СТРОИТЕЛЬСТВО

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MAIN DIRECTIONS AND DEVELOPMENT OF ARTIFICIAL INTELLIGENCE IN THE CONSTRUCTION INDUSTRY

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Abstract

This research paper analyzes the integration of artificial intelligence with current technologies. The possibilities and methods of integration with modern innovations are revealed, according to the studied and analyzed information from scientific sources around the world. The result of integration and possibilities of further development are demonstrated. A detailed description of the disadvantages and advantages of applying innovative technologies with integrated artificial intelligence in the construction industry is provided. The writing of this paper serves to familiarize both the scientific community and the civilian population with the possibilities and prospects of development of the construction industry through the introduction of artificial intelligence technology.

Relevance: the study of current and effective technologies that have proven themselves with a positive side in the construction industry. Analysis of their implementation and use in modern realities.

The aim of the research: to study the currently demanded technologies in the world construction practice with the influence of artificial intelligence on them, to consider in detail the efficiency of use in terms of economy, preservation of ecology and natural resources, ensuring safe labor activity, the possibility of further modernization and development with the provision of both disadvantages and advantages.

Materials and methods: study of scientific literature, research papers, Internet sources, private channels and opinions of active enthusiasts interested in and working on the process of implementation and development of innovative technologies.

Results and conclusions: the methodology of introduction and use of modern technologies in the construction industry is outlined, advantages and disadvantages of innovations are described. The basic concepts of modern technologies, their essence and demand in the world are studied, the necessity of their application and exploitation is described.

The purpose of the research article is to inform and familiarize both the scientific community and the civilian population with the work done to study and describe both the importance and effectiveness of the application of modern technology in the construction field, providing personal guidance according to the examples given.

Keywords: artificial intelligence, construction industry, innovative technologies, construction, life, structures.

ОСНОВНЫЕ НАПРАВЛЕНИЯ И РАЗВИТИЕ ИСКУССТВЕННОГО ИНТЕЛЛЕКТА В СТРОИТЕЛЬНОЙ ИНДУСТРИИ

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Реферат

В данной научно-исследовательской работе проводится анализ интеграции искусственного интеллекта с актуальными технологиями. Раскрываются возможности и методы интеграции с современными инновациями, согласно изученной и проанализированной информации с научных источников по всему миру. Демонстрируется результат интеграции и возможности последующего развития. Предоставляется подробное описание недостатков и преимуществ применения инновационных технологий с интегрированным искусственным интеллектом в строительной индустрии. Написание данной работы служит для ознакомления как научного сообщества, так и гражданского населения о возможностях и перспективах развития строительной сферы путём внедрения в неё технологии искусственного интеллекта.

Актуальность: изучение актуальных и эффективных технологий, зарекомендовавших себя с положительной стороны в строительной индустрии. Анализ их внедрения и использования в современных реалиях.

Цель исследования: изучить востребованные на данный момент технологии в мировой строительной практике с влиянием на них искусственного интеллекта, подробно рассмотреть эффективность использования с точки зрения экономики, сохранения экологии и природных ресурсов, обеспечения безопасного ведения трудовой деятельности, возможности последующей модернизации и развития с предоставлением как недостатков, так и преимуществ.

Материалы и методы: изучение научной литературы, научно-исследовательских трудов, интернет-источников, частных каналов и мнения активных энтузиастов, интересующихся и работающих над процессом разработки и внедрения инновационных технологий.

Результаты и выводы: изложена методология внедрения и использования современных технологий в строительной индустрии, описаны преимущества и недостатки инноваций. Изучаются основные понятия современных технологий, их сущность и востребованность на мировой арене, описывается необходимость их применения и эксплуатации.

Назначение научно-исследовательской статьи заключается в информировании и ознакомлении как научного сообщества, так и гражданского населения с проделанными трудами по изучению и описанию как важности, так и эффективности применения современных технологий в строительной сфере с предоставлением личных наставлений согласно приведённым примерам.

Ключевые слова: искусственный интеллект, строительная индустрия, инновационные технологии, строительство, жизнедеятельность, конструкции.

Introduction

Thanks to daily progress in the evolution of innovative technologies, the construction industry is rapidly moving to a new stage of development, introducing technologies such as artificial intelligence into its industries and processes. By improving the quality of tasks performed in compliance with set deadlines, increasing the economic component of the construction industry and complying with safety requirements, artificial intelligence technology has advanced in its development for years to come, forcing scientists and private enthusiasts to delve deeper into its study to provide the world with a new model for conducting the construction industry.

The active introduction and application of innovative technologies in the construction business demonstrates positive dynamics in solving

complex and energy-intensive problems. Scientists are considering the issue of creating a universal tool capable of changing the construction industry and replacing all currently available technologies by combining them with subsequent development opportunities. By analyzing available data from around the world, the scientific community is experimenting with the application and development of technologies that can solve several different problems without separating them into different methods.

The analysis of the conducted experiments and scientific sources around the world shows great motivation to move to a new level of development of innovative technologies in the construction industry. The most effective result in solving the tasks set was demonstrated by artificial intelligence technology, thanks to which it became possible to simultaneously achieve an increase in the economic indicators of enterprises, effective conservation of natural resources and the environment, improving the quality of worker protection when performing assigned tasks by means of tracking and monitoring the work process in real time.

The aim of the study is to examine the effectiveness of integrating artificial intelligence into the construction industry and to determine the impact of the use of the technology in question on human life in general. Ideas for integrating artificial intelligence with currently available technologies are put forward; results are provided that facilitate the creation of a conclusion on the work carried out, outlining ideas and recommendations for the subsequent use of technologies with integrated artificial intelligence.

Main tasks that contribute to achieving the goals are:
− study of the results of the application of artificial intelligence which available in the public domain;
− consideration of current innovations in the construction industry;
− study of the scientific works which related to the topic and its consideration;
− study of the artificial intelligence integration effectiveness with current technologies;
− consideration of the population's response to the use of innovative technologies;
− analyze situation to achieve and formalize the discussion and result of the research.

The methods of conducting the research are studying and collecting information from scientific research sources, analyzing samples and movements of the application of technologies in real life, statement of personal opinion based on analysis of information and drawing conclusions.

