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EXPERIENCE IN THE USE OF ARTIFICIAL INTELLIGENCE IN MAKING MANAGERIAL DECISIONS IN THE CONSTRUCTION OF REAL ESTATE

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The article deals with the problem of using artificial intelligence (AI) in the construction sector, since these systems are not being actively implemented, though AI capabilities can significantly simplify the entire process of erecting buildings and structures, including the development of improved business plans, adjusting the progress of the project directly on the construction site, making suggestions for management decisions in case of deviations from schedules and logistics plans. The experience of Chinese and domestic construction organizations in this area has been studied. A scheme for the implementation of an artificial intelligence system in construction production has been developed, the necessary resources for the development of machine learning in this area have been analyzed. It is concluded that for correct decision-making it is necessary to apply the principles of discrete mathematics, in particular, the distribution of expert assessments accepted as linguistic variables on the Harrington desirability scale with the construction of the membership function.

Keywords: artificial intelligence, BIM modeling, construction organization, Harrington scale, generative design, neural network, information technology, diagrids

1 INTRODUCTION

In construction, heuristic methods of managerial decision-making are widely used, which are reduced to creative techniques that cannot be called optimal. Heuristics implies choosing a decision that was previously accepted as correct, since it has already given a positive result. Nevertheless, it was on the basis of heuristics that such a program as "General Problem Solver" was developed, in which the first attempts were made to comprehensively solve intellectual problems. Further software development was based on a creative approach and self-learning programs. Thus, the method of embedding the source object into the system, which should be transformed into the final, desired object through a series of intermediate iterations, has acquired special significance. It is on this principle that the construction of objects is organized: for example, first there is an empty construction site, on which the construction of a house is consistently carried out. The final object here is a finished building.

It can be assumed that control over the construction of an object can be entrusted to artificial intelligence (hereinafter – AI). The implementation of this does not cause any special difficulties and can be presented in the form of a simple algorithm(Fig.1).

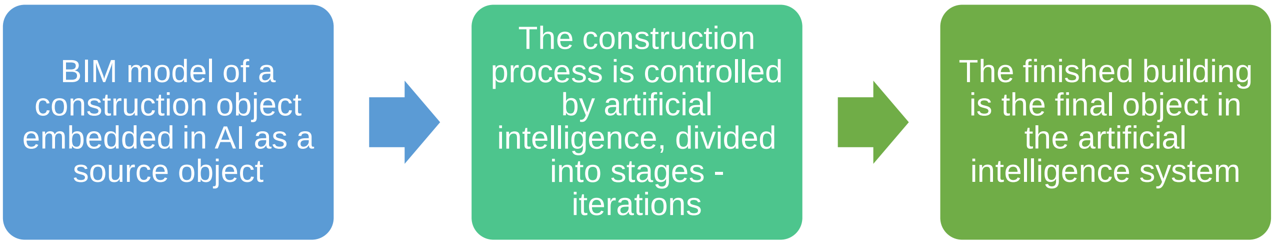

Fig. 1. Algorithm for the application of artificial intelligence in the construction sector

Of course, this is a simplified scheme, since there are a number of problems and unsolved problems here. First of all, it is inertia of thinking and unwillingness of representatives of the construction sector to introduce innovations. As a result, if BIM technologies have been successfully used abroad for a long time, then in Russia this process is at an initial stage. In domestic practice, the introduction of AI is still perceived cautiously, and the translation of "artificial intelligence" for some reason has an anthropomorphic character, although reasonableness here is relative and limited by the same mathematical logic laid down by man and assuming, again, a human evaluation of the results.

Although there are already separate attempts to completely transfer construction management to machines and they will be discussed further, nevertheless, the algorithms on the basis of which artificial intelligence works are very complex and difficult to control. Therefore, today it makes sense to develop hybrid systems that would make it possible to make not so much an operator and a manager of a construction project as an effective assistant.

2 MATERIALS AND METHODS

How the control scheme should be organized in terms of stochastic processes and dynamic changes in the implementation of construction projects. Of course, the principle by which the system should work in the management of construction production should be based on mathematical modeling, where the main approach will be to identify deviations from the set values of any parameter and make management decisions [1,2]. Adjustments are made provided that the deviation is of critical importance or is of a massive nature. The system should be provided with a sufficient volume of source data of both macroeconomic and intra-industry nature, a complete list of current legislation in the construction sector, have access to the necessary online systems, be constantly updated and developed.

