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Artificial Intelligence and Environmental Protection of Buildings

Sztuczna inteligencja i ochrona środowiska budynków

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Abstract
Global environmental pollution has an extremely negative impact on the population of the planet and threatens the future of mankind. One of the main sources of waste and toxic emissions into the atmosphere is the construction sector. It is necessary to find ways to minimize the damage caused to nature. Currently, artificial intelligence technologies are among the most promising ways to improve the environment. Automatic control systems solve a number of problems related to reducing costs and resources, full use of renewable energy sources, improving the safety of energy systems, and many others.
The purpose of this article is to determine the functionality of artificial intelligence technologies and ways of their application in *green* construction. To solve this problem, methods of analysis and synthesis of existing information models were applied. The article discloses automatic control systems in the design, construction, and operation of buildings. These include well-known methods, such as Building Information Model, Machine Learning, Deep Learning, and narrow-profile ones: Response Surface Methodology, Multi-Agent System, Digital Twins, etc. In addition, the study states that when planning and arranging *green* buildings must adhere to the following principles: high energy efficiency, rational use of natural resources, adaptation to the environment and climate, ensuring comfort and safety for residents. The article presents the standards of *green* construction existing in the world. This work can serve as a guide when choosing information models and is of practical value in the development of *green* buildings.

Key words: ecology, energy efficiency, *green* buildings, information model, automatic control system

JEL Classification: Q1, Q5, Q56

Streszczenie
Globalne zanieczyszczenie środowiska ma niezwykle negatywny wpływ na naszą planetę i zagraża przyszłości ludzkości. Jednym z głównych źródeł emisji odpadów i substancji toksycznych do atmosfery jest sektor budowlany. Konieczne jest znalezienie sposobów na zminimalizowanie szkód wyrządzanych przyrodzie. Obecnie technologie sztucznej inteligencji należą do najbardziej obiecujących sposobów poprawy stanu środowiska. Układy automatyki rozwiązują szereg problemów związanych z redukcją kosztów i zasobów, pełnym wykorzystaniem odnawialnych źródeł energii, poprawą bezpieczeństwa systemów energetycznych i wieloma innymi.
Celem artykułu jest określenie funkcjonalności technologii sztucznej inteligencji oraz sposobów jej zastosowania w *zielonym* budownictwie. Zastosowano metody analizy i syntezy istniejących modeli informacyjnych. W artykule

opisano systemy automatycznego sterowania w projektowaniu, budowie i eksploatacji budynków. Należą do nich dobrze znane metody, takie jak Building Information Model, Machine Learning, Deep Learning, oraz wąskoprofilowe: Response Surface Methodology, Multi-Agent System, Digital Twins itp. Ponadto badanie stwierdza, że podczas planowania i aranżacji *zielone* budynki muszą spełniać następujące zasady: wysoka efektywność energetyczna, racjonalne wykorzystanie zasobów naturalnych, dostosowanie do środowiska i klimatu, zapewnienie komfortu i bezpieczeństwa mieszkańcom. W artykule przedstawiono standardy *zielonego* budownictwa istniejące na świecie. Praca ta może służyć jako przewodnik przy wyborze modeli informacyjnych i ma praktyczną wartość w rozwoju *zielonych* budynków.

Słowa kluczowe: ekologia, efektywność energetyczna, zielone budownictwo, model informacyjny, system automatycznego sterowania

Introduction

Protecting the ecology of the planet is an extremely important issue in the modern world. The damage caused to the environment leads to catastrophic consequences for humanity. The consequences of climate change are fires, floods, drought and more. Harmful emissions also adversely affect human health (The Paris Agreement, 2020). To minimize the negative impact, it is necessary to take appropriate measures to preserve nature.

The problem of ensuring sustainable development has been relevant for many years. The essence of sustainable development is to define viable schemes that take into account and balance the economic, social, and environmental aspects of human activity (Pershakov et al., 2016; Karches, 2022). The main characteristic of sustainable development is the ability to control all processes based on the use of a system approach and modern information technologies. The sustainable development is ensured by combining and balancing the three components of each entity's activities: social, economic, and environmental. Modern conditions of development require humanity to reduce resource consumption, switch to alternative types of materials and renewable energy sources, and implement resource-efficient and low-waste technologies.