Discussion

Daily progress in the technology development provides the opportunity to integrate innovations into any area of human life. The construction industry is not ignoring these innovative technologies, offering expanded application opportunities at every stage of the construction business. The introduction of innovative technologies into the construction industry allows eliminating the risk of injury to workers during performing assigned tasks, reduce the amount of labor required to complete works, to improve the economic performance of both large enterprises and small businesses, bringing with it an effective increase in profits for the state treasury, allowing to improve the quality of life of the population [1]. In addition, innovative technologies are capable of maintaining the environment by minimizing harmful emissions and saving natural resources. Among the most popular innovations that have positive dynamics of exploitation, the following technologies can be distinguished [2]: BIM (Building Information Modeling); 3D printing; recycled and eco-friendly materials; energy-saving methods; robotics; sensors; laser scanning; Big Data.

BIM (Building Information Modeling) – a technology that allows the work of several specialists in different fields to be combined into one whole, while creating a 3D model of an object filled with initial information and data. Working with the technology in question occurs through the use of data, which is stored on one server. Access to the server is open to all project participants.

3D printing – technology, the use of which makes it possible to print both structures, parts, elements necessary for construction work, and small building structures, such as bridges, cottages. The use of this technology is in demand among small businesses providing services for the production of materials and the construction of estate complexes [3].

Recycled and eco-friendly materials – the technology of processing human waste into materials, the use of which is relevant both in the construction industry and in many other industries, has leading indicators of demand among the population due to the preservation of the environment and natural resources.

Energy saving methods – The relevance of this method lies in the development of processing and efficient use of both solar and wind energy obtained through accumulation and distribution, while allowing to reduce the amount of emissions into the environment.

Robotization – technology that reduces the risk of injury to people or effective use of humans and resources in the workplace by using robots that are programmed and configured to perform specific tasks.

Sensors – The use of this technology allows for remote and immediate monitoring of the condition of various structures, the operation of which plays an important role in human life.

Laser scanning – a technology that allows for the creation of a 3D model of an object in the shortest possible time using points obtained with an accuracy of 0.5–5 mm through preliminary scanning [4]. The effective use of this technology can be identified in areas of the facility where access is difficult or where it is located in a zone that is dangerous to human life.

Big Data – a large flow of information and data, the processing and structuring of which is only possible on industrial computers, since everyday personal computers are not capable of accommodating and processing such a volume of data. Effective use of this technology allows achieving high results in many areas of human activity by providing analyzed information.

At the moment, the artificial intelligence technology stands out for its effectiveness in scientific literature and expert works [5]. Since this innovation is in its infancy, the scientific community is just beginning to delve deeper into its study by providing publicly available results of the application and operation of artificial intelligence both in laboratory and in real life conditions. This technology already has positive development dynamics, providing effective results of its application (Figure 1).

At the moment, the greatest demand for the use of artificial intelligence is in such countries and states as the USA, Russia, Poland, Germany, China and Japan [7]. Having an infinite reserve of development, artificial intelligence allows for continued experimental implementation and application in all spheres of human life.

Artificial intelligence (AI)

Progress does not stand still, scientists and private enthusiasts around the world put forward their innovations for the benefit of improving human life, achieving high marks from both the population and organizations that exploit scientific developments. Humanity has a desire to create an innovation that can replace conventional technologies and unite all of this into one, thereby achieving a positive result in the construction of vital areas. Artificial intelligence, if properly developed by scientists, is capable of providing humanity with a solution to this issue. The daily involvement of the population in the use of basic and primitive capabilities of artificial intelligence technology expands the range of studies and increases the likelihood of subsequent progress in the development of this area [8, 9].

Due to the continuous and persistent development of modern technologies capable of making a positive impact on the construction industry and human life in general, it becomes possible to integrate artificial intelligence into technologies that have received enormous recognition from world experts in the field of technology development, as well as specialists who have applied these innovations in the work process. For the most successful integration of artificial intelligence with modern technologies, it is necessary to thoroughly study each of the innovations, take into account the economic part of this issue, provide for possible unforeseen costs, and ensure high indicators of human safety, as well as the relevance of use with the possibility of subsequent potential development.

Currently, the most effective and proven innovations on the world stage are: *BIM; 3D printing; Laser scanning; Robotics* and *Big Data.* A detailed examination of these innovations does not raise the slightest doubt about the relevance and effectiveness of their use, both from an economic point of view and from the worker safety point of view. In addition to their proven positive qualities, these innovations lend themselves well to parallel integration with artificial intelligence technology, allowing for new opportunities in the construction industry, the formation of a new labor market, increased economic performance, increased productivity, and improved quality of human life. Therefore, it is necessary to thoroughly study and describe the options for possible integration of artificial intelligence with the above technologies with construction industry.
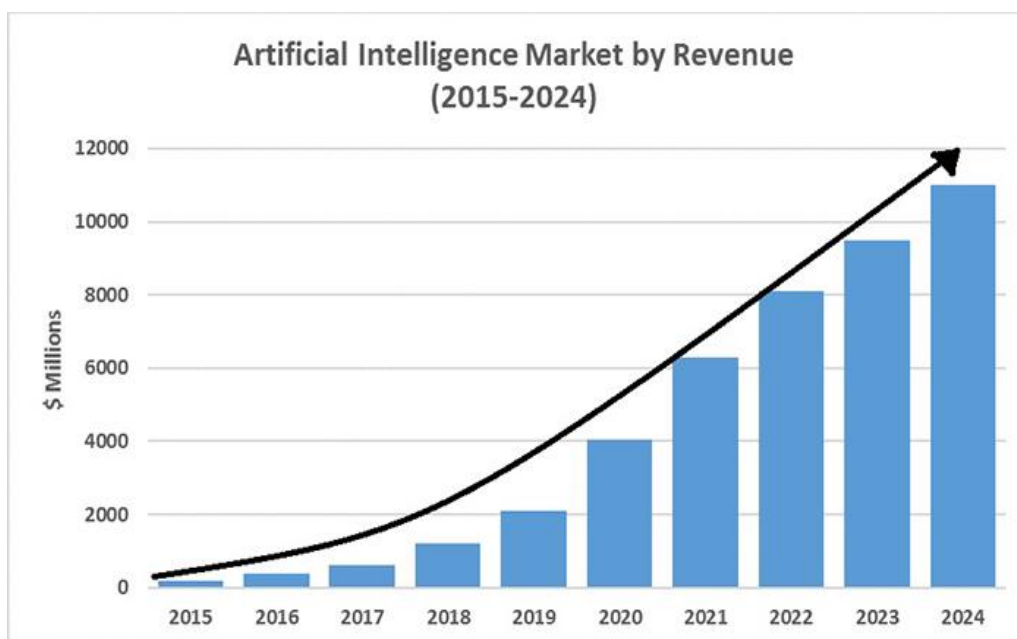
Figure 1 – Artificial Intelligence Market by Revenue [6]