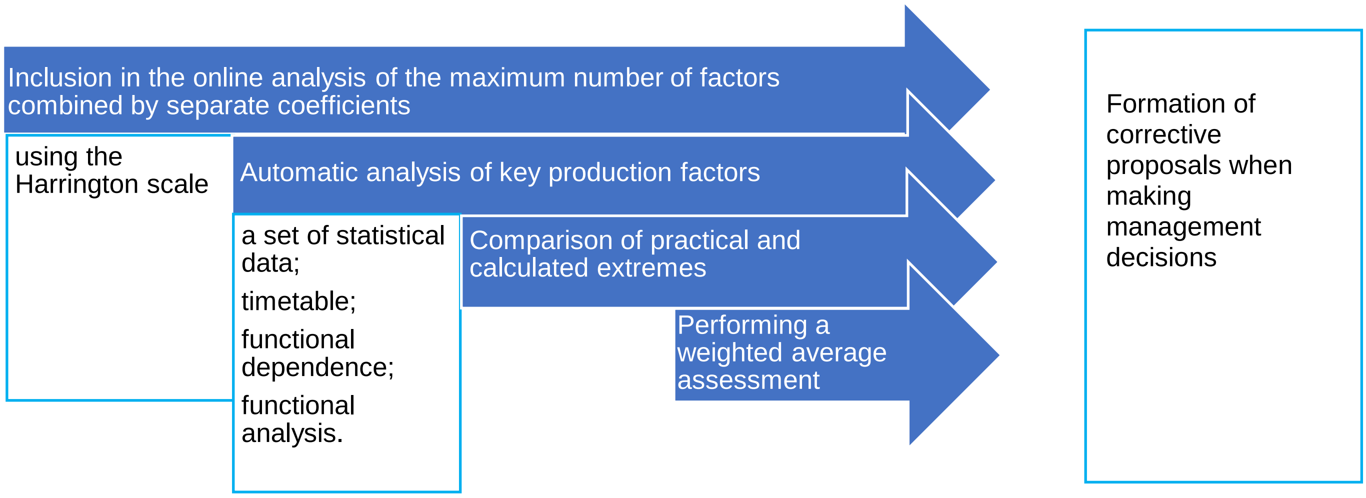

Fig. 2. The mechanism of automated analytical evaluation in matters of critical corrective proposals of the artificial intelligence system

The mechanism of automated analytical evaluation in matters of critical corrective proposals of the artificial intelligence system (Fig. 2) for enterprises should be based on the following parameters.

1. Inclusion in the online analysis of the maximum number of factors combined by separate coefficients, which are determined by combining pie charts with the Harrington scale and calculated by an individual method for each factor. All indicators are combined into a single database.

The processes occurring during the construction are well described by the discrete mathematics of sets. Of course, the construction process is influenced by an infinite number of factors, but in practice it is irrational to attribute the organization and management of construction to the domain of infinite sets, since it is not difficult to determine the list of basic parameters that need to be guided. So, if we are talking about logistics or compliance with the construction schedule of the facility, then time, labor and material resources are key here. In this case, the Harrington scale sets the desired level for these indicators [3,4]. However, if we talk about making decisions on a specific investment project, the expert manager should rely on a much broader list of criteria. And if financial indicators can be pre-calculated, it is not always possible to unambiguously assess all related aspects. This is where the Harrington scale is especially relevant, which will reflect the probability distribution of an event (for example, achieving the required level of profit), indicating the degree of probability from very high to very low [5]. This approach will allow us to determine the degree of deviation of each indicator from a given value – a certain ideal for this parameter. Moreover, a risk assessment may be a special criterion in such cases, because, despite the advantages, if the construction of this real estate object is planned, for example, in a seismically dangerous zone, then it is necessary to evaluate this indicator. Despite the fact that investment risks are assessed in various ways, but both from the point of view of determining the degree of risk, and in general, expert assessment methods are widely used when making decisions about investments in construction, in which, for example, a certain numerical value is set for each level of risk [6]. However, in such cases, a specific number will not be completely correct and must be placed in probability ranges, and the estimate itself is relative. It is difficult to overestimate the introduction of artificial intelligence here, for which it is proposed to modify the method of expert assessments and apply the fuzzy inference system, first invented by Lotfi Zadeh. Algorithms based on the principles of fuzzy logic allow assigning numerical values to such vague concepts as "very good", "better", "more profitable". At the input, the manager can set ranges of similar floating estimates, and the program based on the theory of fuzzy sets will process the data and output digital values again. This approach will allow integrating expert assessments, where both a human and an artificial intelligence based on statistics and the entire array of data obtained can act as an expert.

