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Sustainable Development of Enterprises in Conditions of Smart Ecology: Analysis of The Main Problems and Development of Ways to Solve Them, Based on Artificial Intelligence Methods and Innovative Technologies

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Relevance: Currently, the sustainability and profitability of any company is directly related to its interaction with the environment. In the 20th century it was believed that stable development is impossible, if the company focuses its production on the preservation and protection of the environment. Since the second half of the 20th century, ideas have been increasingly heard that sustainable economic development cannot be achieved at the expense of the predatory depletion of natural resources. The environmental agenda plays an important role in the ESG principles, largely formulated by UN Secretary-General Kofi Annan, reflected in Sustainable Development Goals 12–15, reflected in Resolution 70/1 - Transforming our world: the 2030 Agenda for Sustainable Development. Companies such as Tesla Motors, called “green giants”, have proven by their experience and development dynamics that in today’s environment a business that does not have a negative impact on the environment can be profitable and successful. Thus, modern trends in the development of the world economy determine the relevance of the present study, aimed at studying the new conditions of economic activity by enterprises - the conditions of smart ecology and development of recommendations for the effective transformation of enterprises under these conditions. The purpose of this study is to analyze and identify the main problems of sustainable development of enterprises in terms of preservation and protection of the environment - “smart ecology”, and based on the formulated problems the authors have developed ways to overcome them. The subject of the study are managerial and other relationships arising during the implementation of innovative Smart projects by enterprises.

Methods: In the process of analyzing the problems and developing ways to overcome them and the transition of enterprises to the conditions of smart ecology, the authors used

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methods of system analysis, methods of statistical analysis, methods of artificial intelligence.

Results: The conducted analysis shows that in modern conditions of development of innovative technologies in Russia there is no unified approach to the process of effective management of breakthrough development projects. The analysis proposed the concept of SMART ecology and showed its importance for understanding the processes taking place in the modern world. Factors influencing the effectiveness of the implementation of innovative smart ecology projects have been identified. Methods that can be used during the implementation of these projects were proposed.

Keywords: sustainable development, smart ecology, expert systems, sustainable development issues, artificial intelligence

INTRODUCTION

The relationship between the sustainable development of enterprises and environmental conditions first began to be actively mentioned in the 70–80s of the 20th century, when the problem of resource exhaustion became significant. It was during this period that the UN developed the global concept of sustainable development without harming future generations, which is reflected in the Sustainable Development Goals contained in Resolution 70/1—Transforming our world: the 2030 Agenda for Sustainable Development (Vinuesa, et al., 2020). The concept of sustainable development has become the basis for a profound rethinking of the strategic and tactical behavior of both individual corporations and nations. An important part of the new strategic behavior is concern for the environment, which has now become an integral part of any company's vision of strategic development.

Previously, it was believed that sustainable development of a company was impossible in the context of preserving non-renewable resources and reducing the negative impact on the environment, because such activities are associated with huge investments of capital. Nowadays such companies as Tesla, Chipotle, Ikea, Unilever and others have proved by their own example that economic activities based not on cost minimization but on social benefit are more profitable than those of traditional companies.

Conditions of smart ecology define transition of the enterprises to new conditions of conducting economic activity in which sustainability is defined not by economy of financial resources, but by ways of their reception (Rogachev, 2021a). The distinctive feature of the companies working in the conditions of smart ecology is that the social good, on a par with sustainability, is the main factor of profit.

Sustainable development of enterprises in a smart ecology is possible if they follow the following principles:

1) Since the sustainability of enterprise development is primarily determined by its policy and strategy, special requirements are imposed on the head of the company. It is the head of the company who should direct the company's work to the conditions of smart ecology, he should promote the concepts of "green economy" and monitor the timely changes in the company, corresponding to changes in the environment.
2) One of the most important factors in ensuring the sustainable development of the enterprise should also be breakthrough innovations, i.e., new developments of the company, corresponding to the conditions of the smart ecology. The peculiarity of such innovations is that they cannot include products and technologies that were used for traditional economic activities and have been upgraded for the conditions of smart ecology.
3) The goals of the enterprise should be reoriented, traditionally the main goal of any economic activity is to make a profit, in the conditions of smart ecology the main goals of the enterprise along with profit should be the introduction of environmentally safe technologies, increasing the welfare of society, reducing the burden on the ecosystem, the preservation of the environment for future generations.
4) The concept of sustainability is a characteristic of the company, not a goal to which it aspires. The smart ecology condition changes the very concept of sustainability, which includes an equitable and economical use of resources, a switch to renewable raw materials and strict compliance with environmental rules and regulations.
5) Accordingly, all of the above-mentioned principles define the requirements for the behavior of employees of the company and the organization as a whole. All employees must be responsible not only to their job duties, but also to the principles determined by the conditions of smart ecology, the company's activities and its results must be transparent to the owners, investors and customers. All activities must be conducted on the basis of mutual cooperation.

All of the above principles are defined by the conditions of smart ecology, formed and developing together with the processes of digital transformation of the economy. The main conditions for classifying enterprises as smart ecology are as follows (AI for Sustainable Development Goals, 2022):

- The activities of enterprises should contribute to the welfare of society.

- The use of resources must be conservative, the share of recycled raw materials must be significantly higher than the share of non-renewable raw materials.
- Enterprises must use the latest saving technologies and technologies that reduce harmful emissions and waste.
- There should be a division of responsibility for environmental pollution between all enterprises and organizations involved in the life cycle of the product.
- Investments of enterprises in the protection of ecosystems and biodiversity, in the preservation, restoration and support of the environment must be constant and continuous in nature.

Thus, based on the principles and conditions of smart ecology, the authors formulated the following definition:

Smart ecology is a branch of science about such interaction of living organisms among themselves and with the environment, which does not have a negative destructive impact on the state of nature, does not deplete natural resources and supports biodiversity, achieved through the widespread use of conservation technologies, modern advances in the IT-sphere and scientific and technological progress.

The development of the smart ecology reflects a fundamental shift from an export-raw business model to a digital one, which requires a redefinition of sustainable enterprise development.

Traditionally, the sustainable development of an enterprise was defined as a positive change in its financial and economic indicators over a long period of time. The authors modernized this concept taking into account the conditions of digital transformation and the development of smart ecology - under the sustainable development of the enterprise the authors understand such an economic activity, which is able not to affect the natural assets, preserve resources and reduce the negative impact on the environment together with the achievement of strategic and operational goals and profit, part of which is necessarily sent to protect the ecosystem and improve the level and quality of life.

Despite the active development of digital transformation processes not only in the economy, but also in all processes of human activity, enterprises pass it and adapt to the conditions of smart ecology at a slow pace. This situation is associated with a number of problems that hinder the pace of digital transformation of companies, corresponding to the conditions of the smart ecology.

As can be seen from **Figure 1**, the authors refer to the main problems:

1) Complexity. Any "smart" technology requires the appropriate software to manage and control it. The problem is that with a significant number of breakthrough technologies, an enterprise is faced with the need to use multiple types of software, which causes the complexity of monitoring and switching between them.
2) Safety. "Smart" technologies are based on the concept of IoT (Internet of Things), which is the ability of "smart" things to interact with each other, excluding humans as an object that controls them by transmitting information. Since all interaction is based on the transmission of certain data, there is a problem of leakage of this data, i.e. the problem of information safety.
3) Increase in production costs. This problem is caused by the high cost of smart technologies and smart equipment, which is necessary for sustainable development, also the constant introduction of breakthrough innovations, requires significant investment in research and bringing them to the stage of implementation. Since one of the factors of sustainable development of the enterprise in a smart ecology is the orientation of the enterprise to preserve the environment and increase the welfare of the population, this leads to high tax deductions, as it is taxes that are the main tool of the income redistribution system, through taxes the funds for environmental protection and funds allocated for social purposes are collected.
4) Increase in the unemployment. Another problem of the functioning of enterprises in a smart ecology is the loss by employees of their jobs. This is primarily due to the fact that the introduction of "smart" technology contributes to the automation of labor and frees up labor resources. Also, due to the fact that some jobs do not meet the conditions of the smart ecology, it is expected that there will be a tendency to reduce them.
5) Employee adaptation. Another important problem is the inability of employees to perceive and use the latest technology. Employees who are used to traditional technologies and do not have the skills necessary to work in a changing environment, do not support the introduction of innovative technologies, and thus hold back the pace of digital transformation.
6) Cultural changes. The conditions of smart ecology do not act selectively, they apply to all spheres of human life and activity, so in addition to the digital transformation of enterprises, cultural transformation of people is necessary (United Nations, 2022).

