“Selection of indicators for the scenario modeling of the progressive countries’ economic development”

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SELECTION OF INDICATORS FOR THE SCENARIO MODELING OF THE PROGRESSIVE COUNTRIES' ECONOMIC DEVELOPMENT

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Abstract

The study aims to improve methodical approach for formalizing the sustainable development models for progressive countries by suggesting the relevant representative indicators. The study is performed using the statistical approach to determine the suitability of data for further modeling using indicators of variation, taking into account the normality of the population distribution as the main criteria of the data set quality. The study highlights the results of processing measurable quantitative economic, social, and environmental indicators of different countries that may be used for identifying possible changes in the world's sustainable development. The authors select the indicators for scenario modeling of the sustainable development of Brazil, India, China, Republic of Korea, and the USA, as well as suggest a set of relevant affecting factors. To confirm the meaningful impact of different factors, such as biological balance, conflicts intensity, corruption perception and other, a neural network is developed, and its preliminary training on the test data is conducted. The obtained results can be used to predict economic changes in the world under the influence of specific economic, social, and environmental factors.

Keywords sustainability, economy, forecast, data set, factors, neural network

JEL Classification C45, C82, O10

INTRODUCTION

Modern economic and political transformations cause the need to predict possible significant changes, leading to lower quality and safety of life. One of the problems facing the modern world is the problem of ensuring the countries' sustainable development. The basis of the development of territorial units, besides the implementation of their resource potential and effective international partnerships, is a development strategy based on the principles of the sustainable development concept. To provide the strategic focus of the activities and public administration instruments, it is necessary to understand the desired vector of the development in an unstable global environment.

The desired vector of the development of a country is understood as a focus of activities that determine its competitive position in the global market. An important step for this vector's definition is to study the economic situation in a particular country and create scenarios for its socio-economic and environmental development in the near future. The economic development scenarios creation is an application task related to the usage of a significant data set. This should be taken into account when choosing scenario modeling tools since the forecast sufficiency depends on their type and quality.

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This study is a logical continuation of the authors' work on finding possible ways of modeling the countries' development in part of the choice of indicators of the economic component of their sustainable development.

The research aims to provide information support for scenario modeling of the economic development of the world's advanced countries based on the principles of the sustainable development concept. To achieve this aim, the following tasks have been solved: to generalize the scenario modeling methods; to justify the choice of key indicators for scenario modeling; to determine the factors influencing the change in the values of key indicators, taking into account their type; to summarize the possibility to use a neural network as the tool for processing the data for further modeling of the countries' development.

The contribution and the added value the study brings to the existing literature is as follows: the study contains the results of processing a significant amount of data from international databases regarding the possibility of their use to model the countries' development; this will help in substantiation of the relevant method of scenario modeling using neural networks, as the article specifies the data sets of countries (Brazil, India, China, South Korea, the USA) for all components of sustainable development, which are homogeneous and normally distributed.

The paper has a traditional structure and contains the literature review, methods, research results, discussion, including limitations of the study, and conclusion. In the results, the primary set of indicators for scenario modeling grouping them by different directions is presented, suggesting the main factors affecting the indicators of the countries' development and highlighting the graphic results of identifying the dependencies between indicators of the sustainable development using a neural network.

1. LITERATURE REVIEW

The fundamental concept, which determines the direction and limitations of this study, is the concept of sustainable development; therefore, it is appropriate to summarize the main idea of this concept, concretized in scientific works of Justice and Casadevall(2019), Klarin (2018), Renko (2018), R. Jovovic, Draskovic, Delibasic, and M. Jovovic (2017), Bienia, Dykiel, and Bragiel (2019), as well as in previous studies (Zgurovsky et al., 2018, 2019). In general, the concept is a continuation of the theory of "noosphere" formulated by Vernadskyi (1944), which was a necessary platform for the development of the concept of balanced environmental, social, and economic development. The idea of the sustainable development of society was generalized during the world summits of the United Nations in 1992 in Rio de Janeiro and Johannesburg in 2002. The new concept considers three main components of sustainable development of the society (economic, environmental, and social) and provides the resource-saving vision through balancing the relevant processes of production, consumption, and utilization. In general, sustainable development is "the development that meets the needs of the present without compromising the ability of future generations to meet their own needs" (General Assembly of the United Nations, 1987, p. 43).

The research of the scenario-based approach to the definition of options of the course of events, in particular the vectors of the economic development of the countries of the world, was highlighted in numerous works of Ukrainian (Shyian & Ulianchenko, 2017; Heiets, 2012) and foreign (Hiltunen, 2009; Amer, Daim, & Jetter, 2013; Borio, 2012; Zweck, Braun, & Rijkers-Defrasne, 2014; Ringland, 2013; Flynn, Ford, Pearce, & Harper, 2018; Altshuler, Holland, Hong, & Li, 2016) researchers.

According to Hiltunen (2009), "scenarios are valuable tools for futures thinking in organizations of many kinds" (p. 151). The scientist considered that scenarios, as many future techniques, have two purposes. Firstly, they help us be prepared for alternative futures, and they question our persistent beliefs about the future. The scientist considers that they give a range of possibilities for the future immediately. According to Hiltunen (2009),"sce-

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narios help us also to innovate the futures possible to us by helping to break our mental models and by that, at best, to encourage us to create something new" (p. 151). According to Heiets (2012), the existing contradictions in the correlation of the functioning of society, the state, and the economy are generalized. This study allows us to identify the directions of their interaction to ensure economic development.