Based on the input elements, the so-called membership function is constructed, which shows how much an element of a universal set belongs to a fuzzy set [7]. Thus, in the case of assessing logistics at a construction site, each element of the process (workers, machines) is a subset evaluated on five levels (Harrington scale) from "very good" to "very bad", which in this case is called a linguistic variable of a fuzzy universal set of all possible state assessments are limited to specified percentage intervals. For an investment project, this is, respectively, "very low risk", "low", "medium", "high", "very high risk". The evaluation result varies from 0 (absolutely does not belong to the set) to 1 (completely belongs to the set).

Thus, the expert assessments introduced in this case are arranged in accordance with the Harrington desirability scale and depending on the formula:

$$У= \exp(-\exp(-y)) \quad (1)$$

where y is the level of the desirability coefficient determined by the expert (a linguistic variable for the membership function) relative to the base level.

Next, a software algorithm of the so-called fuzzy inference rule is formed, consisting of a sequential evaluation of all parameters and the formation of the final result. Any corrective suggestions can be accepted according to the same principle, setting any linguistic variables as input to artificial intelligence.

2. Automatic analysis of key production factors (sales, cost, production volume, etc.), including:
- the system receives a set of statistical data by obtaining an array of all necessary information;
- drawing up traffic schedules taking into account all key factors;
- finding the functional dependence for these graphs (actually converting discrete values into analog dependence), for example, by the least squares method;
- analysis of the function by finding the extremum of the function by double differentiation.
3. Comparison of practical and calculated extremes.
4. Performing a weighted average estimate based on a given trigger threshold to transition to a decision-making model.

The next step should be the development of a methodology for the formation of corrective proposals when making managerial decisions.

3 RESULTS AND DISCUSSION

Taking into account these factors, we will consider the possibilities of introducing artificial intelligence at each stage of construction production.

Any construction project begins with an idea, which is embodied in the form of a business plan submitted to the relevant local authorities. At this stage, artificial intelligence can be used both to assess risks and to coordinate actions with the state, investors and developers. For example, connecting the databases of a construction company to the Unified Information System of Housing Construction in Russia, the Unified State Register of Expert Opinions of Construction Objects (hereinafter referred to as the Unified State Register), official construction and legal resources allows you to significantly expand the information base on the basis of which certain management decisions are made. Thus, all the risks of a specific business plan can become an initial set of data that will be analyzed and taken into account by the AI when developing a financial model. By itself, the economic calculation, which at the moment is usually performed manually in Microsoft Excel, can also be performed by a more intelligent system [8, 9].

Of course, the most promising for making managerial decisions are neural networks that can self-learn and issue a decision even on the basis of incomplete data, clearing them of probabilistic "noise" [10, 11]. Such systems can evaluate the prospects of a business project, give the probability of profitability of the project not as it happens in a conventional financial model based on a simple analysis of profitability, payback period, liquidity and other exclusively economic indicators, where risks are assessed as inherent reducing factors, but in a complex, taking into account all available data. AI here acts as an independent and unbiased expert, whose opinion you can rely on. Thus, machine learning can help not only to plan and optimize the budget of the future facility correctly, but also to adjust the construction time of the facility, create an improved logistics scheme, help with document management, provided that the necessary DBMS is connected [12, 13].

It is impossible not to say that artificial intelligence is indispensable at the stage of direct design of buildings and allows you to perform the most complex architectural calculations [14, 15]. The leading direction here is the introduction of building information modeling (BIM). Recently, two large companies working in the field of analytical and software solutions for integrating workflows in the construction industry – Dodge Data & Analytics and Autodesk - have conducted extensive research in this area. Analysts were interested in the applied implementation and development of BIM and artificial intelligence in the construction industry [16]. The growth of BIM adoption in Europe is shown in the diagram (Fig. 3).