1 BIM

The integration of artificial intelligence with BIM (Building Information Modeling) technology implies both the expansion of the possibilities of application of this technology and the increase of its coefficient of efficiency in the production of works. Considering the BIM technology with integrated artificial intelligence on the example of the initial creation of the information model is possible by analyzing the climatic region of the future building, to determine in advance the efficiency of using certain materials for the construction of the building, its finishing and insulation, determining the remaining service life, as well as the calculation of financial costs, offering variations of both design and structural solution of the building [10]. For the last few years the analysis of the climatic area is performed by providing climatic data to the artificial intelligence, which in turn analyses the area of interest, calculates the possible future climate change, foresees the occurrence of cataclysms and unfavorable conditions. The next step after completing the analysis is to present the results of the work. Based on the analysis, options for using materials in construction are proposed, which, according to the artificial intelligence, will ensure the longest service life for the building being constructed in this specific climatic zone. The estimated cost of purchasing these materials within the country under consideration will also be provided, along with recommendations for carrying out construction activities depending on the time of year. In this way, construction companies can save time on organizational work, while speeding up subsequent processes. For potential customers, this method of integrating artificial intelligence allows to determine in advance the economic benefits of construction works and compare the possible risks of construction and operation of the future object. At the agreement of the conducted analytical works at the initial stages follows the development and modelling of the information model of the building [11, 12]. Including the initial data obtained during the preliminary stage through the analysis of the climatic zone, the model is progressively enriched with informational data as it is developed (Figure 2). This allows the artificial intelligence to analyze deviations from the project and thereby calculate risks that may arise due to these discrepancies. In the future, when the customer receives the information model, which was developed using artificial intelligence, it is possible to continue using this technology without the necessary training, allowing only to supplement the initial data and information related to the adoption of new norms and regulations in the construction industry.

2 3D printing

3D printing currently one of the leading technologies in use around the world. This technology has gained interest among construction giants around the world, as well as among small commercial firms due to its positive qualities, offering both the customer and the contractor economically favorable conditions for the construction and subsequent operation of objects co-created on the basis of 3D printing. Due to the integration of artificial intelligence into 3D printing technology, it is possible to avoid both systemic and human errors in construction work. Artificial intelligence is able to take responsibility for selecting the optimal material and exclude possible operator errors, to carry out post-processing of printing, thereby eliminating its defects, saving time and materials for manual revision of the object, to determine the optimum height and density of the printing layer, as well as the trajectory (Figure 3).
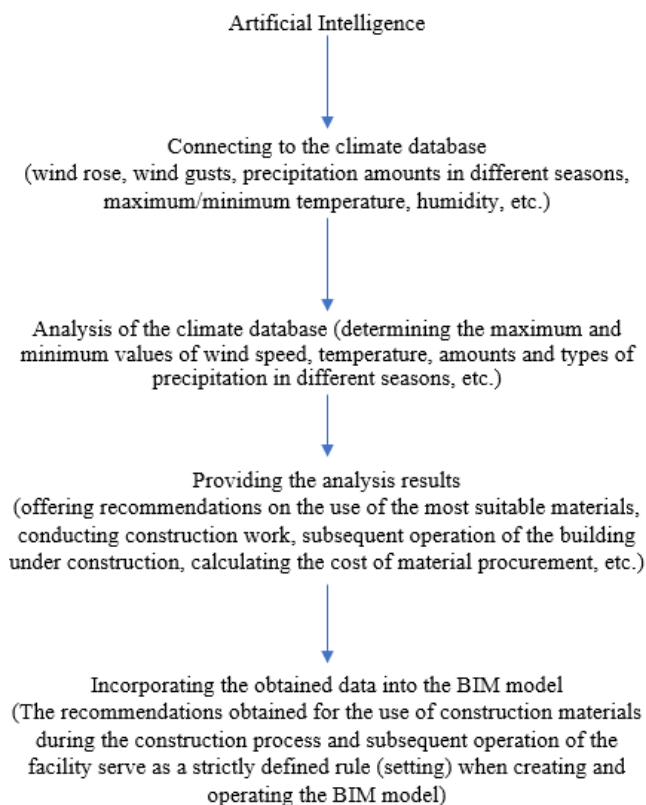

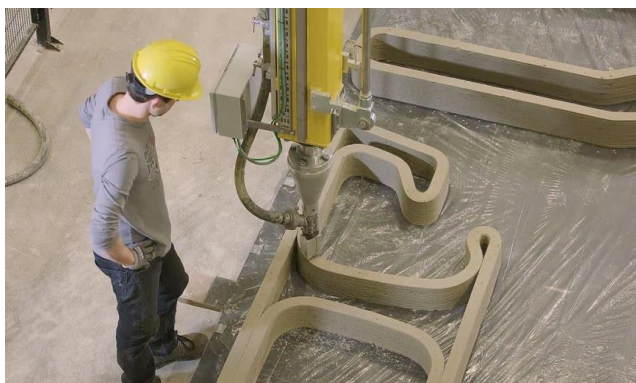**Figure 2** – Step-by-step process of AI interaction with BIM

Figure 3 – Example of 3D printing of a building [13]