In 2015, 17 Sustainable Development Goals were approved at the UN Summit on Sustainable Development. They all aim to end poverty, protect the planet, and ensure peace and prosperity for all of humanity. Goal 12: Responsible consumption requires an urgent reduction of environmental impacts through changes in the production and consumption of resources and goods (UN Sustainability Goals, 2015). Under the influence of consumer demand and a competitive environment, manufacturers are forced to meet the requirements of voluntary environmental standards and systematically work on improving the environmental characteristics of products, improving technology, and modernizing production.

As China leads in the production of sulphur dioxide and solid waste on the world stage, the issue of protecting the environment in the state is acute. Due to the long-term neglect of the environmental situation by the Chinese authorities, the incidence rate among the population due to environmental pollution is high. It also affects the decline in the level of the country's gross domestic product. Since the early 2000s, the government has implemented a strategy to protect natural resources and the environment. The introduction of environmental standards for enterprises, strict control over emissions of harmful substances, and investment in alternative energy projects have improved the ecological situation in China (Zakharov & Kalashnikov, 2020). One such project is the use of artificial intelligence to protect the environment of buildings, also called *green* buildings. It is understood that the design, construction, and operation of such buildings completely eliminate or reduce damage to the environment. For this, alternative energy sources are used, and the consumption of resources such as water and energy are reduced. Recycling technologies are used, construction materials are non-toxic and environmentally friendly, and energy audits of buildings are carried out (About Green Building, 2019).

Chinese researchers Y. Zhang et al. (2019) in the article studied the prospects for the use of *green* buildings throughout the world. The factors on which the further development of new technologies in this area depends were considered. The degree of distribution of *green* buildings in countries such as the USA, Great Britain, Japan, China, and some European countries is estimated. The reasons why the concept of *green* building has not been widely adopted in China have been identified. The study of the factors influencing the development of *green* houses is also carried out in the work of the authors W. Wang et al. (2021). The analysis is carried out using the WINGS algorithm using a neural network. The authors determined that the main factor for the development of the *green* construction industry is extensive project financing. The article also presents theoretical evidence of the effectiveness of the use of *green* buildings in China and offers recommendations for decision-making for government agencies on the introduction of this technology.

I. Akomea-Frimpong et al. (2022) raised a similar question in an article. The results of the study also show that increasing economic returns contribute to the widespread use of *green* buildings in construction. An important aspect of the design of such projects is public participation. The work of S. Gohari et al. (2020) explores the impact of citizen participation in the European smart city project Horizon 2020 + City Change in Trondheim, Norway.

The article provides recommendations for government authorities on what decisions should be made when implementing energy-saving projects in order to prevent possible problems or misunderstandings with the public. The concept of using artificial intelligence in the construction of environmentally friendly buildings was also studied in the work of Australian researchers R. Dowling et al. (2021). Recommendations are given for the implementation of the *smart* city system, depending on the population density and the form of government.
Many scientists around the world are studying the topic of *green* construction. However, these studies do not reveal all the features of the use of automatic control systems in this area. For a greater understanding of the possibilities of modern technologies, it is necessary to consider more widely the ways of using intelligent models in the construction of *green* buildings. The purpose of this work is to determine the most effective combinations of artificial intelligence technologies in the construction sector, aimed at improving the environmental situation.