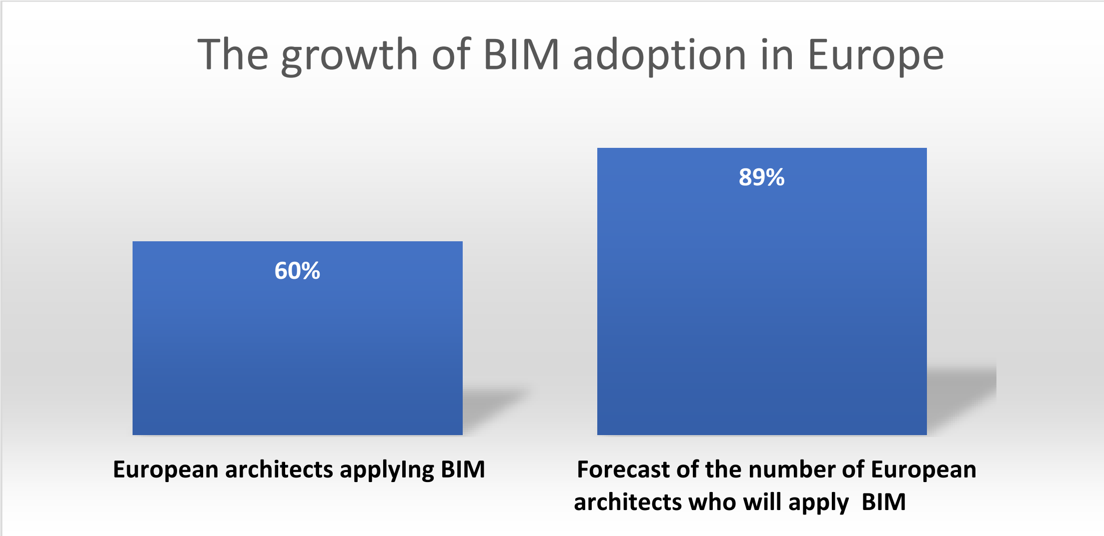

Fig. 3. The growth of BIM implementation in Europe

Surveys conducted among the top management of European construction and design groups, reports of leading architects clearly show a significant reduction in project risks for 6 groups of indicators, as shown in the diagram (Fig. 4), and this is the main goal of implementing such systems.

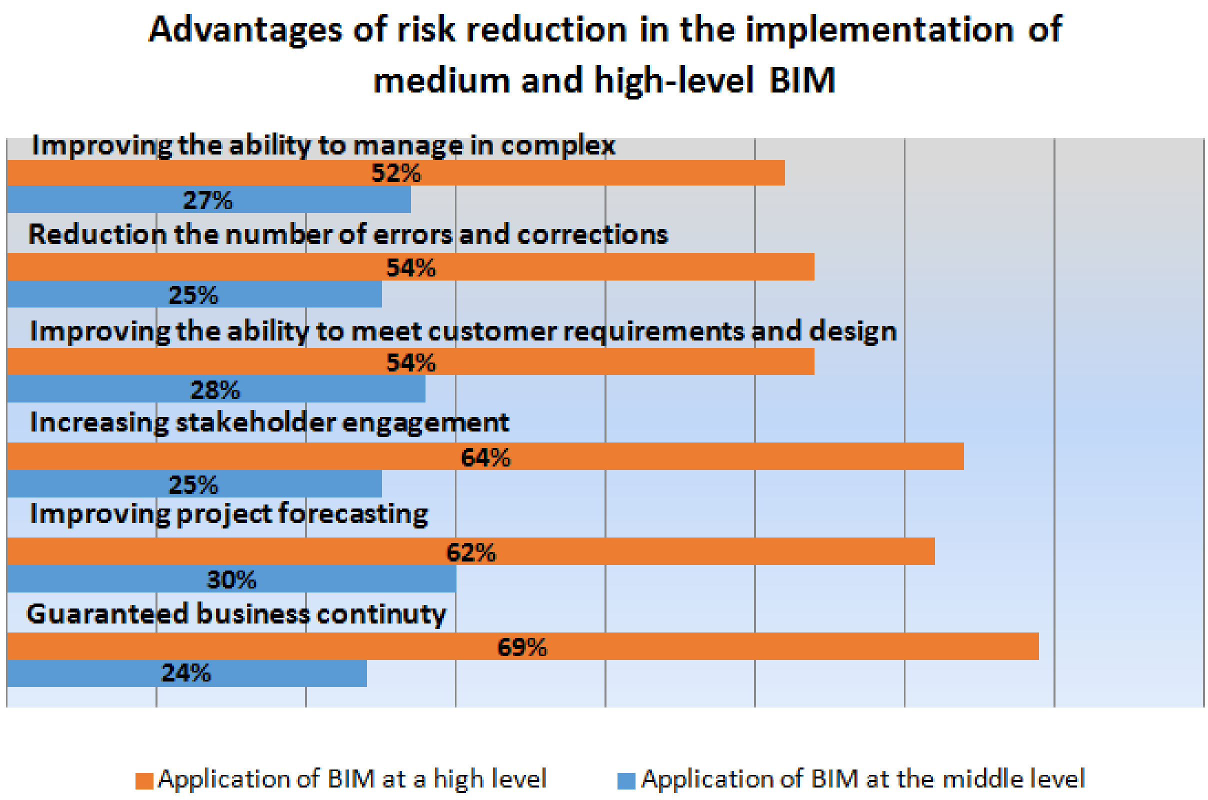

Fig.4. Risk reduction in the implementation of BIM in the European construction industry