Based on the peculiarities of the functioning of enterprises in the conditions of smart ecology, the authors have developed the following approaches and options for solving the identified problems.

METHODOLOGY

The purpose of this study was to formulate a definition of smart ecology based on the existing characteristics of economic activity, to identify the features of sustainable development of the enterprise in a smart ecology, to develop possible solutions to the problems arising in the transition of enterprises to new forms of activity.

The following general scientific and private methods and methodological approaches were used in the research—systems theory, analytical and systematic approaches.

Sustainable development of enterprises in modern conditions, in particular in the field of environmental problems, inevitably relies on a set of interrelated innovations. As part of the

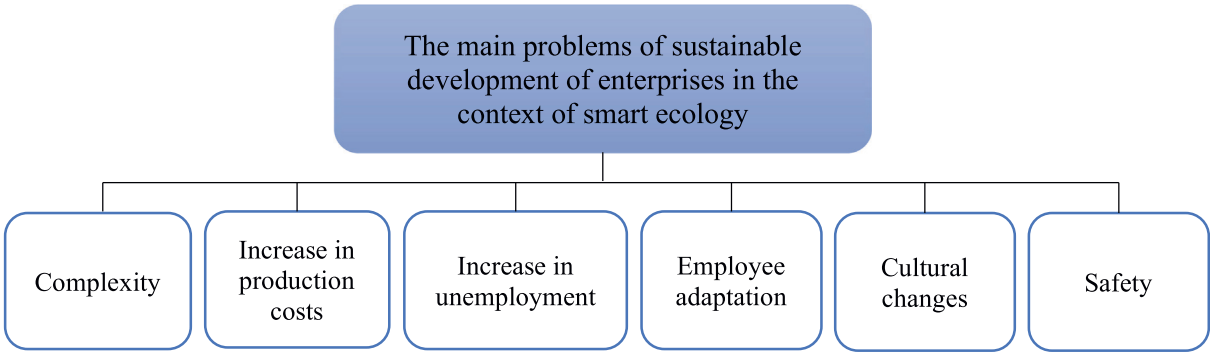

FIGURE 1 | The main problems of sustainable development of the enterprise in the conditions of smart ecology (Open School of Business, 2016).