The fundamental action in the development of an object using a 3D printer is the development of its model [3]. Often, the model of objects is taken from a catalogue or developed by specialists for a long time, leaving behind the possibility of errors made during construction, which are determined after printing. These errors can be related both to human factor, omission of some moments during construction, and systematically made. Artificial intelligence, in its turn, is able to generate and work out the model of the object, thus excluding the probability of occurrence of both errors of specialists, related to the human factor, and system errors, related to the malfunction of software, in parallel checking the model for the possible occurrence of collisions. This possibility of artificial intelligence integration allows to diversify and expand the library of models, thereby increasing the financial flow coming from customers, reduces the probability of errors in the construction of the model, saving time and money of both the customer and the contractor. This method, due to its low cost, is able at the state level to act as an environmentally friendly and cost-effective solution for the mass construction of housing facilities, allowing to reduce the growth of homelessness of citizens, increase the economic performance of the state, as well as to act as an innovative solution to housing problems after cataclysms [14]. In January 2025, the state of California experienced catastrophic destruction of housing units due to massive fires. The cost of reconstruction of the city limits is estimated in billions of dollars, the terms of construction works are estimated in several ten years, which entails an increase in the growth of prices for construction services and an increase in the number of people without permanent residence. This method of integrating artificial intelligence with 3D printing technology can act as a kind of airbag for the state of California, accelerating the process of construction of housing facilities, replacing the usual U.S. method of construction using flammable wooden frame, reducing the growth of the number of people in need of housing facilities [15].

3   Laser scanning

Laser scanning is in great demand among specialists in various spheres of human activity. In the construction industry this technology is an integral part of pre-project and other works. Thanks to its functionality and capabilities, such as the accuracy of scanning objects with a frequency of up to 0.5-5 mm, the ability to operate and conduct work at any time of day, without being tied to the daylight hours, full integration with the information model of the object, supplementing it with the necessary values, the possibility of remote scanning, which is quite relevant in situations where the necessary object is located in an inaccessible area or in a dangerous area for humans [4]. It should also be highlighted the fact that laser scanning has minimal costs in terms of work time, which contributes to the acceleration of all subsequent processes, saving labor costs of workers and increasing the speed of construction works. Integration of artificial intelligence with this technology can provide a more efficient result of scanning works due to automatic rework of the model created based on the results of scanning. Since laser scanning works can take place at any time of the day and do not depend on the daylight hours, the final result may often include collisions of the model, which are processed and refined by specialists, spending a lot of time. Artificial Intelligence is able to detect in advance the occurrence of collisions due to insufficient or unreliable data received on the server, informing the engineer managing the scanning process, who in turn will take measures

to re-run the work in the area with identified deficiencies. In addition to alerting specialists when conflicts are detected during scanning, the AI technology is able to perform model edits by recognising such areas and correcting them through analysis of the problem area. The analysis is based on studying the problem area from all 360 degrees, recognising the top and bottom points, width and height, depth and convexity of this part of the model [16]. This analysis allows to increase and refine the accuracy of the scanned model, which results in less time spent on re-scanning and manual refinement of the model. Taking into account the fact that laser scanning technology is often also used for scanning monuments, landmarks or other objects of old and dilapidated buildings, the drawing documentation for which is most often lost or in disrepair, the approaches to such objects have a high risk of injury for workers [17]. Laser scanning technology makes it possible to restore these data through its functionality, providing remote work, minimising the risk of injury, saving the number of specialists involved, and providing minimal costs in terms of both time and funding (Figure 4).
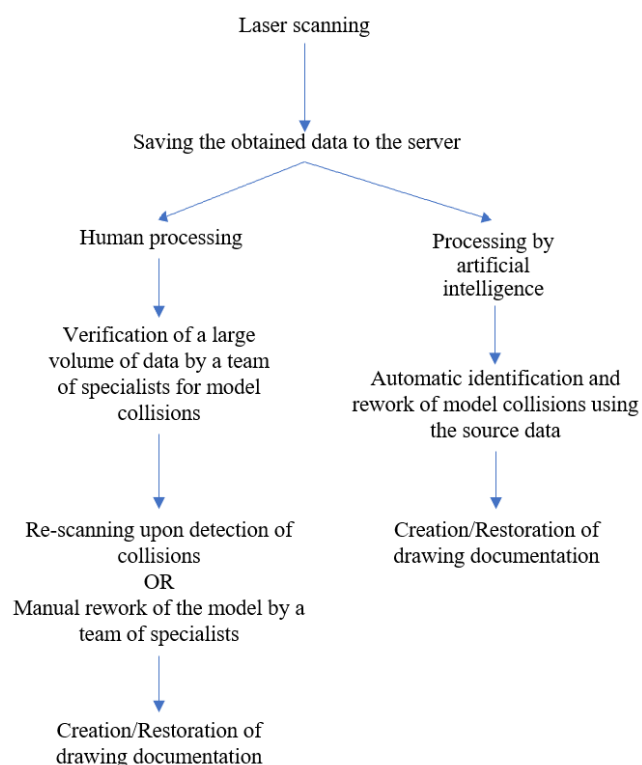