Shyian and Ulianchenko (2017) analyze the mechanism of the economic cycle formation under the influence of economic agents' expectations. They consider that one of the main reasons for the termination of economic growth is the generation and accumulation of systemic risk in the economy due to unreasonable expectations. The proposed approaches to explaining the economic cycle mechanism can be applied to forecast it in some countries, such as the USA. Borio (2012) also studied the role of the financial cycle in macroeconomics. The comparative study of Zweck, Braun, and Rijkers-Defrasne (2014) presented an overview of the essential content and focus of major technology forecasts.

Ringland (2013) puts forward a framework for connecting foresight to strategic decisions in organizations. He proposes a four-stage strategy cycle process. The selecting priorities and implementation can go up to the policy- and decision-makers. The research of Zweck, Braun, and Rijkers-Defrasne (2014) for suitable technology forecasts was focused on North America, Europe, emerging countries, and future economic powers. The research included supranational activities in the context of the "European Forward Looking Activities" of the European Commission and the European Technology Platforms. Flynn, Ford, Pearce, and Harper (2018) identified and evaluated how participatory scenario planning approaches could be used to study climate change impacts, adaptation, and vulnerability.

The World Economic Forecasting Model developed by Altshuler, Holland, Hong, and Li (2016) allows the Development Policy and Analysis Division (DPAD, United Nations), producing consistent forecasts for the global economy. The model proposed by the authors can also be used to produce alternative scenarios around the central forecast. In the paper of Amer, Daim, and Jetter (2013), the differences between qualitative and quantitative scenario methods, their advantages and disadvantages have been analyzed. The authors were looking for an explanation of why quantitative scenario methods often lead to many so-called "raw" scenarios that need to be further refined, discussed, and verbally described. They examined solutions for the problem of validation addressed in scenario studies.

Zgurovsky (2002) analyzed the available scenario-based modeling methods and considered a systematic approach to the development of scenarios of future events in various spheres of human activity. Sukhorukov and Kharazishvili (2012) proposed a new approach to forming the methodological basis of system modeling, forecasting, and diagnostics of Ukrainian regions' socio-economic development, taking into account the shadow economy. According to individual macroeconomic indicators, the creation of the long-term scenarios for the economic growth of the countries of the world was carried out by the analysts of the Organization for Economic Cooperation and Development (OECD, 2012). Since 1981 it has been continuously carried out by the researchers of "Oxford Economics" based on commercial grounds for about 200 countries.

Janicke (2012), Loiseau, Saikku, Antikainen, Droste, Hansjurgens et al. (2016) studied the principles of sustainable development in the formation of the countries'economic development strategy. Fedulova (2016) substantiates the inextricable relationship between the innovative and economic development of countries on the example of Ukraine and the EU countries.

It should be noted that some scientists have already performed the research in the field of scenario modeling of economic development. Rudneva, Pchelintseva, and Gureva (2018) proposed a cognitive model for scenario modeling of the economy. This model offers five components for developing a model: economic, social, environmental, investment, and innovative. However, the limitation of this model is the level of use – regional.

Considering the exhaustibility of natural resources (including energy), the authors believe that this

factor is a prerequisite for the model. Scenario analysis of future energy trends (International Energy Agency, 2019) deeply highlights the issues of sustainable development of the world, particularly the forecast of energy consumption and other environmental indicators up to 2050 on a global scale. However, this approach does not allow modeling the countries' economic development taking into account the environmental component.

In the work "Approach to form the territorial system development strategy using simulation and scenario modelling tools" (Nizamutdinov & Oreshnikov, 2019), a conceptual scheme for implementing the simulation model is proposed. In general terms, the scheme provides the adaptation of the SAM methodology to formalize economic agents' expenses and incomes balance. This approach involves using econometric methods, fuzzy logic theory, and soft computing algorithms, which allows considering the influence of qualitative indicators. However, the authors' model does not provide the systematic approach, i.e., the influence of social, economic, and environmental factors on the country's development.

Four scenarios on different ways of striving for a sustainable future in the work of Svenfelta, Alfredsson, Bradley, Faure, Finnveden et al. (2019) show many potentially possible ways available to reach sustainability targets. Stakeholder reactions show a great interest in discussing possible futures without being restricted by a short-term focus on economic growth. However, the authors' approach does not consider the decline in the economic growth of the world economy. Therefore, these constraints must be taken into account in the newly developed model.

Researchers have formed a theoretical and methodological basis for creating scenario-based models for the economic processes and phenomena forecasting. However, the research problem of the world countries' sustainable development processes is the complexity of the well-founded project scenario modeling in the conditions of the need to process a significant amount of heterogeneous input data. Therefore, the development of the models has to be carried out involving additional data processing tools. This fact determines the feasibility of this research and the relevance of the topic.

This research is the continuation of the previous authors' scientific attempt to explain the possibility of using the neural networks for economic scenario modeling (Gavrysh, Zgurovsky, Kukharuk, & Skorobogatova, 2018).

The analysis of the results of the existing scientific articles in this area leads to the conclusion that there is no one general methodological approach to the countries'scenario modeling, including a triad of indicators: economic, environmental, and social. Thus, this study aims to consider such a triad and develop a relevant list of indicators for further scenario modeling of the countries' sustainable development using neural networks.

2. METHOD

The methodology for assessing the sustainable development processes contains interdisciplinary models known in natural, economic, and social sciences, and the methodology of applying formal statistical methods and expert assessment methods to analyze sustainable development processes.