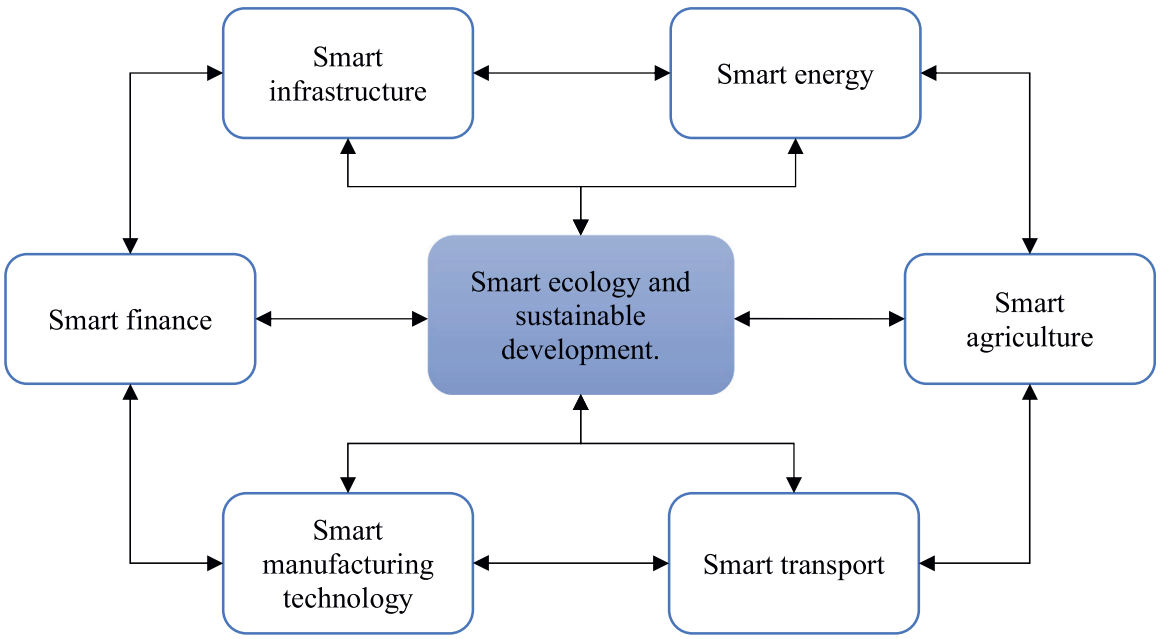

FIGURE 2 | The main directions of solving the problems of sustainable development of enterprises in a smart ecology (Open School of Business, 2016; Investlab, 2020).

development of a new technological mode about once every half century traditionally appears a cluster of closely related and mutually supporting innovations (Glazyev et al., 2019). However, at present, in the process of formation of a new technological mode, it is impossible to determine with a high degree of probability which of the many innovations appearing now will be effective enough on their own; which will give sufficient synergy with other innovations for their rapid development; and which will disappear (**Figure 2**). Nevertheless, enterprises must constantly make decisions to implement innovations that contribute to sustainable development. Sustainable development of enterprises is necessary not only to maintain a high level of competitiveness, but also to prevent or offset huge losses from risk situations that are both natural (such as the diesel fuel leak in 2020 in Norilsk, which occurred as a result of melting permafrost) and political or economic character (such as the introduction of fees for carbon emissions).

Within the emerging cluster of innovative technologies of the sixth technological mode, important elements can be "green" technologies of energy generation; electricity storage technologies; technologies that reduce energy losses and reduce emissions (in particular, recycling technologies of raw materials and other types of resources); technologies that reduce the carbon footprint and so on (Skiter et al., 2021). On the other hand, for example, carbon footprint reduction requirements may affect a company's logistics processes, require changes in technology to move cargo within the company as well as raw materials and finished product between facilities, and even change the degree of flexibility in manufacturing processes, for