Figure 4 – Step-by-step process of AI interaction with laser scanning

4   Robotics

Robotics has excellent indicators of effective implementation in all spheres of human activity all over the world. The construction industry is also not ignoring this technology, replacing elementary human labor with less fussy and more cost-effective electronic units-robots by operating and implementing this technology everywhere, mankind began to think about the complete replacement of human labor force by trained robots, thus protecting their enterprises from human errors, as the production of works related to the use of this technology does not require daily rest and monthly payment of labor. By replacing live labor force, enterprises and various organizations, both giants on the world stage and small private businesses, have increased their economic performance in multiples tasks, allowing production to operate 24 hours a day [18]. In addition to the increased profit margins and reduced monthly costs, organizations also benefit from quality production, which is difficult to monitor without the intelligence to detect defective production. All it takes is the slightest machine malfunction in robotic production, which will lead to defective products, resulting in production losses. Integration of artificial intelligence with robotics can be a solution to this problem. Since robotics is associated with actions clearly defined by the software, there are mishaps that can be solved by deviating from the necessary work prescribed by the software, solving the problem and then returning to the task at hand (Figure 5).
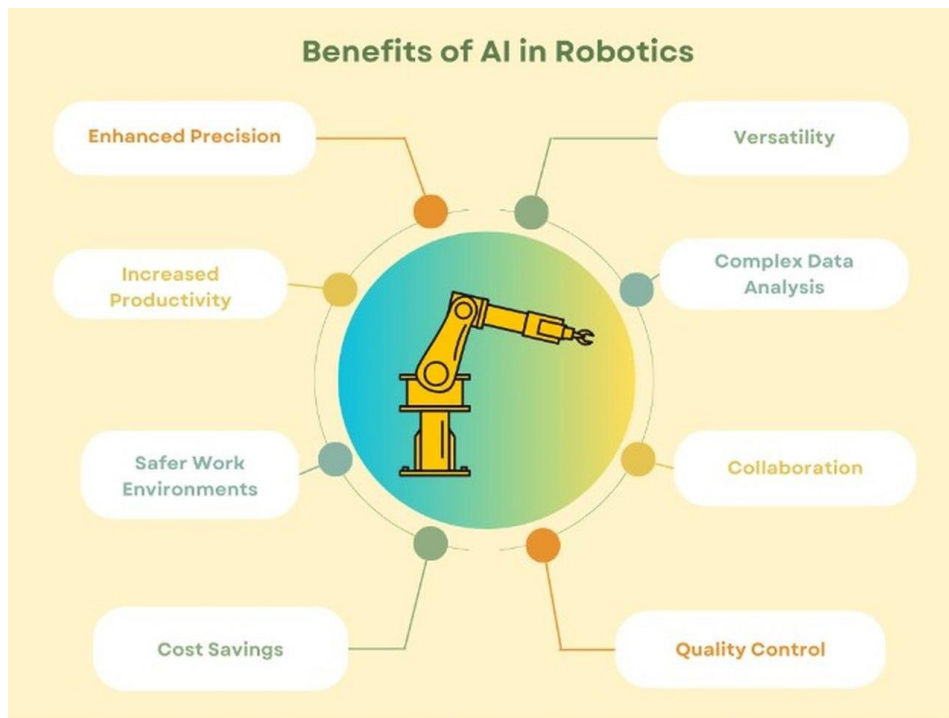
Figure 5 – Benefits of AI in Robotics [19]

The artificial intelligence integrated into the robot is able to eliminate this problem by analyzing the production situation. When a defect or atypicality of a product is recognized, the artificial intelligence analyses the entire production system, finding the catalyst of the problem, dealing with it itself, or, if it cannot be solved by itself, signaling the problem to a specialist. This integration helps to reduce the number of financial losses due to the production of defective products, to further reduce the workforce involved, to maintain and improve the quality of products, and to increase profit growth.

5 Big Data

Big Data technology is aggressively taking over all possible areas of human activity, and the construction industry has not been ignored. The application of this technology in construction has expanded the range of possibilities for specialists through their brilliant skills in analyzing large amounts of data. Specialists have had the opportunity to participate in the development and execution of those works whose rationality and benefits were widely questioned, with scepticism on the part of leading experts [20]. Experimenting with the implementation of bold projects, the embodiment of which occurred due to complex, but at the same time fast, by human standards, analysis, large companies have increased their economic performance, provided jobs for a large number of people, provided the world with an innovative view of making complex decisions. Integration of artificial intelligence with Big Data technology will allow analyzing and proposing informed decisions related to risks for companies. This method of integration will increase the speed of processing even more information and data flow, which entails a jump in financial gain for companies, reducing the growth of subsequent risks, ensuring the safety of both workers and subsequent exploiters [21]. Since the fundamental decision-making process is the analysis of possible risks, artificial intelligence integrated with Big Data technology will allow the final result to be put forward according to human thinking (Figure 6).

There are different types of risks, the impact of which is reflected in the degree of rejection or acceptance of a project. The human mind often evaluates each risk differently, and the occurrence of one risk can be overshadowed by decisions related to subsequent risks. Since Big Data technology is more focused on system-defined analyses, decision making can be reduced to rejecting the agreement of an emerging risk despite the fact that this risk can be ignored in favour of achieving a subsequent positive outcome [23]. Artificial intelligence, in turn, can approach this issue according to human thinking, while analyzing much more information.
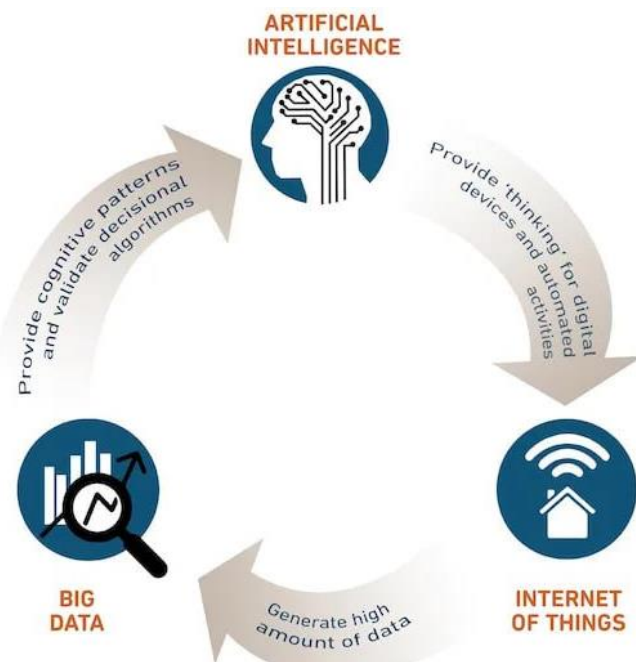

Figure 6 – The principle of Artificial Intelligence working with Big Data [22]

Advantages and disadvantages

Having studied each of the most popular innovations at the moment, capable of delivering high efficiency rates both in the construction industry and in everyday human life through integration with artificial intelligence technology, it is necessary to highlight their advantages and disadvantages, the influence of which can significantly affect both the subsequent development of technologies and the global innovation race.

1. Advantages:
– reduction of the amount of financial costs for project implementation;
– achieving high results in maintaining and improving working quality of workers and people;

− reduction in the number of workers involved in project implementation;
− reduction of risk occurrence at all stages of work;
− remote control of work;
− speed of work activities;
− approach to solving and implementing work issues in accordance with human thinking;
− providing opportunities for development;
− environmentally friendly activities with reduced use and release of harmful materials.

2. Disadvantages:
− reduction in the number of workers;
− lack of implementation and operation engineers;
− lack of funding due to lack of social acceptance;
− the initial stage of technology development with unsolved problems in the system;
− analysis of completed actions to identify errors.