Fig. 5. Autodesk office in Toronto, designed with the help of artificial intelligence

And this opens up the widest opportunities for project management, because it allows you to choose the right solution. This delegation of part of the powers of a human architect to artificial intelligence is called generative design. For example, the same company Autodesk has set a seemingly difficult task for AI – not just to design the office of the Canadian branch of the company, but to create exactly the best option, taking into account all the conditions of the place and the requirements for lighting, style, security, etc. The machine went through thousands of options and after several days of "thinking" offered a few closest to the required ones. As a result of the work, the flowers are even tended here, and the building fits perfectly into the surrounding urban environment (Fig. 5).

Danil Nagy, designer and senior researcher at the Autodesk The Living research group, said in an interview: "The starting point for our use of generative design was an attempt to determine which aspects of the architectural design process were the most difficult and difficult for people to think about, as well as figure out how to find a computer that would work with them for us." Generative design programs can play a crucial role in helping architects solve practical problems that arise during the design process, such as creating a spatial layout. In addition, this approach makes it possible to increase the economic efficiency of the entire development process by creating projects, since the basis of all tutu is improved communication and coordination between all project participants. For example, a building transformed into a point cloud using a 3D scanner can be studied by any user, be it a designer or the customer of the project himself. Visual representation of information using VR-reality allows a potential buyer of an apartment to walk through his future real estate, which will undoubtedly facilitate the sale of housing. Thus, since architecture and construction is not only a process of creativity and material creation of buildings, but also a long, complex interaction with the contractor, the customer, government agencies, etc., simplification and acceleration in this area inevitably leads to lower costs at all levels. Thus, generative design makes it possible to achieve previously impossible levels of construction planning and direct implementation of projects, maximize efficiency and accelerate the involvement of stakeholders [18].

However, information models of buildings and structures and generative design are only structural parts of intelligent systems proposed for implementation in the construction industry. An integrated approach to maintenance, which perceives the management of construction projects as something holistic and time-controlled, is the most correct strategy for the formation of a management system in the construction of buildings and structures.

A striking example here is the construction of the headquarters of the Central Television of China in Beijing (Fig. 6), designed by one of the most famous architects in the world, Rem Koolhaas. This unique building with a height of 234 meters is an unusual closed contour that visually has no supports and hangs in the air. However, in fact, this seismically robust building was precisely calculated using artificial intelligence and implemented using diagrid – uneven tubular structures that allow you to redistribute weight so that you can defy gravity. During the implementation of the project, artificial intelligence was widely used, to which part of the human functions in project management were transferred. Chinese builders do not stop there and in 2024 they plan to build a giant dam that will be printed on a 3D printer, and the entire construction process will be completely controlled by artificial intelligence without human participation. It is assumed that the complete elimination of the human factor will minimize errors during the construction of an important hydrological facility.

Of course, such boldness and breadth are due to the fact that the Chinese construction complex has long been widely used and has extensive experience in the construction of the most unusual buildings and structures. Russian builders are just beginning to introduce artificial intelligence and smart home systems, but the first successes are already there. For example, an elite residential complex "Meltzer Hall" is being built in St. Petersburg (Fig. 7), which has caused the most heated discussions since the publication of the project, which did not prevent the Studio 44 project from becoming the winner of the international Golden Trezzini award in the field of design and architecture. This residential complex was designed with extensive use of BIM technologies. Architectural solutions are surprising, the technological equipment of the future complex also meets the highest requirements, introducing a smart home system up to voice control of elevators. The construction itself in the Petrogradsky district of St. Petersburg is planned to be carried out again under the control of artificial intelligence.