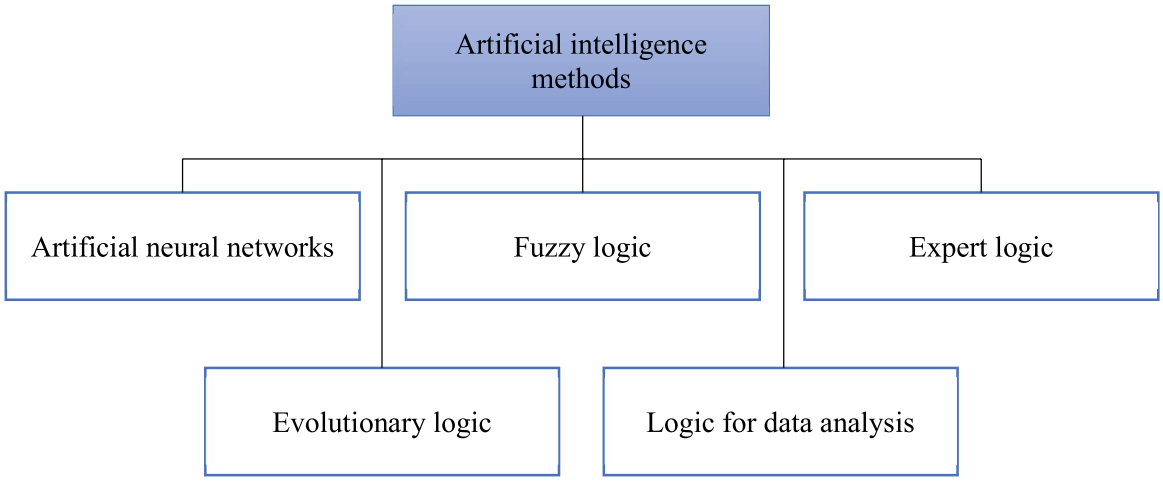

FIGURE 3 | Main groups of AI methods and algorithms (TAdviser, 2020; Codernet, 2021).

example, to reduce inventory levels (or even produce JIT "just-in-time"). And, of course, such large-scale optimization will ensure sufficient efficiency only with the introduction of modern artificial intelligence tools, modern tools for monitoring, analysis of big data, creating channels for continuous exchange of information between enterprises.

First of all, to solve the problems of sustainable development of enterprises, the widespread introduction of breakthrough technologies is necessary, such as:

1) the use of alternative energy sources to replace fossil fuels, both for production purposes and in the home, namely solar, tidal, wind and biomass energy (Naugolnova, 2014).
2) the use of artificial intelligence technologies in agriculture, since this industry uses 70% of the world's fresh water reserves and its share of greenhouse gases in the total amount is 13% (Open School of Business, 2016; Investlab, 2020; Educator's Notes, 2018), the use of IoT, based on special platforms like Arduino, will increase the efficiency of tillage technologies and reduce the amount of used resources.
3) Transition to environmentally friendly transport types will reduce the size of the carbon footprint (Laidlaw, 2022).
4) IT-technologies in production based on special platforms that allow automatic regulation of processes, remote control, monitoring of various values that monitor the condition of conveyors, reactors and other equipment and provide control of pollution levels and the volume of waste.
5) The introduction of smart finance technologies that provide competent taxation, which ensures effective control of the harmful effects on the environment and forms "ecological habits" of business leaders, employees and the population as a whole.
6) Formation of the "smart" infrastructure which will provide effective implementation and functioning of all the above-mentioned technologies.

It should be noted that not all innovations currently being created will be used in 40–50 years. Moreover, the logic of interaction between individual technologies may also change - for example, vehicle weight reduction technologies being developed to reduce the carbon footprint may significantly increase the efficiency of electric motors in these vehicles, reducing energy consumption when traveling long distances - and the inability to store large energy reserves is now one of the main problems of batteries for electric vehicles.

It is very likely that not all innovative technologies have the expected effect. And in this case, enterprises have two ways to implement innovations. The first way is to implement effective innovations, thus reducing the costs associated with technological and market risks caused by the implementation of ineffective innovations. However, it takes quite a long period of time to separate effective innovations from ineffective ones, which creates the risk of lagging behind the leading organizations. In order to overcome this lag, it will require significant scientific potential, large financial investments, and high flexibility in decision-making, so as not to miss the moment when the effectiveness of innovation is already proven, and the lag from the advanced organizations has not yet become critical.

The second way is to independently develop and implement advanced technologies, ensuring itself the role of a leader in sustainable development, attracting cheaper investments and reducing the risks associated with changes in regulation. However, this path creates obvious technological risks associated with the unknown characteristics of the applied innovation; market risks, primarily associated with a possible incorrect assessment of demand for the innovative product and with the unpredictable actions of competitors; reputational risks associated with the possible ineffectiveness of implemented solutions.