The research information base consists of quantitative data of the non-profit organization the Educational and Scientific Complex "World Data Centre for Geoinformatics and Sustainable Development", the World Bank database, international analytical reports (OECD, 2012), research articles and monographs of Ukrainian and foreign scientists: Altshuler, Holland, Hong, and Li (2016), Amer, Daim and Jetter (2013), Flynn, Ford, Pearce, and Harper (2018), Hall and Allen (1997), Hiltunen (2009), Janicke (2012), Ringland (2013), Zweck, Braun, and Rijkers-Defrasne (2014).

The features of various methods of scenario modeling are considered in the research works of Bidyuk and Zagorskaya (2012), Morgunov (2011), Zgurovsky (2002), and others. The results of the processing of these works are presented in Table 1, which contains a summary of the principles and features of the application of various methods of scenario modeling.

Analysis of the available scenario modeling methods showed that the most acceptable in the research is the Bayesian model method, which ena-

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Table 1. The main methods and types of scenario modeling

Source: Bidyuk and Zagorskaya (2012), Morgunov (2011), Zgurovsky (2002).

No.	Name	Principle of method	Reference
1	The visual scenario	It helps to describe the ideal or most desirable perspective	Bidyuk and Zagorskaya (2012)
2	The project scenario	It visualizes expectations proceeding from the current situation	
3	The route scenario	It compares the current and future situation to develop change strategies	
4	The alternative scenarios	They demonstrate a set of possible future changes to limit uncertainties that are difficult or impossible to predict	
5	Delphi method(Delphos)	It is necessary to obtain the conclusions of the expert group on the future "behavior" of one or several interrelated system characteristics, which aroused interest. The obtained results are used to create possible scenarios for the "behavior" of the system under research	Zgurovsky (2002)
6	The cross-impact method	It is based on using expert conclusions on the events that could characterize the future at a certain period. For example, if it is necessary to envisage the development of the telecommunications industry, it is necessary to determine which important future events will fully reflect the development scenarios of this sector	
7	The Saaty method	The method is based on the condition of "focusing" or "convergence" to something common with respect to the conclusions of experts and the actions of numerous performers of a complex process, which is being forecasted. That is, in this case, the method is based on the "causal" perspective of the processes, and that is the basis for the development of the future scenarios	
8	The method of the scenario writing	The presented empirical method of writing scenarios is based on two categories. The first category is related to the probabilistic nature of the scenarios under development; the second is based on experts' conclusions of a quality nature. Therefore, conceptual thinking, empirical presumptions, and expert conclusions are basic aspects of scenario writing	
9	The Bayes models method	The principle of this method is to determine in the group of scenarios how realistic each of them is, that is, the method can be viewed as a tool to support decision-making, which will enable to really and accurately guide the technological foresight researchers on possible future scenarios	
10	The foresight method	The foresight process assesses possible scenarios of the development of individual areas of science and technology, identifies potential technological horizons, but it is not a "forecast" in the sense of guessing the future. Foresight comes out of options for a possible future that may occur when certain conditions are met	Morgunov (2011)

bles us to determine the probability of occurrence of the most realistic scenarios for the countries of the world and minimize the use of subjective expert assessments.

The study approach takes into account the fundamentals of economic system modeling and the features of forecasting the economic processes in a particular country, for instance, using a set of indicators by such sectors as households, firms, government, and foreign sector (Altshuler, Holland, Hong, &Li, 2016). In its content, the subject of this research is wider as it includes the economic processes of a country and its sustainable development as a whole. However, the scientific statements of Altshuler, Holland, Hong, and Li (2016) and Hall and Allen (1997) allow us to figure out the features of identifying and formalization the interrelations of different economic indicators.

The main findings of an article of Amer, Daim, and Jetter (2013), namely the comparison of quantitative and qualitative methods of the scenario planning, were considered when choosing the rates for further modeling, meeting the requirements for the data set, the sample and the interpretation of the obtained relations. That helps to enhance the probability of high accuracy of our future model. The results of the studies of Flynn, Ford, Pearce, and Harper (2018) and Hiltunen (2009) were also considered in part of understanding the features of working on the forecast and the structure of the scenario planning process.

The approach of the article of Janicke (2012) was taken into account in part of considering the ability of the developed countries to create eco-innovations for sustainability faster despite the low growth rates. This statement became the basis for choosing the data for the environmental part of the future scenario.

The results of studies of Ringland (2013) and Zweck, Braun, and Rijkers-Defrasne (2014) are important for understanding as the scientists attempt to analyze the historical development of the foresight technology implementation in the scenario modeling practice and figure out the topical fields of forecasting, which were most discussed by scientists.

The research was carried out using general scientific methods (generalization, scientific abstraction, concretization, systematization, comparison) when analyzing the available methods of scenario modeling, determining the key indicators of the world economy's development and factors affecting their change; special methods (statistical analysis methods, in particular, variations analysis) for the formation of the final set of appropriate sample indicators for modeling.

To determine the feasibility of scenario modelling by all indicators, the analysis of homogeneity of the sets of indicators across countries was carried out. For this purpose, the quadratic coefficient of variation is used, which is calculated as the ratio of the root-mean-square standard deviation and the mean value in the aggregate/cumulatively. To be able to use parametric methods, it is also important to make sure that the population is normally distributed. There are many criteria by which one can determine whether a data set belongs to a normal distribution. One of them is a two-way David-Hartley-Pearson test (David, Hartley, & Pearson, 1954), which, according to Dolgov (2017), is relatively easy to use and powerful enough. The statistical coefficients help to check the quantitative property of the data sets and the reasonability to apply the relevant forecasting methods from Table 1.