Materials and methods

The methodological approach of this article is based on the methods of analysis, with the help of which the features of the presented *smart* technologies of *green* construction was revealed, and the synthesis of artificial intelligence models introduced in the planning, construction, and operation of buildings. The synthesis method made it possible to generalize and group the considered automatic control systems, highlighting entire complexes of the most effective technologies. The totality of the presented methods allows us to consider the possibilities of applying artificial intelligence methods in practice from different angles. The study was carried out in five stages.
In the first stage of the study, the need to protect the environment of buildings is argued. Statistical information is presented on the degree of pollution of the atmosphere, water resources, emissions of toxic gases and waste, as well as the level of electricity consumed by the construction sector. The main provisions of the Chinese green building standard GB/T50378-2014 and the factors that prevent the wide spread of this direction were described. Recommendations for their overcoming are given. In the second stage, an explanation is given of how, with the help of *smart* technologies, monitoring, collection of the physical parameters of the building, and their processing are carried out. The necessity of using artificial intelligence in construction is substantiated. It also analyses the principle of operation of Deep Learning algorithms and neural networks that are embedded in the building structure.
In the third stage, a synthesis of technologies aimed at increasing the efficiency of the construction process by reducing the use of materials and resources was carried out. It is indicated what relationship must be taken into account when planning *green* buildings to ensure a safe impact, both on the environment and on the health of residents. The ways of using the Building Information Model in the creation of *green* houses and its advantages are investigated. The workability of the grey correlation analysis is analysed, with the help of which the environmental performance of the building is assessed. It is studied how it is possible to standardize the measured parameters. The requirements for building materials for *green* houses are listed. Also at this stage, the importance of observing environmental protection during construction is argued. The most common types of pollution in the process of building construction are listed. In order to reduce or completely prevent the negative impact on nature, a set of existing rules for the design and construction of *green* buildings are presented. A combination of technologies is proposed to simplify the design process.
At the fourth stage, those artificial intelligence models are considered that are aimed at the processes of collecting, processing, and optimizing design parameters. A description is given of ways to increase the life cycle and simplify all stages of the construction of *green* buildings using a set of presented models. The issues of waste disposal and the introduction of biogas plants were studied. A recommendation is given on the application of a control system model for the effective management of biogas production. The consequences of the intermittent current generation in power plants of *green* buildings are considered and ways to solve this problem are proposed. The features of the design of the power supply system in *green* houses are analysed. Summing up the mentioned technologies, complexes of information models are proposed that contribute to the solution of the main tasks of designing, building, and operating *green* buildings. At the final stage of the study, after comparing existing publications on this topic, the conclusions of this article, its features, advantages, and disadvantages are formulated.

Results

According to the assessment of world environmental pollution for 2010, 23% of air pollution, 40% of drinking water pollution, 50% of toxic gas emissions, 50% of garbage, and 50% of ozone depletion are accounted for by the construction sector (Thorpe et al., 2010). By 2018, the situation in this industry had not changed much: carbon dioxide emissions into the atmosphere amounted to 39%, of which 11% came from the production of building materials. It should be noted that the level of final energy consumption of the construction sector at the global level was 36% (Global Status Report…, 2019). Therefore, it is necessary to introduce modern technologies in order to reduce the damage caused to nature. Under the influence of the decarbonisation policy, *green* construction was created, which implies the maximum reduction of pollutant emissions, the rational consumption of natural resources, and the use of smart technologies in the planning, construction, and operation of buildings. When designing *green* buildings, it is required to take into account how the building materials and energy carriers used will affect the environment. It is necessary that resources be used efficiently and do not harm human health and nature (Wu et al., 2019). To achieve this goal, China has created a green standard GB/T50378-2014, according to which this area is divided into six categories, which include land-saving and environmental conservation, energy saving and energy consumption, water saving and rational use of water resources, quality control of the indoor environment, management of application programs (Assessment standard…, 2014).

However, green building has not become a universally accepted concept. The possibility of the application directly depends on the economy of the state, geography, and resources (Ding et al., 2018). The use of artificial intelligence in the construction of buildings can significantly improve the environmental performance of the construction area, but the presence of such technologies leads to a sharp increase in the cost of projects. The cost of some green building projects is estimated to be 10% higher than conventional buildings (Jinkang, 2019). This is a significant obstacle to the spread of *green* construction. Therefore, it is necessary that such projects be not only environmental and energy efficient, but also economical.