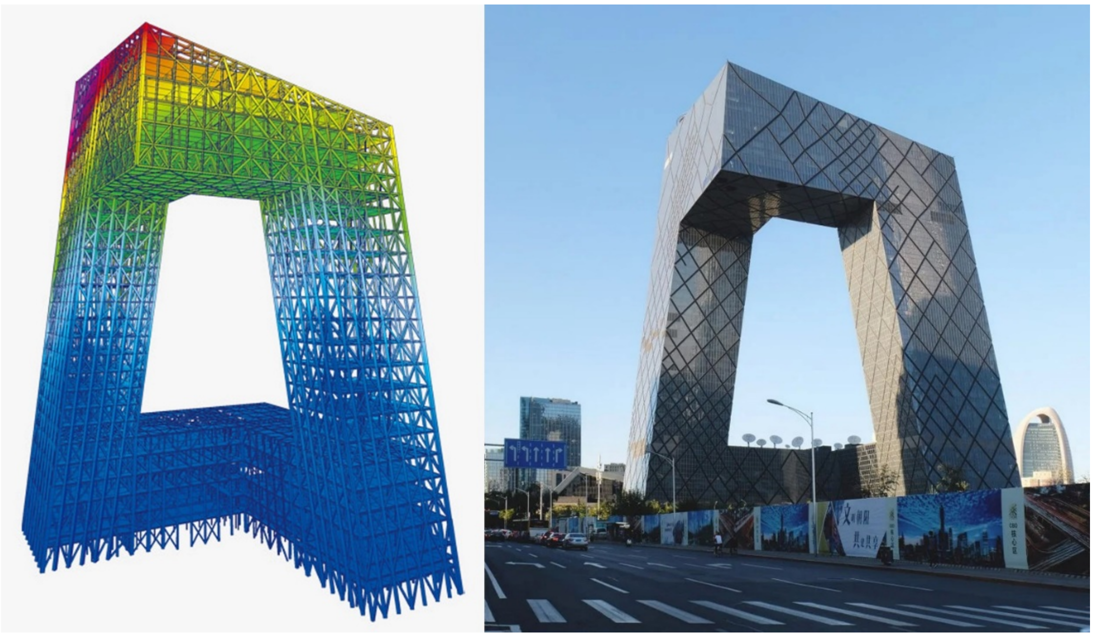

Fig. 6. The headquarters of China Central Television in Beijing

Fig. 7. Residential complex "Meltzer Hall", St. Petersburg

This pilot project was implemented on the basis of technology developed by the Russian Foundation for the Development of Information Technologies (RFDIT), which was created on the basis of Federal Law No. 127-FZ of 23.08.1996, adopted by the Government of the Russian Federation with the aim of developing innovations and developing domestic IT products. One of them was the system developed by FRDIT together with Alfa Faberge, which performs the functions of the developer of the Meltzer Hall residential complex.

The control program is based on traditional BIM scanning with the formation of a point cloud, comparing the degree of realization of the object with the currently planned one. In addition, this artificial intelligence system can effectively regulate the construction time, track the reporting documentation on the progress of construction. He is also responsible for creating a package of tender documentation, selecting a contractor and controlling logistics [19]. Moreover, the system allows you to neutralize any negative impacts during construction on neighboring buildings. The developers of this innovative software claim that the implementation of the system will replace a whole staff of engineers, cost estimators, designers, etc.

Such systems are particularly interesting from the point of view of feedback. Huge prospects open up when integrating artificial intelligence data with government agencies performing supervisory and control functions. Here the human factor and the possibility of concealing violations during construction are completely excluded. Any of the inspection bodies, be it fire protection or architectural supervision, will be able to connect to the system and, without leaving the facility, pre-check for violations of the requirements of regulatory documents, compliance with construction deadlines (when implementing construction projects with state funding).

Thus, for use on construction sites, the so-called agent-oriented approach to the organization of artificial intelligence systems is extremely interesting, which, based on a variety of sensors and video cameras, will allow artificial intelligence to observe the construction site, analyze the visual image, its compliance with this stage of work, compare with the required indicator of the degree of completion of work. Here you can also track the security level [20]. For example, the system should issue a signal about the violation of certain instructions by employees. This may signal an incorrect location of the construction site if there are no enclosing protective structures or there is no sink for construction equipment. Obviously, it is much better if these violations are noted by artificial intelligence than by a construction inspector during a direct inspection of the object. Correction of construction errors is necessary both for the management of the contractor company, and for the developer and the customer of the object, which is often the same developer [21].

The implementation of projects often leads to budget adjustments, schedule disruptions and even freezing of construction. But even here, comprehensive monitoring using artificial intelligence avoids a significant number of problems.

Thus, the logistics system provides ample opportunities, since the import and unloading of materials, the speed of movement of construction vehicles, lagging or advancing the construction schedule are easily fixed by artificial intelligence systems, and simultaneously on any number of construction sites [22]. With the help of artificial intelligence, it is much easier to implement network planning and corresponding highly intelligent schedules for the construction of facilities, while today in Russia calendar planning is mainly used.