3. RESULTS

For a systematic approach to creating a scenario for the development of a country's economy, it is proposed to use indicators of an integrated nature in such areas of countries' functioning as finance, energy, macroeconomic situation, GDP structure. When choosing indicators for the development of the model, the authors proceeded from the provisions of the concept of sustainable development – the balance between the economic, environmental, and social development of the country. Therefore, several mentioned aggregated directions were chosen, including indicators characterizing the country's economy, environment, and social development.

For each direction, initial sets of statistical indicators are formed for the following countries: the USA, China, India, Brazil, South Korea. The indicators' collected values are estimated using the methods of mathematical statistics (in particular, the method of analysis of variations) on the possibility of their prediction. Table 2 describes a primary set of indicators for further making a scenario.

The calculation of the coefficient (V_σ) by the dynamic series of development indicators of the countries of the world, as well as the secondary processing of the data set according to the indicators of the sample countries, enabled identify indicators that should be removed from the analysis due to the high level of variation, inconsistent average values or lack of available data (Table 3). Thus, the authors consider three main criteria for selection:

- the population/sample has to be:

1) homogeneous (by coefficient V_σ);
2) normally distributed (David-Hartley-Pearson test);
3) complete (all data for the relevant period must be available);

- the list of indicators has to include three aspects of sustainable development: economic, social, and environmental.

Forecasting of the indicators from Table 3 is performed, taking into account the factors affecting the change of their values. Such factors are measured and expressed by the indicators of the functioning of the countries of the world according to different components of sustainable development (social, economic, environmental). The factors are selected based on the availability of data from the World Bank database, as well as guided by the basic principles of factor analysis. The sets of factors of a sample of indicators are based on the data of Table 3 (Table 4).

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Table 2. The primary set of indicators for scenario modeling of the countries' sustainable development

Source: World Bank (n.d.), Gavrysh, Zgurovsky, Kukharuk, and Skorobogatova (2018).

Direction	Indicator	Brief description
Finance	Interest rate spread	The interest rate set by banks for loans to private sector clients. The factors that determine the size of interest rates are different for each country, but the principle of comparability has been complied with to calculate this indicator
	Bank capital to assets ratio	The ratio of bank capital and bank reserves to total assets. Capital and reserves include the funds contributed by owners, retained earnings, general and special reserves, reserves, and adjustments to the cost of bank capital
	Stocks traded, the total value	The total number of shares valued, both domestic and foreign, multiplied by the corresponding prices
	Official exchange rate	The exchange rate set by the national authorities, or the rate set in the foreign exchange market, which is fixed by law
Energy	Energy use	This indicator means the use of primary energy before turning it into other types of final fuel consumption equals the of local production plus imports and changes in stocks, net of exports and fuels supplied to ships and planes used as international transport
	Alternative and nuclear energy	Includes hydro and nuclear, geothermal, and solar energy, among others
	Renewable energy consumption	The share of energy from renewable energy sources in the total final energy consumption
Macroeconomic situation	GDP	The added value created by all the manufacturers in the economy
	GDP per capita	The sum of the gross value added of all resident producers in the economy included taxes, minus any subsidies not included in the cost of production, excluding depreciation
	Exports of goods and services and Imports of goods and services	Dynamic analysis of these indicators will take into account the degree of dependence of a country from the world economy (integration of national production into the world economy)
	Foreign direct investment	Dynamic analysis of this indicator allows predicting the investment attractiveness of a particular country which is important for three components of the sustainable development improvement
	Inflation	Analysis of the indicator in dynamics will determine the degree of stability of the country's macroeconomic situation and the ability of state government to manage the country effectively
Structure of GDP	Industry, value added	Includes the added value in the mining industry, construction, generation of electricity, water, and gas
	Agriculture, value added	Includes forestry, hunting, and fishing, as well as growing crops and livestock products
	Services, etc., value added	Includes the added value of wholesale and retail trade (including hotels and restaurants), transport and government, financial, professional and personal services such as education, health care, and real estate services

Table 3. List of indicators for forecasting the countries' economic development

Source: World Bank, World Data Center.

No.	Thenameofthemetric	Availability of an indicator in the sample by country*				
		Brazil	India	China	Korea	USA
1	Energy use	+	+	+	+	+
2	Alternative and nuclear energy	+	+	–	+	+
3	Renewable energy consumption	+	+	+	–	+
4	GDP	+	+	+	+	+
5	GDP per capita (constant 2010 USD)	+	+	+	+	+
6	Exports of goods and services	+	–	+	+	+
7	Imports of goods and services	+	–	+	+	+
8	Foreign direct investment, net	+	+	+	+	+
9	Inflation, consumer prices	+	+	+	+	+
10	Industry, value added	+	+	+	+	+
11	Agriculture, value added	+	+	–	–	+
12	Services, etc., value added	+	+	+	+	+
13	Official exchange rate	+	+	+	+	+
14	Stocks traded, total value	+	+	+	+	+
15	Interest rate spread	+	–	+	+	–
16	Bank capital to assets ratio	+	+	+	+	+

Note: We use a symbol "+" to mark the indicators which are available and full for the analyzed period; we use a symbol "–" to mark the indicators which are unavailable and/or are not full for the analyzed period.