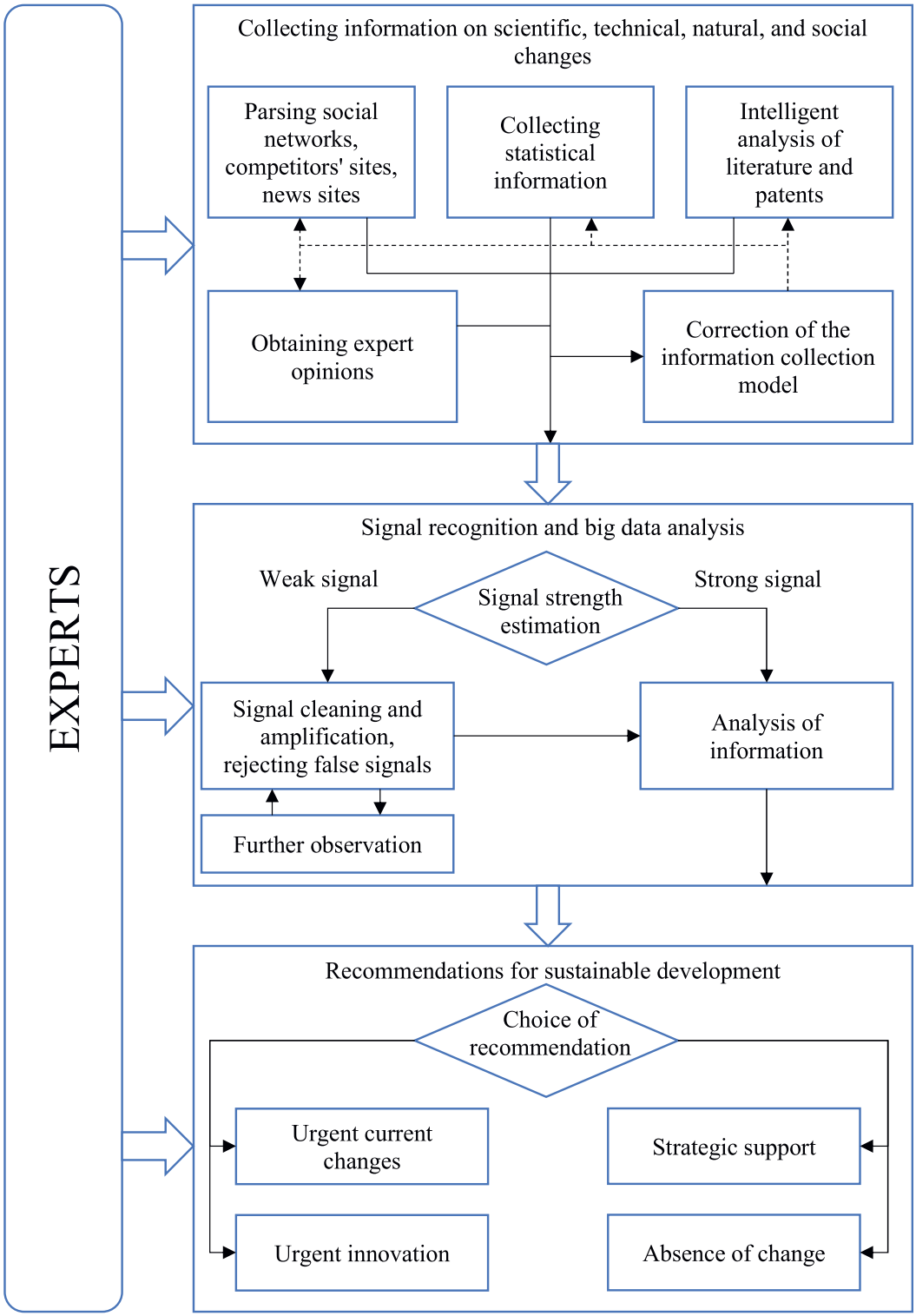

FIGURE 4 | Scheme of functioning of the expert system to support sustainable innovative development (Andreyeva et al., 2015).

RESULTS

Thus, innovation management in the context of the fourth technological revolution is associated with a number of risks, regardless of the strategic path chosen by the enterprise. To manage such risks, it is necessary to work effectively with heterogeneous information arising in the internal and external environment of the organization. This information, in particular, includes the results of the most modern fundamental research; patent analysis; analysis of current and planned changes in legislation; information about the technologies used by competitors; about changes in consumer needs of the product in the main market and the opportunities offered in other markets; and, of course, huge amounts of financial, technological and social information within the organization. To ensure flexible work with such a volume of information, often unstructured, fuzzy, contradictory, and carrying weak signals, the knowledge of individual specialists is obviously not enough. To manage such risks (at least in large organizations) for the purposes of sustainable development it is necessary to create an information system of decision support, organizing the work of experts, collecting and producing analysis of big data and identifying weak signals. Such a system can be developed in individual enterprises, or created as part of the activities of consulting firms or government projects to support innovation.