Stage of business plan development

- More objective assessment of project implementation risks
- Effective financial planning
- Formation of accompanying documentation

Design and construction stage

- Application of BIM technologies at all stages, including architectural calculations
- Formation of estimates, tender documentation and project documentation for submission for project examination
- Creating an optimized network schedule instead of a calendar plan
- Selection of contractors
- Direct control over construction at the construction site (logistics, violations in the field of security and technical advertising, access control to the construction site, etc.)
- Regular reports on the progress of construction
- Search for deviations with the formation of an extraordinary report sent to the management of the construction organization
- Search for management solutions and suggestions for adjustments
- The possibility of connecting state supervision bodies to the artificial intelligence system to increase the transparency of construction production

Commissioning stage

- Preliminary assessment of compliance of the constructed facility with the requirements of technical regulations and project documentation
- Formation of the necessary documents for obtaining a permit for commissioning
- Notification of construction control bodies on completion of construction
- Interaction and exchange of information with the "Smart Home" system, which should work at the input facility

Fig. 8. Extended scheme of artificial intelligence application in accordance with the stages of construction project implementation

Separately, it is necessary to note the possibilities of artificial intelligence in the construction and repair of pavement. Thus, the intelligent system of Rosavtodor could analyze the condition of roads, visually scanned by drones, and transmit operational information to repair crews about the need to restore a specific destroyed section of road. This road control system is actively used in the USA [23].

At the stage of completion and commissioning of the facility, artificial intelligence can also conduct a preliminary assessment of the compliance of the constructed facility with the requirements of technical regulations and project documentation, form the necessary documents to obtain a permit for commissioning.

The further life cycle of buildings can also be controlled and extended by integrating artificial intelligence databases of construction organizations and smart home systems operating during the operation of the real estate object, as well as artificial intelligence systems of state construction and supervisory authorities [24].

Thus, the extended scheme of the artificial intelligence algorithm in the construction sector should look like this, as shown in Figure 8.

Among the necessary information resources, interactive communication with which an artificial intelligence system should be provided, can be called:

- state resources in the field of construction (Unified State Register of Conclusions, State Register of Real Estate, etc.);
- regularly updated legal databases;
- internet portal of regional authorities of the region where the project is being implemented;
- integrated systems of domestic software in the field of architecture and construction;
- other necessary information resources.

4 CONCLUSIONS

Based on all of the above, it can be summarized that the widespread introduction of artificial intelligence in construction is primarily a state task, since it greatly facilitates, accelerates and simplifies communication between all participants in the implementation of construction projects. The state often acts as their initiator, developer. Of course, integration with highly intelligent systems will reduce the cost of the entire construction process, especially considering that many social or industrial facilities are valued at significant amounts financed from the state budget, and savings here can be critically important.

5 REFERENCES

[1] Azati: Artificial intelligence in construction. Internet portal: Business network, from https: //elport.ru/news/Azati_iskusstvennyiy_intellekt_v_stroitelstve_1258&page=514, accessed on 2023-02-06.

[2] Matreninskiy, S.I., Gorbaneva, E. P., Mishchenko, A. V., Bredikhina, N. V. (2022). Methodological approach to planning the reconstruction of urban environment. Journal of Applied Engineering Science. Vol.20, № 1, 206-211, DOI: 10.5937/jaes0-34560

[3] Lyubchenko, V.Y., Iskhakov, A.F., Pavlyuchenko, D.A. (2020). Rating of Organization's Energy Efficiency Based on Harrington's Desirability Function. International Multi-Conference on Industrial Engineering and Modern Technologies (FarEastCon), p.1-6, doi:10.1109/FarEastCon50210.2020.9271239.

[4] Bredikhina, N.V. (2021). Strategic aspects of the production and economic potential of urban investment and construction sector. Journal of Applied Engineering Science. Vol.19, № 2, 483-487, DOI: 10.5937/jaes0-31444

[5] Souza, A., Lima, G., Nalon, G., Lopes, M., Oliveira, A., Lopes, G., Olivier, M., Pedroti, L., Ribeiro, J., Franco de Carvalho, J.M. (2021). Application of the desirability function for the development of new composite eco-efficiency indicators for concrete. *Journal of Building Engineering*. 40. 102374. DOI:10.1016/j.jobe.2021.102374

[6] Sadollah, A. (2018). Introductory Chapter: Which Membership Function is Appropriate in Fuzzy System? Fuzzy Logic Based in Optimization Methods and Control Systems and its Applications. Tehran, Iran, DOI:10.5772/intechopen.79552

[7] Lapidus, A., Shesterikova, Y. (2021). A Study of a Comprehensive Quality Indicator of Multi-Storey Residential Buildings While the Indicators of the Groups Factors are Changing. IOP Conference Series: Materials Science and Engineering. 1079. 032023. DOI:10.1088/1757-899X/1079/3/032023