Artificial intelligence is used to create building automation systems. This not only reduces energy consumption but also increases the comfort and safety of living quarters. Computational Intelligence, Soft Computing, and Distributed Artificial Intelligence are used in construction (Dounis, 2010). The iBuilding technology, created on the basis of Distributed Artificial Intelligence, allows monitoring premises, and tracking of unused living space for possible redevelopment or use of this territory for commercial purposes (Serrano, 2022). Deep Learning algorithms are used that analyse incoming data with a given logical structure. In this case, a multi-level system of algorithms is used, which is called neural networks. It is similar to the functioning of the human brain, since Deep Learning algorithms identify patterns between data and classify information according to the same principle as people and (What is deep learning…, 2022). In iBuilding technology, neural networks are embedded in buildings to collect data from the premises and predict possible values. Based on the information received, the designers make further commercial or operational decisions. This allows you to increase the energy efficiency of the building, thereby reducing the harm to the environment. To assess the economic benefits of *green* houses, the methods of entropy weights and the Analytical Hierarchy Process are used. The introduction of green building technologies and related equipment reduces the use of building resources, as a result, energy consumption and emissions are significantly reduced. When designing a *green* building, it is necessary to adapt the system to local climatic conditions (Lu et al., 2022).

In conventional architectural design, due to the lack of intelligent data processing, it is often necessary to make adjustments during the construction process. To optimize the work, a method for designing *green* buildings based on Building Information Model (BIM) technology was proposed. This technology includes simulation and control of the digital display of the structure. The use of BIM allows you to identify defects in the design and increase efficiency by predicting and reducing potential costs. In the process of *green* construction, it is necessary to take into account the relationship between architectural and natural features. The design of the building must positively influence the health of the occupants and the environment, and make full use of the energy of the sun, wind, or other renewable sources. As an example, the article by X. D. Zhao and C. P. Gao (2022) proposed a method for assessing the energy-saving effect of *green* buildings based on BIM. This platform made it possible to analyse the systems of energy supply, water supply, sewerage, heating, ventilation, and air conditioning. The authors proved that with the help of BIM technology it is possible to reduce the energy consumption of buildings while maintaining the ecological situation the norm.

In the construction of buildings, concrete, cement, glass and ceramics are mainly used. On the one hand, these materials are highly durable and adapt well to the environment, but most of them are non-renewable resources. This causes significant harm to the environment. To solve this problem, it is necessary to expand the use of *green* materials, which significantly reduce the degree of pollution, are not toxic and radioactive. The determination of the energy-saving and environmental effect of *green* building materials is carried out using a grey correlation analysis. In the study of C. Wang (2021), a comprehensive algorithm for assessing the environmental performance of a building is proposed, with the help of which the efficiency of materials used in construction is calculated. In addition, when using such a system, it becomes possible to create environmental and energy-saving standards for *green* buildings. Material structure, strength and stiffness, pollution intensity, bearing capacity and cost were selected as variables in this analysis. An important factor is also the degree of thermal insulation of materials. The author believes that the proposed technology will contribute to the further development of the theory of environmental protection in the construction industry. Having determined the possibilities of using *green* building materials and their impact on the environment, further construction of *green* buildings will be simplified and improved. To confirm the efficiency of the proposed method, an experiment was conducted in the Simulink software. A wooden structure was simulated as a basis for testing the environmental and energy saving effect. The author of the study determined that the maximum effect of energy saving is most noticeable in winter and summer. The proposed algorithm allows you to consume less energy, make the interior warm in winter and cool in summer, reduce the time of using air conditioners and positively influence the environment. In addition, the technology can significantly reduce construction costs by accurately determining the volume and type of materials required.

Waste of natural resources, high noise levels, dust pollution, and toxic emissions from construction paints and coatings are common on a construction site. The issue of pollution during the construction of buildings is in most cases ignored (Wei, 2021). The technology of construction of *green* buildings contributes to the resolution of the issue of environmental pollution. To minimize environmental impact, materials must be sealed prior to transport to avoid the spread of dust during transport. The height of dust generation in the working area should not exceed 1.5 m. Noise control at the construction site should be carried out in accordance with international standards, less noisy equipment should be selected and soundproofing should be carried out. Wastewater must go through several stages of treatment, before being discharged, water quality control is required. When designing, it is important to take into account the geographical features of the area. If there are not enough water resources in the region, their consumption should be reduced to the lowest possible level. Thus, by combining grey correlation analysis, Machine Learning and BIM algorithms, the construction of buildings is greatly simplified at the initial stages and contributes to cost reduction, more accurate selection of materials and their quantity.