In our opinion, an effective solution to the totality of the identified problems and tasks is to develop an expert system based on artificial intelligence methods used to support decision-making procedures.

As is known, there are five main groups of artificial intelligence methods used for decision support purposes: artificial neural networks; fuzzy logic; expert logic; evolutionary logic; logic for data analysis (**Figure 3**). For the purposes of solving the problems of enterprise sustainable development in a smart ecology, the authors propose to use the following of them:

- Artificial Neural Networks (ANN), which is reasonable to apply for the purposes of image recognition in "smart" agriculture, speech recognition to adapt employees to breakthrough technologies, recognition of signs and objects for various control procedures (Rogachev, 2021b)
- Fuzzy logic, to involve experts in the decision support process, as these artificial intelligence methods are more qualitative in their analysis than neural networks. This group of methods can be used to make decisions on the implementation of certain innovations, to determine the main objectives and the scale of agricultural production.
- Logic for data analysis is designed to analyze huge amounts (Big Date) of data and find patterns in it. These methods are applicable for the purpose of developing a company strategy, taking into account the conditions of smart ecology.

Based on the highlighted methods of artificial intelligence in the framework of this study, the authors developed the structure of the expert system to support sustainable innovative development of the enterprise, taking into account the features of the tasks arising from qualitative changes in the economy, as well as taking into account the capabilities of modern information technology, reflected in **Figure 4**. This system was developed on the basis of materials (Andreyeva et al., 2015).

At the stage of collecting information, it is necessary to use various methods of recognition, methods of processing big data. Machine learning methods with and without a teacher (expert) may also be in demand. AI makes it much easier to study both innovative and commercial activities aimed at achieving the goals of sustainable development, and to track the achievement of these goals by improving the quality of the collection and processing of primary data on the state of the environment or, for example, poverty in different regions (Alsharkawi et al., 2021).

At the stage of signal recognition and analysis can be used fractal methods used in modern radio systems (Educator's Notes, 2018), mathematical models of decision-making, methods of stability analysis. Mathematical models that take into account ESG issues, which have a significant system component and require the joint work of specialists from different fields, should be widely used.

At the stage of developing recommendations for sustainable development, in our view, neural networks can be widely used, as well as various decision support methods, including methods of data visualization, methods of multicriteria analysis, and so on.

The first module of the described system is designed to collect information from all available sources. As can be seen from **Figure 4**, the database is formed from free Internet sources, statistical data, as well as on the basis of the intellectual analysis of the texts of scientific literature and patents. As part of the intellectual analysis of textual information is carried out pre-processing and transformation of the corpus: document breakdown, identification and extraction of the main content, separation of documents into paragraphs, segmentation, lexemization, labeling with parts of speech. The information is collected within the framework of developed observation plans, trained artificial intelligence systems and other models, which must be adjusted as necessary to ensure the high quality of the collected information under constantly changing conditions. The collected data undergo a cleaning and quality control process. Since the information collection and preparation phase of the analysis and modeling processes is one of the most important, distorted data or omissions in the data can lead to false results. After the data are checked and prepared, they are transferred to the second module.

The second module is designed to process the information collected in the first module. The information is considered as a set of strong and weak signals necessary to assess the changes taking place, possible threats and risks, as well as opportunities (Potapov, 2008). While strong signals can directly become the main for analysis, weak signals are rather noisy and are lost against the background of other, more definite information. Special methods should be used for their purification and amplification. Strong signals and purified weak signals are analyzed by statistical methods and intelligent methods based on specially created models. Also in this module model training, consisting in repeated procedures of signal estimation, and comparison of model predictions with real data is carried out.