[8] Sushkova, O.V. (2020). Features of the use of artificial intelligence technology by self-regulatory organizations in the activities of subjects of business law. *Bulletin of the University named after O.E. Kutafin (MSUA), №* 7, 68-75, doi.org/10.17803/2311-5998.2020.71.7.068-075

[9] Gorodnova, N.V. (2021). Application of artificial intelligence and nanotechnologies in the investment and construction sector of Russia. Vestnik NSUEU, No.3, 81-95, doi.org/10.34020/2073-6495-2021-3-081-095

[10] Miller, T. (2018). Explanation in artificial intelligence: insights from the social sciences. Artif Intell 267:1–38. https://doi.org/10.1016/j.artint.2018.07.007

[11] Gazarov A.R. (2020). Benefits of using artificial intelligence in the construction industry. Izvestia of the Tula State University. Technical science, No. 4, 136-139.

[12] Abioye, S. O., Oyedele, L. O., Akanbi, L., Ajayi, A., Davila Delgado, J. M., Bilal, M., Ahmed, A. (2021). Artificial intelligence in the construction industry: A review of present status, opportunities and future challenges. Journal of Building Engineering, 44, Article 103299. https://doi.org/10.1016/j.jobe.2021.103299

[13] Boonpheng A., Kongsong W., Kongbenjapuch K.,Pooworakulchai Ch., Harnphanich B., Roikulcharoen S. (2020). Benefits of blockchain technology and cryptocurrency for construction engineering management, International Journal of Management (IJM), 11(10), 1484-1494. DOI: 10.34218/IJM.11.10.2020.135

[14] Sheldon, A., Dobbs, T., Fabri, A., Zavoleas, Y., Gardner, N., Hank Haeusler, M., Ramos, C. (2019). Putting the AR in (AR) chitecture-Integrating voice recognition and gesture control for Augmented Reality interaction to enhance design practice. Proceedings of the 24th CAADRIA Conference, DOI:10.52842/conf.caadria.2019.1.475

[15] Vigneault, M., Boton, C., Chong, H., Cooper-Cooke, B. (2020). An innovative framework of 5D BIM solutions for construction cost management: a systematic review, Arch. Comput. Methods Eng. 27 (4), 1013-1030, DOI:10.1007/s11831-019-09341-z

[16] Zheng, R., Jiang, J., Hao, X., Ren, W., Xiong, F., Ren, Y. (2019). bcBIM: A Blockchain-Based Big Data Model for BIM Modification Audit and Provenance in Mobile Cloud, Mathematical Problems in Engineering, p. 1-13, doi.org/10.1155/2019/5349538

[17] How are AI technologies used in design and construction? Internet portal: Tenant, from https://www.arendator.ru/articles/162070-kak_tehnologii_ii_ispolzuyutsya_v_proektirovanii_i_stroitelstve, accessed on 2023-02-06.

[18] Munawar, H.S., Ullah, F., Qayyum, S., Shahzad, D. (2022). Big Data in Construction: Current Applications and Future Opportunities. Big Data and Cognitive Computing, 6 (1), https://doi.org/10.3390/bdcc6010018

[19] Kaushik, S. (2018). Use of Information Technology in Construction Industry for Supply Chain Management, International Research Journal of Engineering and Technology (IRJET), 05 (07), 258-265

[20] Rajyaguru, A.H. (2022). Analytical Study of Construction Equipment Management System at Construction Sites, International Journal of Civil Engineering and Technology (IJCIET). 13(9),14-21, doi: https://doi.org/10.17605/OSF.IO/5CF6K.

[21] A platform using artificial intelligence to detect errors during construction has raised $ 10 million. Internet portal: Business network, from https://elport.ru/news/platforma_ispolzuyuschaya_isk usstvennyiyy_intellekt_dlya_1258, accessed on 08.11.2023-02-06.

[22] Every day INDUS.AI controls more than 100 million square feet of construction sites using artificial intelligence. Internet portal: Business network, from https://elport.ru/news/kajdyiy_den_INDUSAI_kontroliruet_bolee_100_million_1258, accessed on 2023-02-06.

[23] AI was taught to determine where it is necessary to repair the road in the first place. Internet portal: Habr, from https://habr.com/ru/post/419245, accessed on 2023-02-06.

[24] "Smart homes" from Sber and GC "Ingrad" will appear in Moscow. Internet portal: Business network, from https://elport.ru/news/umnyie_doma_ot_sbera_i_gk_i ngrad_poyavyatsya_v_moskve_25382, accessed on 2023-02-06.

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