There is an intelligent model GANN-BIM, which is a synthesis of Genetic Algorithms (GA), Artificial Neural Networks (ANN) and BIM technologies. The model is used to optimize the process of designing *green* buildings. GANN-BIM allows you to process large amounts of information while using less computing power. Self-configuring Wireless Sensor Networks are used to monitor physical and environmental indicators such as temperature, sound and light intensity, vibration, barometric pressure, power line voltage, wind direction, pollution levels and chemicals. Using the obtained data, it becomes possible to correctly design the ventilation system and reduce the level of waste. Motion detection sensors significantly reduce energy costs by automatically turning off the lights when no one is in the room. The automation system controls the operation of air conditioners and heating devices, equalizing the temperature in the premises to the optimum. The system allows not only to reduce the level of water consumption. If you have your own water treatment plant, wastewater from showers, washing machines and dishwashers can be treated and reused for watering the garden, washing cars, etc. The combination of BIM technology and artificial intelligence algorithms makes it possible to simplify the stages of planning and building *green* buildings, increasing them life cycle through the rational use of resources and further exploitation (Wan et al., 2022).

Waste recycling and energy production from biogas in green houses is also becoming possible thanks to the use of artificial intelligence technologies. An article by Iranian researchers M. M. Shahsavar et al. (2021) describes a model of a biogas production control system in *green* buildings, based on Response Surface Methodology, and the principle of Petri nets. The following machine learning algorithms were used to build an intelligent model: a random tree, a random forest, an artificial neural network, and an adaptive network fuzzy inference system. The authors have proven that the application of the Response Surface Methodology leads to the optimization of parameters in the production of biogas in *green* houses. Thus, if there is a biogas plant in the building, it becomes possible to include it in the overall control system. However, the use of alternative energy has some significant drawbacks, one of which is the lack of guaranteed safety in the operation of such power plants.

Unstable current generation in wind, solar or biogas power plants can negatively affect the overall power supply system of the building. To improve reliability, the technologies of Micro Grids, Energy Storage Systems, and Multi-Agent System (Jonban et al., 2021) should be integrated. The use of such a multifunctional energy management system is due to the fact that Micro Grids guarantees the maintenance of a stable power supply, and the additional use of Energy Storage Systems increases the reliability of the system. However, the control of such an electrical system is complicated. To solve this problem, the authors of the study implemented a Multi-Agent System, where the individual components of the system are distributed, and management has become decentralized and autonomous. Agents in the Green Building Multi-Agent System perceive changes in the physical or environmental parameters of the environment and make decisions about further actions based on a given program. In the described energy management system, control structures are divided into substructures, each of which solves its own task. Consequently, the agents of the proposed system can regulate the mains voltage and current of the connected device using a given decision-making procedure. This reduces electricity consumption and increases the safety of buildings.

Data management in the green building system is also carried out using Digital Twins technology. It is applicable for not only measuring and processing indoor parameters. The Digital Twins model can be used in enterprises to simplify the assembly, operation and maintenance of products. It is used in the system of services to ensure the life of the population, urban and environmental management (Yang et al., 2022). By varying the combinations of these technologies, the task of choosing artificial intelligence technologies in the design and construction of *green* buildings are greatly simplified. For example, you should combine the methods of entropy weights, Analytical Hierarchy Process and BIM at the initial stages of construction. This will contribute to the optimal choice of building resources and their quantity. A combination of gray correlation analysis, Machine Learning and BIM algorithms is also applicable for these purposes. When designing, it is necessary to take into account environmental conditions, and the use of renewable energy is a prerequisite for *green* buildings. To determine the required parameters and ensure the reliability of the operation of the green building system, it is possible to apply GANN-BIM or Digital Twins along with Micro Grids, Energy Storage Systems and Multi-Agent System.

