a global environment.

5. Conclusion

The results of modelling well approximate the actual data; the total square error is 3%. This allows us to conclude that the simulated neural networks will be sensitive to variations in input parameters and accordingly can be used to predict the development of the enterprise in the future. According to the results of forecasting over the next 5 forecast periods, the financial condition of many enterprises is expected to improve in many financial indicators. However, for some parameters, management should pay attention to their dynamics, possible negative trends, or stability over a long period of time, and, accordingly, adjust the strategy of business systems.

Practice shows that the use of neural networks to predict the development of the enterprise depending on the correctness of the configuration of forecast models allows for obtaining high-precision results with minimal time. The proposed methodological approach, which is based on neural network tools, allows for modelling the state of enterprise development in different scenarios of the impact of global environmental factors. The proposed tools for forecasting the key parameters of enterprise development taking into account changes in global factors will allow the company's management to timely adjust its development strategy. It should be noted that the use of a neural network, which is based on a combination of layers Kohonen and Grossberg, avoids situations in which it is impossible to draw a clear conclusion about the state of the enterprise.

Also, the range of models for diagnosing the state of development of enterprises based on the apparatus of artificial neural networks can be expanded using different sets of explanatory variables. Such neural networks can be used to analyze the company's activities in relation to various functions (financial support, marketing activities, sales policy, etc.) and diagnose the development of business

systems for analytical purposes and to ensure various management decisions, such as investing. The built models allow increasing efficiency of management of development of the enterprise.

Thus, the method of modelling can be a tool for assessing the global environment and enterprise development. Regarding the identity of such models for enterprises of one industry or field of activity, it is necessary to take into account the general list of exogenous parameters and the actual realistic data on the state of development of the enterprise itself. It should be noted that each company in the process of development in a global environment, has its own unique experience, and capabilities, and works with significant amounts of information, based on its inherent abilities using the acquired knowledge and information. That is, there can be no single model of development common to all systems, each model is unique.

Thus, the development of the enterprise takes place in one scenario or another, determining the vector of development and change. This vector is limited to pessimistic and optimistic scenarios. Appropriate boundaries allow us to assess the possible future state of the enterprise, which is determined by the dynamics of indicators, strategic potential, and emerging risk situations. Risky events can be predicted, but it is impossible to determine the exact time of their occurrence. Coincidences must be limited by certain limits of the possibilities within which management decisions are made.

The most probable baseline scenario determines the strategic direction of the enterprise, based on the conditions of the global environment, and changes in the internal and external environment. That is, the choice of target orientation is more important than developing a strategy for enterprise behaviour within the current scenario.

If the vector of enterprise development deviates towards the pessimistic scenario, management decisions should be aimed at preventing the vector from going beyond the critical values of indicators. In this case, the company should focus on a survival strategy, according to which business systems reduce the production of unprofitable and unprofitable goods, reduce the number of employees, limit innovative modernization development programs, decide to eliminate certain units and minimize costs. That is, the help of various means of the enterprise ensures viability in the target market.

If the vector of development deviates towards an optimistic forecast, enterprises have the opportunity to improve. In this case, growth and diversification strategies are appropriate, which include increasing market share, expanding production, increasing profits and more. In order to influence the results of the planned scenarios, the company should be able to use available resources to increase the probability of the most favourable scenario.

The formation of enterprise development scenarios allows to form possible options for strategies in the early stages of strategic planning and determine the conditions for adaptation and flexibility through the timely identification of threats and opportunities, as well as to assess the degree of achievement and effectiveness of management decisions. A prerequisite for scenario forecasting is constant monitoring of the situation. Factors that affect the state of development of the enterprise and may contribute to the deviation from the most likely scenario are retrospectives and futures. Timely detection of these factors allows you to prepare the company for future changes in the external environment. Futures factors do not guarantee that the company will grow smoothly and will maintain stable dynamics, as at any time there may be unforeseen adverse circumstances that are accidental, under the influence of which the company may deviate from the most likely development scenario. In case of deviations from the scenario, corrective actions must be taken. The use of a scenario approach in the management of enterprise development allows us to form flexible and reliable strategies, gain confidence in management decisions and determine directions for action if events occur in one way or another.

Thus, to determine the strategic direction of enterprise development in the global environment, a system of indicators is formed. The factor system reflects the strategic priorities and structure of development processes, identifies the most important factors, and determines the structure of each factor and the relationship between indicators. Factors' assessment reveals the degree of influence of factors and their focus on the process of enterprise development. As a result of the research the set of factors determining the state of development processes is revealed, systematized and classified, and the technique of measurement of quantitative characteristics of influence of factors is developed. On this basis, the tools for forecasting the development of the enterprise based on modelling are formed. As a result, according to the forecast development scenarios, the following development strategies can be distinguished: gradual development; unsustainable development due to insufficient degree of adaptability; decline and crisis due to

loss of adaptability. The strategy of gradual development is most used among the studied companies.

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