Table 4. Main factors affecting the indicators of the countries' development

Source: World Bank, World Data Center for Geoinformatics and Sustainable Development.

No.	Nameofthefactor	Component ofdevelopment		
		Economic	Environmental	Social
1	Biologicalbalance	–	+	
2	Conflicts intensity	–	–	+
3	Corruption perception	+	–	
4	Charges for the use of intellectual property, payments	+	–	–
5	Domestic credit to the private sector	+	–	–
6	Depth of the food deficit	–	–	+
7	Military expenditure	+	–	–
8	Total inventory of nuclear weapons	+	–	–
9	The producing of missiles	+	–	–
10	Uranium production	+	–	–
11	Arms exports (SIPRI trend indicator values)	+	–	–
12	Arms imports (SIPRI trend indicator values)	+	–	–
13	External debt stocks, total	+	–	–
14	Environmental Performance Index	–	+	–
15	Employment to population ratio, 15+, total	–	–	+
16	Natural gas reserve	+	–	–
17	Coal reserve	+	–	–
18	Geothermal, biomass and other energy use	+	–	–
19	Hydro energy use	+	–	–
20	Nuclear reserve	+	–	–
21	Oil reserve	+	–	–
22	Solar energy use	+	–	–
23	Wind energy use	+	–	–
24	Freedom of speech	–	–	+
25	Global Cybersecurity Index	–	–	+
26	GDP perpersonemployed	+	–	–
27	CO2 emissions	–	+	–
28	Health expenditure	–	–	+
29	High-technology exports	+	–	–
30	Household final consumption expenditure	+	–	–
31	ICT Development Index	+	–	
32	Internet users	–	–	+
33	Life expectancy	–	–	+
34	Market capitalization of listed companies	+	–	–
35	Number of airports	+	–	–
36	Navigable waterways	+	–	–
37	Patent applications	+	–	–
38	Paved highways	+	–	–
39	Portfolio investment, net	+	–	–
40	Access to potable water	–	+	–
41	Rail lines	+	–	–
42	Gross national income(GNI), Atlas method	+	–	–
43	School enrollment, tertiary	–	–	+
44	Public spending on education	–	–	+
45	Research and development expenditure	+	–	–
46	Researchers in R&D	+	–	–
47	Technical cooperation grants	+	–	–
48	Gini coefficient		–	+
49	State fragility	+	–	–

To make any further forecasts regarding the changes in the values of indicators mentioned above, the scenario modeling is proposed to be performed using a neural network that should undergo preliminary training using test data of a similar nature. The general structure of the neural network is shown in Figure 1.

Figure 1 shows the results of identifying the dependencies between indicators of sustainable develop-

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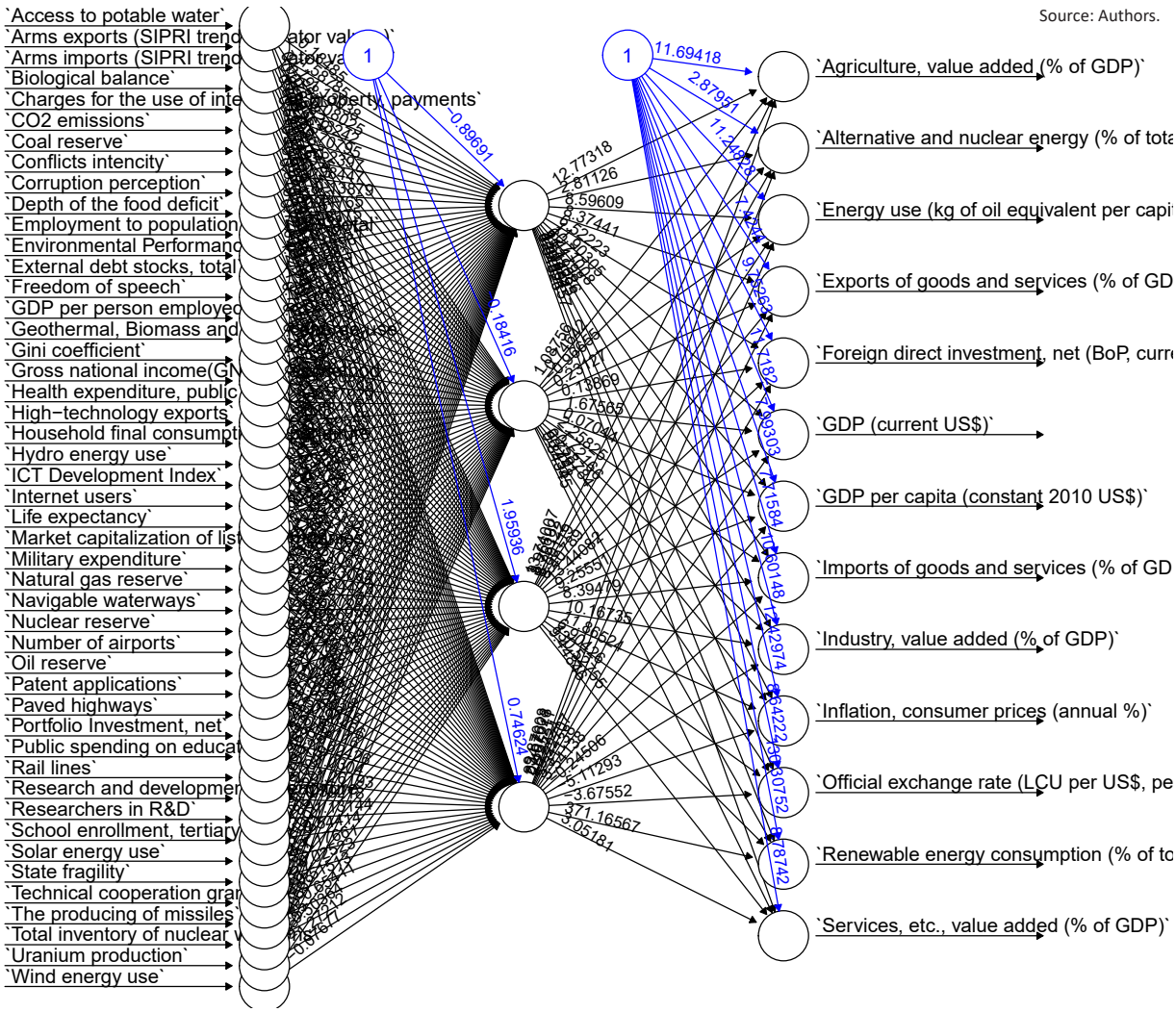