Discussion

A detailed description of machine learning algorithms is presented in an article by Turkish researchers M. M. Kaya et al. (2021). This paper presents the possibilities of using artificial intelligence for domestic use in *green* houses. The authors conduct a comprehensive analysis of automatic control methods, determining in which areas one or another algorithm can be used. The article describes in detail the principle of artificial intelligence, and its types: Artificial Narrow Intelligence, Artificial General Intelligence, and Artificial Super Intelligence. The first area of application of artificial intelligence, which affects researchers, is the energy industry. Ways to improve the performance of power systems and increase the reliability of electric current generation using alternative energy sources are being studied. The advantages of *smart* devices are considered, such as *smart* sockets, autonomous lighting, self-learning thermostats, etc. The second area is agriculture. By introducing artificial intelligence methods into the agricultural industry, it becomes possible to control the cultivation and harvesting of crops. Also, artificial intelligence technologies are used to automate greenhouses and control the use of fertilizers. Water supply is the third area covered in this article. This includes daily tracking of water consumption. These systems can generate consumption statistics as well as shut off the flow of water when a leak is detected. The paper provides an explanation of the structures of Machine Learning, Supervised Learning, Unsupervised Learning, Reinforcement Learning, Deep Learning, and Deep Reinforcement Learning, their advantages and disadvantages.

Australian scientists S.K. Baduge et al. (2022) consider the use of artificial intelligence, Machine Learning, and Deep Learning in manufacturing, architectural design, and visualization, monitoring of construction works, operation of buildings and enhance the life cycle of the structure. The article presents ways to apply artificial intelligence, Machine Learning, and Deep Learning at all stages of a green building, from the conceptual stage, to design, operation, and maintenance. The study describes the history of the emergence and evolution of artificial intelligence, the prospects for further development of the technologies of the fourth industrial revolution, and also provides a simplified description of the mechanism of action of Machine Learning and Deep Learning. The authors gave an overview of data collection methods and summarized the application of these artificial intelligence technologies in construction. As a result, it was confirmed that Machine Learning and Deep Learning increase the efficiency of the construction process since they have advanced computing capabilities and can operate with large amounts of information. Machine Learning algorithms make it possible to predict the properties of building materials, which will contribute to the development of durable and sustainable resources. End-of-life buildings can be disposed of and recycled with the support of robotic systems. The authors of the work also mention the possibility of integrating artificial intelligence methods and 3D printing technology for building construction, which will significantly speed up the design, production, and testing of objects. The researchers argue that those processes that currently take several weeks can be completed in a couple of hours in the future.

In the joint work of the Chinese and Dutch researchers Y. Shen and M. Faure (2021), on the example of China, the dynamics of the development of *green* construction are considered, and the legal instruments that can be used to spread it are studied. The article presents the theory of reasonable regulation and economic analysis of law. It was found that despite the positive impact on the environment and the reduction in energy consumption, construction costs are often higher than acceptable. The authors give the following recommendations for promoting this industry: the state should exercise command and control over the construction of green buildings, provide subsidies or green loans programs, purchase the required resources to motivate private companies to participate in green building, and most importantly – create an appropriate legal and regulatory framework aimed at promoting green building.

F. Xue and J. Zhao (2021) consider methods for assessing and costing the life cycle of a *green* building in the article. With the spread of energy-saving technologies, China's construction companies should create a new strategy aimed at developing a green economy. Several difficulties have been identified that hinder this process. They lie in the low awareness of the personnel of construction companies about the concepts of energy management, the lack of understanding of the structure and functioning of *green* buildings. In addition, there are misunderstandings among employees regarding the use of *green* technologies, which leads to inefficient arrangement of such buildings and the lack of adaptation of the structure to environmental conditions, and, consequently, high costs. A survey was conducted among the personnel of construction enterprises to determine their degree of awareness in the field of energy management. The results of the survey showed that 90% of senior managers are aware of ways to save energy, while the situation with operational managers is just the opposite. The number of lower-level employees who understand the principles of energy saving is extremely small – about 5% of the total. Therefore, for the sustainable development of *green* construction, it is necessary to increase the competence of workers, which will contribute to the correct design of *green* buildings.