The third module should interpret the results of the machine analysis and develop recommendations for changing the innovation policy of the organization, taking into account changes in the

external and internal environment. At this stage, based on the information obtained in the previous modules and relying on the tools of artificial intelligence, fuzzy logic, visualization and data representation, experts in the subject areas evaluate scenarios of enterprise development under different variants of system behavior. The pre-designed set of solution options is evaluated on the basis of the information obtained, the dominant solution options are discarded, the possibility of combining solutions to obtain a synergistic effect is studied, and the non-dominant solution alternatives are ranked by potential effectiveness. Also at this stage there is a presentation of recommendations in the most convenient form for potential stakeholders.

DISCUSSION

The result of the system activity is a flow of information for the management of the organization and stakeholders about the opportunities and threats arising for the enterprise due to innovative development in the external and internal environment in the field of smart ecology, as well as recommendations for behavioral adjustments to ensure effective and sustainable development of the organization.

Comparison of the proposed system with the known ones (Andreyeva et al., 2015) allows us to note the following significant differences and advantages:

- the possibility of adjusting the information collection model
- additional evaluation of the quality of the data transferred to the model by means of expert evaluation
- control of the reliability of the obtained results through the use of expert judgments.

In addition, the creation and use of the system described in **Figure 4** will ensure the sustainability of enterprise development in the implementation of innovations that promote ESG transformation, will facilitate the attraction of financial resources for the systematic development of smart ecology, will quickly achieve the goals of creating a green, safe and socially responsible entrepreneurship.

CONCLUSION

One of the important concepts that have appeared in the scientific turnover in the XXI century is the concept of noosphere - a hypothetical sphere of interaction between society and nature, in the boundaries of which intelligent human activity becomes a determining factor of development, it is also sometimes designated by the term "anthroposphere" (Vernadskiy, 1988; Macpherson, 2021). However, in recent decades there is a significant symbiosis between the human mind and artificial intelligence, which complement each other, creating a qualitatively changed noosphere. Human activity is no longer an independent factor influencing nature, but relies heavily on advances in computer technology, which have become part of the human mind from a tool. Under these conditions it is possible to speak not about ecology, but about smartbecology; not about the biosphere or the noosphere, but about the e-noosphere, in which the achievements of modern science become an independent factor influencing the ecology and sustainability of the development of the planet as a whole. In this regard, the study of sustainable development of the enterprise in the new prevailing conditions becomes relevant. Since such conditions of development are only being formed, initially it is necessary to form a theoretical basis of definitions, reflecting their main aspects.

In this study, the authors formulated a concept of smart ecology, which allowed to identify and show the close relationship between the conditions of smart ecology and the sustainable development of the enterprise. The main problems arising for the enterprise in the implementation of a sustainable development strategy in a smart ecology were highlighted, which allowed to consider and evaluate the possibility of using artificial intelligence to solve these problems.

The study shows that artificial intelligence is used to solve a whole range of tasks, both related to smart ecology and related to other goals of sustainable development. AI is used to optimize drip irrigation, identify plant diseases, create digital twins of mobile towers and optimize power consumption on them, solve medical problems, including the fight against COVID-19 (Artificial Intelligence for Sustainable Development, 2020). However, it should be noted that artificial intelligence can both contribute to and hinder the goals of sustainable development. These threats and opportunities are reflected in some detail in the UNESCO working paper (Goralski and Tay, 2020).

As part of the study, the authors have developed a conceptual model of an information expert system based on the application of machine learning and artificial intelligence, which contributes to improving the efficiency of the introduction of smart ecology technologies in specific enterprises, which accordingly has a positive effect on their sustainable development. For the purposes of leveling the negative influence of artificial intelligence methods on the results of machine analysis, the system introduces the procedure of expert evaluation, which will significantly improve their quality.

AUTHOR CONTRIBUTIONS

NS performed an analysis of the main problems. AR described the debatable issues. NK formulated the definition of smart ecology. AS and IT developed a model of expert system.

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