Figure 1. Diagram of an obtained neural network

ment. The figure shows a relationship between the indicators, and they can participate in the factor analysis of sustainable development. Further network training will provide more detailed results. The input layer of Figure 1 is the value of 4 groups of indicators of a country's development, presented in Table 4. The hidden interlayer is the calculation procedure (identifying dependencies and developing the forecasting models). The output layer is a scenario of the development of a country completed using the proposed model.

4. DISCUSSION

The problem of the scenario modeling is a widespread one, and, accordingly, the solution of its main issues can be considered from different angles. This study is a generalization of the quantitative measurement of the development of the world's countries, adjusted for the quality of the data sets provided by international organizations, such as the United Nations and World Bank. Unlike the existing ones, the author's approach is based on the principles of sustainable development and includes quantitative indicators characterizing the economic, social, and environmental vectors of the country's development. Given the lack of similar research results in the available literature, it may be assumed that relatively new results were obtained to continue previous studies (ICSU, 2018) on analyzing the level of sustainable development of the world.

This makes the forecast more accurate and possible for developing a scenario for any country's development and carrying out a comparative analysis of the development of national economies.

Besides, it is necessary to take into account that the analysis is based only on quantitative indicators. The analysis of the available methods of scenario modeling showed that the most acceptable in the research is the Bayesian model method, which enables us to determine the probability of occurrence of the most realistic scenarios for the countries of the world, as well as to minimize the use of subjective expert assessments.

The obtained results are the subject for the additional scientific substantiation. Besides, it is necessary to take into account that the analysis is based only on quantitative indicators. The most justified scenario is the one that stipulates accounting for a greater number of factors that impacted the calculated macroeconomic indicators. Therefore, when selecting the sources of information for scenarios creation, it is important to consider the data completeness, accuracy, access to the source, and the ability to verify the values presented. At the same time, there are obstacles in the process of development of adequate scenario-based models, namely heterogeneity of the set of indicators based on which the forecasting should be carried out; the absence of data values of a specific indicator for a particular year; the need to develop a forecast for more than three years with a low level of the information content of average values; nonlinear dependencies between the factor and performance indicators; significant arrays of quantitative data must be processed for a limited period.

The obtained neural network shown in Figure 1 helps to reduce the number of such problems. At the time of completion of the collection of indicators-factors using the research software, the specialists of the Educational and Scientific Complex "World Data Centre for Geoinformatics and Sustainable Development" began the training of the neural network using the test data.

CONCLUSION

Given the above, one can conclude that the scenario modeling of the world's development can be carried out using the data of appropriate relevance and quality. Having processed a significant array of data from around the world, based on a statistical approach and using a neural network, the authors concluded that it is now possible to make a qualitative forecast of the development of Brazil, India, China, Republic of Korea, and the USA, predicting changes of the following indicators: energy use, alternative and nuclear energy, renewable energy consumption, GDP per capita, exports of goods and services, imports of goods and services, industry (value added), agriculture (value added), services (value added), official exchange rate.

The empirical results reported herein should be considered in light of some limitations: those that result from the methodology and those that result from issues with the researchers. The list of countries is limited to countries with progressive economies characterized by similar growth rates of key economic indicators. The approach should not be applied to those countries of the world that have quite different features of development, significant historical and cultural differences, and different priorities of public administration, as additional hypotheses need to be put forward to compare such countries. The study is also limited to the data available to researchers in free databases since the study involves using neural networks, which requires additional training and testing. The obtained results are as relevant as the neural network has been trained for a limited time before the publication of the general study's intermediate results.

A promising direction for further research is the training of the neural network, which will allow us to minimize the level of the developed forecast's subjectivity and obtain objective estimates of the level of sustainable development of the world for the period up to 2025.