Results
Having considered and analyzed the possibilities of artificial intelligence in integration with various innovative technologies, which occupy leading positions among specialists from all over the world in terms of demand and efficiency of task performance, it is necessary to draw a conclusion. Artificial Intelligence is at an early stage of development, with shortcomings in the development associated with the lack of qualified personnel capable of establishing the workflow of this technology and at the same time, despite the studied flaws of the system demonstrates high performance and quality of available labor. The development and study of this technology can lead to the realization of a completely new and universally demanded mechanism of doing business. Increasing the economic component and developing the technique of safe working process for both humans and the environment, artificial intelligence remains in the center of attention of specialists and scientists, which allows for the early stages of private development of this direction without requiring huge investments. Based on the above analysis, we can say:
− the impact of artificial intelligence on the construction industry is leading humanity to progress in replacing conventional thinking with an artificially created mind that is not inferior to human intelligence in any way;
− the number of people interested in studying and implementing artificial intelligence is growing at a rapid pace, contributing to the development of human thinking;
− innovations currently being used are capable of demonstrating even better results in terms of quality of work due to integration with artificial intelligence;
− increasing the amount of financial investment in the development of innovative technologies can improve and enhance the quality of human life;
− artificial intelligence technology has no boundaries in development, providing humanity with the opportunity to endlessly modernize and develop itself as the most important tool of life.

Conclusion
This research work can provide scientists and private enthusiasts with a knowledge base and capabilities of artificial intelligence technology for its further study and development. The implementation and use of artificial intelligence in everyday and professional human life is in great demand, providing an opportunity for both small and large businesses to develop and use products that have no analogues on the market, contributing to improving the quality of human life, increasing the economic indicators of countries, saving the costs of energy used and replenishing environmental reserves by reducing the use and emission of harmful substances into the atmosphere.

Publicly available indicators of the operation and implementation of artificial intelligence in all spheres of human life demonstrate positive results, the improvement of which has an unlimited reserve of development. On the world stage, artificial intelligence has proven itself to be a good thing, presenting humanity with clear benefits from its use.

In addition to the positive experience of using artificial intelligence technology, you should remember to control it. Scientists have not yet fully studied the perception of the technology in question of certain flows of information, data, and knowledge, which could subsequently have a negative impact on humanity as a whole.

References
1. Kashiripur, M. M. Vozmozhnosti iskusstvennogo intellekta v stroitel'noj industrii / M. M. Kashiripur, V. A. Nikolyuk // Vestnik Tomskogo gosudarstvennogo arhitekturno-stroitel'nogo universiteta. – 2024. – № 26 (1). – S. 163–178. – DOI: 10.31675/1607-1859-2024-26-1-163-178.
2. Iskusstvennyj intellekt v stroitel'stve. – URL: https://bim-info.ru/articles/iskusstvennyy-intellekt-v-stroitelstve/?ysclid=m6iy8lgea3788520490 (data obrashcheniya: 10.01.2025).
3. Kashiripur, M. M. Novye tendencii i innovacii v stroitel'stve: stroitel'stvo s pomoshch'yu 3D printera / M. M. Kashiripur, S. B. Garagozov // Inzhiniring i ekonomika: sovremennoe sostoyanie i perspektivy razvitiya : sbornik materialov studencheskoj nauch.-tekhn. konf. v ramkah XX Mezhdunar. nauch.-tekhn. konf. BNTU «Nauka – obrazovaniyu, proizvodstvu i ekonomike» i 78-j studencheskoj nauch.-tekhn. konf. BNTU, 4–5 maya 2022 g. / redkol: O. S. Golubova [i dr.] ; sost. N. A. Pashkevich. – Minsk : BNTU, 2022. – S. 94–99.
4. Innovacii v stroitel'noj otrasli. – URL: https://academy.peri.ru/blog/innovacii-v-stroitelnoj-otrasli-v-2023-godu?ysclid=m5zt1sohmt212267675 (data obrashcheniya: 10.01.2025).
5. Kievska, K. Vnedrenie iskusstvennogo intellekta v stroitel'noj otrasli i analiz sushchestvuyushchih tekhnologij / K. Kievska, S. Cyucyura // Tekhnologicheskij audit i rezervy proizvodstva. – 2021. – № 2. – S. 12–15.
6. Programmnoe obespechenie i tekhnologii // medrectechnologies.com. – URL: https://medrectech.com/industries/software-and-technology (data obrashcheniya: 17.04.2025).
7. Applications of Artificial Intelligence (AI) in the construction industry: A review of Observational Studies / A. Adeloye, O. Diekola, K. Delvin, C. Gbenga // Trends in Applied Sciences Research. – 2023. – Vol. 1, No. 4. – P. 42–52.
8. Kashiripur, M. M. Avtomaticheskij monitoring dlya slozhnyh sooruzhenij i infrastruktury goroda / M. M. Kashiripur, V. M. Borejko // Dorozhnoe stroitel'stvo i ego inzhenernoe obespechenie : materialy III Mezhdunar. nauch.-tekhn. konf. / sost. S. N. Sobolevskaya, E. M. ZHukovskij. – Minsk : BNTU, 2022. – S. 90–94.
9. Iskusstvennyj intellekt i additivnye tekhnologii: perspektivy vzaimodejstviya. Blog 3D-ekspertov // IQB technologies.ru. – URL: https://blog.iqb.ru/ai-3d-printing-intersection/?ysclid=m6ixhtensc502604765 (data obrashcheniya: 08.01.2025).
10. Kashiripur, M. M. Razrabotka podhodyashchej metodologii upravleniya stroitel'nymi proektami / M. M. Kashiripur, A. M. Al'malegi // Inzhiniring i ekonomika: sovremennoe sostoyanie i perspektivy razvitiya : sbornik materialov studencheskoj nauch.-tekhn. konf. v ramkah XX Mezhdunar. nauch.-tekhn. konf. BNTU «Nauka – obrazovaniyu, proizvodstvu i ekonomike» i 78-j studencheskoj nauch.-tekhn. konf. BNTU, 4–5 maya 2022 g. / redkol.: O. S. Golubova [i dr.] ; sost. N. A. Pashkevich. – Minsk : BNTU, 2022. – S. 78–83.
11. Kashiripur, M. M. Tekhnologii chetvertoj volny v stroitel'stve i arhitekture: ot idei do realizacii (chast' 2) / M. M. Kashiripur // Gradostroitel'stvo i arhitektura. – 2024. – T. 14, № 3. – C. 178–193. – DOI: 10.17673/Vestnik.2024.03.22.
12. Kashiripur, M. M. Tekhnologii chetvertoj volny v stroitel'stve i arhitekture: ot idei do realizacii (CH. 3: Primery primeneniya tekhnologij chetvertoj volny v stroitel'stve i arhitekture) / M. M. Kashiripur // Gradostroitel'stvo i arhitektura. – 2024. – T. 14. – № 4. – C. 171–179. – DOI: 10.17673/Vestnik.2024.04.24
13. Avstralijskaya kompaniya Mirreco budet pechatat' doma na 3D-printere // 3dprint.com. – URL: https://3dprint.com/217838/mirreco-to-3d-print-hemp/amp (data obrashcheniya: 18.04.2025).
14. Kashiripoor, M. M. Metaverse city: definition and direction development for urban planning and architecture / M. M. Kashiripoor // Vestnik of Brest State Technical University. – 2023. – No. 3 (132). – P. 2–10. – DOI: 10.36773/1818-1112-2023-132-3-2-10.
15. Kashiripur, M. M. Innovacii v stroitel'stve: stroitel'stvo domov iz othodov / M. M. Kashiripur, I. V. Kuhareva // Inzhiniring i ekonomika: sovremennoe sostoyanie i perspektivy razvitiya : sbornik materialov studencheskoj nauch.-tekhn. konf. v ramkah XX Mezhdunar. nauch.-tekhn. konf. BNTU «Nauka – obrazovaniyu, proizvodstvu i ekonomike» i 78-j studencheskoj nauch.-tekhn. konf. BNTU, 4–5 maya 2022 g. / redkol.: O. S. Golubova [i dr.] ; sost. N. A. Pashkevich. – Minsk : BNTU, 2022. – S. 100–103.
16. Kak s pomoshch'yu lazernogo 3D-skanirovaniya sokratit' riski pri stroitel'stve i rekonstrukcii zdanij i ob"ektov // digital-build.ru. – URL: https://digital-build.ru/kak-s-pomoshhyu-lazernogo-3d-skanirovaniya-sokratit-riski-pri-stroitelstve-i-rekonstrukczii/?ysclid=m6iy1xrd6h211821245 (data obrashcheniya: 07.01.2025).