Q. Li et al. (2020) carried out the analysis of publications in the field of *green* construction. With the help of bibliometric and visual analysis, the main trends in future research in this area were identified. On the basis of the *CAPITAL* structure proposed by the authors, a detailed review of the advanced issues of *green* construction was compiled and recommendations were given for their solution. The leading journals in this area were identified in terms of citation frequency. These include: *Building & Environment*, *Energy & Buildings* and *Journal of Cleaner Production*. I.Y. Wuni et al. (2019) also dealt with a similar issue. The study identified and described the most common areas of research in *green* building and proposed further ways of their development. It is established that out of 195 countries of the world, approximately 44% conduct research in this area. Scientists and researchers of the global north made the greatest contribution to these publications.

Chinese researchers Y. Zhang et al. (2017) compared the standards of *green* building in the UK, USA and China. The Code for Sustainable Homes has been the UK's national standard since 2010. In this system, buildings are assigned a rating from 1 to 6 levels based on nine criteria. Such criteria are: the level of environmental protection, energy consumption, water, pollution, waste, wastewater, carbon dioxide emissions, the quality of building materials and the functionality of the building. Leadership in Energy and Environmental Design appeared in the USA in 1998 and is updated periodically. The certification level corresponds to a 100-point scale, there are 4 levels in total: simple, silver, gold and platinum. The main evaluation parameters are the construction site, the consumption of water, energy, building materials and resources. The Chinese standard GB/T50378-2014 has been described above in this paper. The authors compared the three listed normative documents, summarized the characteristics of each standard, and made recommendations for improving the Chinese system for assessing and certifying green houses.

This article does not disclose all existing artificial intelligence technologies. The paper does not provide a detailed description of the principles of functioning of Machine Learning, Deep Learning technologies, etc. It does not consider ways to promote *green* construction at the national level and does not present a comparison of existing standards in different countries. Nevertheless, the work covers a fairly wide number of artificial intelligence methods used in practice, with the help of which it is possible to monitor and predict the energy performance of a building, control the level of resource consumption and improve the stability of the electrical system. The article can serve as a guide when choosing energy-saving technologies when creating *green* houses or improving existing ones. The direction of *green* construction is currently actively developing. In the future, it is necessary to more carefully study the possibilities that artificial intelligence opens up in the construction of *green* buildings.

Conclusions

The construction sector is currently one of the main causes of large-scale pollution of nature, which has been confirmed by statistical data. To minimize the damage caused, some countries of the world have created standards for *green* buildings. The main principles of each are to preserve the environment by increasing energy efficiency, rational use of water resources, and reducing waste levels. However, while there is a need to introduce sustainable building, the main obstacle is the high cost of green building projects. Artificial intelligence technologies contribute not only to automatic control inside the building and reduce energy costs during operation. With the correct use of intelligent systems, it is possible to achieve a preliminary assessment of the required resources and the replacement of conventional building materials with environmentally friendly ones. Such actions will reduce the risk of additional costs during the construction of buildings. There are a large number of models with which it is possible to realize the collection, analysis, and regulation of environmental parameters, thereby influencing the reduction of resource consumption and increasing the reliability of the system. Many of these artificial intelligence models have been discussed in this article. These include iBuilding technology based on Distributed Artificial Intelligence, entropy weight methods and Analytical Hierarchy Process, Building Information Model, Genetic Algorithms, Artificial Neural Networks, Response Surface Methodology, Multi-Agent Systems, Digital Twins, etc.

The study describes the installation of neural networks in the building structure, powered by Deep Learning algorithms, which monitor the premises and contribute to the adoption of rational decisions by designers. The main aspects that must be taken into account when planning *green* buildings are indicated. These include: adapting the building to the local climate, using safe building materials, making full use of renewable energy, and providing a comfortable and healthy living environment. With the help of artificial intelligence technologies such as Response Surface Methodology, it is possible to manage the production of biogas in green houses, and systems such as Micro Grids, Energy Storage Systems, and Multi-Agent System help to stabilize the energy supply system.

Environmental pollution poses a great threat to the future of mankind. The use of *green* building technologies will improve the ecological situation on the planet. This paper provides recommendations on how to use and combine automatic control systems to simplify the construction of *green* buildings and improve their functioning. However, the article does not cover all possible combinations of information models. Artificial intelligence technologies are multivariate, in the future, it is necessary to continue research in this direction to determine the prospects for the use and combination of information models in green building.

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