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REFERENCES

1. Altshuler, C., Holland, D., Hong, P., & Li, H. (2016). *The World Economic Forecasting Model at the United Nations.* Department of Economic and Social Affairs. Retrieved from https://www.un.org/development/desa/dpad/wp-content/uploads/sites/45/publication/2016_Apr_WorldEconomicForecastingModel.pdf
2. Amer, M., Daim, T., & Jetter, A. (2013). A review of scenario planning. *Futures, 46,* 23-40.https://doi.org/10.1016/j.futures.2012.10.003
3. Bidyuk, P. I., & Zagorskaya, O. I. (2012). Metodyka pobudovy stsenarnoho analizu iz vykorystanniam Baiesivskykh metodiv [Method of scenario analysis construction using Bayes analysis]. *Elektrotekhnichni ta kompiuterni systemy – Electrical and computer systems,8,* 137-142. (In Ukrainian). Retrieved from http://nbuv.gov.ua/UJRN/etks_2012_8_24
4. Bienia, B., Dykiel, M., & Bragiel, E. (2019). Sustainable development – concept, definitions. *Yevropeiskyi vektor ekonomichnoho rozvytku – European vector of economic development, 2*(27), 17-25. Retrieved from https://eurodev.duan.edu.ua/images/PDF/2019/2/4.pdf
5. Borio, C. (2012). *The Financial Cycle and Macroeconomics: What We Learnt?* (BIS Working Papers No. 395). Retrieved from http://www.bis.org/publ/work395.pdf
6. David, H., Hartley, H., & Pearson, E. (1954). The distribution of the ratio, in a single normal sample, of range to standard deviation. *Biometrika, 41*(3-4), 482-493. http://dx.doi.org/10.2307/2332728
7. Dolgov, V. (2017). K otsenke odnorodnosti kolichestvennoy statisticheskoy sovokupnosti i informativnosti yeye srednego znacheniya [To the assessment of homogeneity of quantitative statistical totality and informativity of its average value]. *Teoriya i metodika professionalnogo obrazovaniya –Theory and methodology of vocational education, 2,* 31-36. (In Russian). Retrieved from https://cyberleninka.ru/article/n/k-otsenke-odnorodnosti-kolichestvennoy-statisticheskoy-sovokupnosti-i-informativnosti-eyo-srednego-znacheniya/viewer
8. Fedulova, L. (2016). Innovativeness of the economies of the EU and Ukraine: undertakings to narrow the gap. *Economic Annals-XXI, 156*(1-2), 22-25. (In Ukrainian). http://dx.doi.org/10.21003/ea.V156-0005
9. Flynn, M., Ford, J., Pearce, T., & Harper, Sh. (2018). Participatory scenario planning and climate change impacts, adaptation and vulnerability research in the Arctic. *Environmental Science and Policy, 79,* 45-53. http://dx.doi.org/10.1016/j.envsci.2017.10.012
10. Gavrysh, O., Zgurovsky, O., Kukharuk, A., & Skorobogatova, N. (2018). Methodical support for modelling countries' economic development. *Efektyvna ekonomika – Efficient economy, 4,* 1-5. (In Ukrainian). Retrieved from http://ojs.dsau.dp.ua/index.php/efektyvna-ekonomika/article/view/1152
11. General Assembly of the United Nations. (1987). *Report of the world commission on environment and development: Our common future* (300 p.). Oslo, Norway: General Assembly of the United Nations, Development and International. Retrieved from https://sustainabledevelopment.un.org/content/documents/5987our-common-future.pdf
12. Hall, S. G., & Allen, C. (1997). *Macroeconomic modelling in a changing world: towards a common approach.* Chichester: John Wiley & Sons.
13. Heiets, V. M. (2012). On the unity and contradictions in the development of society, state, and economy. *Ekonomika Ukrainy – Economy of Ukraine, 10,* 4-22. (In Russian). Retrieved from http://nbuv.gov.ua/UJRN/ekukrr_2012_10_2
14. Hiltunen, E. (2009). Scenarios: process and outcome. *Journal of Futures Studies, 13*(3), 151-152. Retrieved from https://jfsdigital.org/wp-content/uploads/2014/01/133-S13.pdf
15. International Council for Science (ICSU). (2016). *Sustainable Development Analysis: Global and Regional Contexts: Part1. Global analysis of quality and security of life* (328 p.). Scientific Supervisor M. Zgurovsky, Kyiv: NTUU "Igor Sikorsky Kyiv Polytechnic Institute". Retrieved from http://wdc.org.ua/sites/default/files/SD2017-P1-FULL-EN.pdf
16. International Council for Science (ICSU). (2018). *Foresight 2018: systemic world conflicts and global forecast for XXI century* (226 p.).

Scientific Supervisor M. Zgurovsky, Kyiv: NTUU "Igor Sikorsky Kyiv Polytechnic Institute". Retrieved from http://wdc.org.ua/sites/default/files/WDC-IASA-FORESIGHT-2018-EN.pdf

17. International Energy Agency. (2019). *World energy model documentation*. Retrieved from https://iea.blob.core.windows.net/assets/d496ff6a-d4ca-4f6a-9471-220adddf0efd/WEM_Documentation_WEO2019.pdf

18. Janicke, M. (2012). "Green growth": From a growing eco-industry to economic sustainability. *Energy Policy, 48,* 13-21. https://doi.org/10.1016/j.enpol.2012.04.045

19. Jovovic, R., Draskovic, M., Delibasic, M., & Jovovic, M. (2017). The concept of sustainable regional development – institutional aspects, policies and prospects. *Journal of International Studies, 10*(1), 255-266. https://doi.org/10.14254/2071-8330.2017/10-1/18

20. Justice, M., & Casadevall, S. R. (2019). Sustainable development: Meaning, history, principles, pillars, and implications for human action: Literature review. *Cogent Social Sciences, 5,*1-21. https://doi.org/10.1080/23311886.2019.1653531

21. Klarin, T. (2018). The Concept of Sustainable Development: From its Beginning to the Contemporary Issues. *Zagreb International Review of Economics & Business, 21*(1), 67-94. https://doi.org/10.2478/zireb-2018-0005