17. Kashiripur, M. M. Nadlezhashchaya metodologiya avtomatizirovannogo monitoringa v processe stroitel'stva / M. M. Kashiripur, A. A. Al'-Sajyab // Inzhiniring i ekonomika: sovremennoe sostoyanie i perspektivy razvitiya : sbornik materialov studencheskoj nauch.-tekhn. konf. v ramkah XX Mezhdunar. nauch.-tekhn. konf. BNTU «Nauka – obrazovaniyu, proizvodstvu i ekonomike» i 78-j studencheskoj nauch.-tekhn. konf. BNTU, 4–5 maya 2022 g. / redkol.: O. S. Golubova [i dr.] ; sost. N. A. Pashkevich. – Minsk : BNTU, 2022. – S. 84–88.
18. Eber, V. Potencial iskusstvennogo intellekta v upravlenii stroitel'stvom / V. Eber // Organizaciya, tekhnologiya i upravlenie v stroitel'stve: mezhdunarodnyj zhurnal. – 2020. – № 12. – P. 2053–2063.
19. II v Robototekhnike. – URL: https://www.technolynx.com/post/ai-in-robotics (data obrashcheniya: 18.04.2025).
20. Kashiripur, M. M. Avtomaticheskij monitoring dlya slozhnyh sooruzhenij i infrastruktury goroda / M. M. Kashiripur, V. M. Borejko // Dorozhnoe stroitel'stvo i ego inzhenernoe obespechenie : materialy III Mezhdunar. nauch.-tekhn. konf. / sost. S. N. Sobolevskaya, E. M. ZHukovskij. – Minsk : BNTU, 2022. – S. 90–94.
21. Ispol'zovanie II v stroitel'stve: primery i budushchee // Gectaro.com : delovoj portal. – URL: https://gectaro.com/blog/tpost/r71jb8yjx1-ispolzovanie-ii-v-stroitelstve-primeri-i?ysclid=m6i7mulcwq9216836 (data obrashcheniya: 08.01.2025).
22. Desyat' osnovnyh tendencij v upravlenii Internetom. – URL: https://humainism.ai/blogs/ten-major-trends-in-internet-governance-2017-mid-year-review (data obrashcheniya: 20.04.2025).
23. Artificial Intelligence for Big Data & How They Work Together // Medium.com. – URL: https://medium.com/@jonraihan/artificial-intelligence-for-big-data-how-they-work-together-6e489f28a831 (data obrashcheniya: 03.01.2025).