22. Kononiuk, A. Yu. (2008). *Neironni merezhi i henetychni alhorytmy [Neural networks and genetic algorithms]* (446 p.). Kyiv: "Kornychuk". (In Ukrainian). Retrieved from http://ep3.nuwm.edu.ua/2252/1/Kononiuk%20NMIGA%20zah.pdf

23. Kukharuk, A. D., Skorobogatova, N. Ye., & Pyshnohraiev, I. O. (2017). Identifying the relationships between the level of countries' economic development and innovation activity. *Marketynh i menedzhment innovatsii – Marketing and management of innovations, 4,* 301-314. (In Ukrainian). http://doi.org/10.21272/mmi.2017.4-27

24. Loiseau, E., Saikku, L., Antikainen, R., Droste, N., Hansjurgens, B., Pitkanen, K., Leskinen, P., Kuikman, P., & Thomsen, M. (2016). Green economy and related concepts: An overview. *Journal of Cleaner Production, 139,* 361-371. https://doi.org/10.1016/j.jclepro.2016.08.024

25. Morgunov, E. V. (2011). Foresight method and its role in managing the technological development of the country. In *Problemy razvitiya rynochnoy ekonomiki [Problems of development of market economy]* (pp. 97-113). Moscow: CEMI RAS. (In Russian)

26. Nizamutdinov, M. M., & Oreshnikov, V. V. (2019). Approach to form the territorial system development strategy using simulation and scenario modelling tools. *Russian Journal of Industrial Economics, 2*(4), 426-442. (In Russian). http://doi.org/10.17073/2072-1633-2019-4-426-442

27. OECD. (2012). *OECD Economic Outlook, volume 2012/1*. OECD Publishing. http://dx.doi.org/10.1787/eco_outlook-v2012-1-en

28. Oxford Economics. (n.d.). Official web-site. Retrieved from http://www.oxfordeconomics.com

29. Renko, S. (2018). The Concept of Sustainable Development. In E. Rudawska (Ed.), *The Sustainable Marketing Concept in European SMEs* (pp. 29-52). Emerald Publishing Limited. http://doi.org/10.1108/978-1-78754-038-520180003

30. Ringland, D. (2013). Budushcheye kak neizvedannoye prostranstvo: integratsiya Forsaita v prinyatiye strategicheskikh resheniy [The future as an unknown space: integration of Foresight in strategic decision-making]. *Forsait – Foresight, 7*(4), 60-69. (In Russian). Retrieved from https://foresight-journal.hse.ru/data/2013/12/26/1341509231/2013-4-5-Ringland-60-69.pdf

31. Rudneva, L., Pchelintseva, I., & Gureva, M. (2018). Scenario Modelling of the "Green" Economy in an Economic Space. *Resources, 7*(2), 29.https://doi.org/10.3390/resources7020029

32. Shyian, D., & Ulianchenko, N. (2017). The role of economic agents' expectation in the formation of economic cycle: on the example of USA. *Economic Annals-XXI, 165*(5-6), 8-12.https://doi.org/10.21003/ea.V165-02

33. Sukhorukov, A. I., & Kharazishvili, Yu. M. (2012).*Modeliuvannia ta prohnozuvannia sotsialno-ekonomichnoho rozvytku rehioniv Ukrainy: monohrafiia [Modelling and forecasting of socio-economic development of regions of Ukraine: monograph]* (368 p.). Kyiv: NISS. (In Ukrainian). Retrieved from https://niss.gov.ua/sites/default/files/2012-12/rozvyt_reg-77b7d.pdf

34. Svenfelta, A., Alfredsson, E.A., Bradley, K., Faure, E., Finnveden, G., Fuehrer, P., Gunnarsson-Östling, U., Isaksson, K., Malmaeus, M., Malmqvist, T., Skanberg, K., Stigson, P., Aretun, A., Buhr, K., Hagbert, P., & Öhlund, E. (2019). Scenarios for sustainable futures beyond GDP growth 2050. *Futures, 111,* 1-14. https://doi.org/10.1016/j.futures.2019.05.001

35. Vernadskyi, V. (1944). A few words about the noosphere. *Uspekhi sovremennoy biologii – Successes of modern biology, 18*(2), 113-120. (In Russian). Retrieved from http://filosof.historic.ru/books/item/f00/s00/z0000885/st000.shtml

36. World Bank. (n.d.). *World Development Indicators*. Official web-site. Retrieved from http://databank.worldbank.org/data/reports.aspx?source=world-development-indicators

37. World Data Center. (n.d.). World Data Center for Geoinformatics and Sustainable Development – official web-site. Retrieved from http://wdc.org.ua/

38. Zgurovsky, M. Z. (2002). Stsenarnyi analiz yak systemna metodolohia peredbachennia [Scenario analysis as system methodology of prevision]. *Systemni doslidzhennia ta informatsiini tekhnolohii–System research and information technology, 1,* 7-38. (In Ukrainian). Retrieved from http://dspace.nbuv.gov.ua/handle/123456789/50211

39. Zweck, A., Braun, A., & Rijkers-Defrasne, S. (2014). International Foresight of the 2000s: Comparative Analysis. *Foresight-Russia, 8*(2), 6-15. Retrieved from https://foresight-journal.hse.ru/data/2014/07/10/1311934215/1-Braun.pdf

http://dx.doi.org/10.21511/ppm.18(2).2020.36