Список цитированных источников
1. Каширипур, М. М. Возможности искусственного интеллекта в строительной индустрии / М. М. Каширипур, В. А. Николюк // Вестник Томского государственного архитектурно-строительного университета. – 2024. – № 26 (1). – С. 163–178. – DOI: 10.31675/1607-1859-2024-26-1-163-178.
2. Искусственный интеллект в строительстве. – URL: https://bim-info.ru/articles/iskusstvennyy-intellekt-v-stroitelstve/?ysclid=m6iy8lgea3788520490 (дата обращения: 10.01.2025).
3. Каширипур, М. М. Новые тенденции и инновации в строительстве: строительство с помощью 3D принтера / М. М. Каширипур, С. Б. Гарагозов // Инжиниринг и экономика: современное состояние и перспективы развития : сборник материалов студенческой науч.-техн. конф. в рамках XX Междунар. науч.-техн. конф. БНТУ «Наука – образованию, производству и экономике» и 78-й студенческой науч.-техн. конф. БНТУ, 4–5 мая 2022 г. / редкол.: О. С. Голубова [и др.] ; сост. Н. А. Пашкевич. – Минск : БНТУ, 2022. – С. 94–99.
4. Инновации в строительной отрасли. – URL: https://academy.peri.ru/blog/innovacii-v-stroitelnoj-otrasli-v-2023-godu?ysclid=m5zt1sohmt212267675 (дата обращения: 10.01.2025).
5. Киевска, К. Внедрение искусственного интеллекта в строительной отрасли и анализ существующих технологий / К. Киевска, С. Цюцюра // Технологический аудит и резервы производства. – 2021. – № 2. – С. 12–15.
6. Программное обеспечение и технологии // medrectechnologies.com. – URL: https://medrectech.com/industries/software-and-technology (дата обращения: 17.04.2025).
7. Applications of Artificial Intelligence (AI) in the construction industry: A review of Observational Studies / A. Adeloye, O. Diekola, K. Delvin, C. Gbenga // Trends in Applied Sciences Research. – 2023. – Vol. 1, No. 4. – P. 42–52.
8. Каширипур, М. М. Автоматический мониторинг для сложных сооружений и инфраструктуры города / М. М. Каширипур, В. М. Борейко // Дорожное строительство и его инженерное обеспечение : материалы III Междунар. науч.-техн. конф. / сост. С. Н. Соболевская, Е. М. Жуковский. – Минск : БНТУ, 2022. – С. 90–94.
9. Искусственный интеллект и аддитивные технологии: перспективы взаимодействия. Блог 3D-экспертов // IQB technologies.ru. – URL: https://blog.iqb.ru/ai-3d-printing-intersection/?ysclid=m6ixhtensc502604765 (дата обращения: 08.01.2025).
10. Каширипур, М. М. Разработка подходящей методологии управления строительными проектами / М. М. Каширипур, А. М. Альмалеги // Инжиниринг и экономика: современное состояние и перспективы развития : сборник материалов студенческой науч.-техн. конф. в рамках XX Междунар. науч.-техн. конф. БНТУ «Наука – образованию, производству и экономике» и 78-й студенческой науч.-техн. конф. БНТУ, 4–5 мая 2022 г. / редкол.: О. С. Голубова [и др.] ; сост. Н. А. Пашкевич. – Минск : БНТУ, 2022. – С. 78–83.
11. Каширипур, М. М. Технологии четвертой волны в строительстве и архитектуре: от идеи до реализации (часть 2) / М. М. Каширипур // Градостроительство и архитектура. – 2024. – Т. 14, № 3. – С. 178–193. – DOI: 10.17673/Vestnik.2024.03.22.
12. Каширипур, М. М. Технологии четвертой волны в строительстве и архитектуре: от идеи до реализации (Ч. 3: Примеры применения технологий четвертой волны в строительстве и архитектуре) / М. М. Каширипур // Градостроительство и архитектура. – 2024. – Т. 14. – № 4. – С. 171–179. – DOI: 10.17673/Vestnik.2024.04.24
13. Австралийская компания Mirreco будет печатать дома на 3D-принтере // 3dprint.com. – URL: https://3dprint.com/217838/mirreco-to-3d-print-hemp/amp (дата обращения: 18.04.2025).
14. Kashiripoor, M. M. Metaverse city: definition and direction development for urban planning and architecture / M. M. Kashiripoor // Vestnik of Brest State Technical University. – 2023. – No. 3 (132). – P. 2–10. – DOI: 10.36773/1818-1112-2023-132-3-2-10.
15. Каширипур, М. М. Инновации в строительстве: строительство домов из отходов / М. М. Каширипур, И. В. Кухарева // Инжиниринг и экономика: современное состояние и перспективы развития : сборник материалов студенческой науч.-техн. конф. в рамках XX Междунар. науч.-техн. конф. БНТУ «Наука – образованию, производству и экономике» и 78-й студенческой науч.-техн. конф. БНТУ, 4–5 мая 2022 г. / редкол.: О. С. Голубова [и др.] ; сост. Н. А. Пашкевич. – Минск : БНТУ, 2022. – С. 100–103.
16. Как с помощью лазерного 3D-сканирования сократить риски при строительстве и реконструкции зданий и объектов // digital-build.ru. – URL: https://digital-build.ru/kak-s-pomoshhyu-lazernogo-3d-skanirovaniya-sokratit-riski-pri-stroitelstve-i-rekonstrukczii/?ysclid=m6iy1xrd6h211821245 (дата обращения: 07.01.2025).
17. Каширипур, М. М. Надлежащая методология автоматизированного мониторинга в процессе строительства / М. М. Каширипур, А. А. Аль-Сайяб // Инжиниринг и экономика: современное состояние и перспективы развития : сборник материалов студенческой науч.-техн. конф. в рамках XX Междунар. науч.-техн. конф. БНТУ «Наука – образованию, производству и экономике» и 78-й студенческой науч.-техн. конф. БНТУ, 4–5 мая 2022 г. / редкол.: О. С. Голубова [и др.] ; сост. Н. А. Пашкевич. – Минск : БНТУ, 2022. – С. 84–88.
18. Эбер, В. Потенциал искусственного интеллекта в управлении строительством / В. Эбер // Организация, технология и управление в строительстве: международный журнал. – 2020. – № 12. – P. 2053–2063.
19. ИИ в Робототехнике. – URL: https://www.technolynx.com/post/ai-in-robotics (дата обращения: 18.04.2025).
20. Каширипур, М. М. Автоматический мониторинг для сложных сооружений и инфраструктуры города / М. М. Каширипур, В. М. Борейко // Дорожное строительство и его инженерное обеспечение : материалы III Междунар. науч.-техн. конф. / сост. С. Н. Соболевская, Е. М. Жуковский. – Минск : БНТУ, 2022. – С. 90–94.
21. Использование ИИ в строительстве: примеры и будущее // Gectaro.com : деловой портал. – URL: https://gectaro.com/blog/tpost/r71jb8yjx1-ispolzovanie-ii-v-stroitelstve-primeri-i?ysclid=m6i7mulcwq9216836 (дата обращения: 08.01.2025).
22. Десять основных тенденций в управлении Интернетом. – URL: https://humainism.ai/blogs/ten-major-trends-in-internet-governance-2017-mid-year-review (дата обращения: 20.04.2025).
23. Artificial Intelligence for Big Data & How They Work Together // Medium.com. – URL: https://medium.com/@jonraihan/artificial-intelligence-for-big-data-how-they-work-together-6e489f28a831 (дата обращения: 03.01.2025).