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FOURTH WAVE TECHNOLOGIES IN CONSTRUCTION AND ARCHITECTURE: FROM IDEA TO REALIZATION (PART 3: SAMPLE APPLICATIONS OF THE FOURTH WAVE TECHNOLOGY IN CONSTRUCTION AND ARCHITECTURE)

ТЕХНОЛОГИИ ЧЕТВЕРТОЙ ВОЛНЫ В СТРОИТЕЛЬСТВЕ
И АРХИТЕКТУРЕ: ОТ ИДЕИ ДО РЕАЛИЗАЦИИ
(ЧАСТЬ 3: ПРИМЕРЫ ПРИМЕНЕНИЯ ТЕХНОЛОГИЙ ЧЕТВЕРТОЙ ВОЛНЫ
В СТРОИТЕЛЬСТВЕ И АРХИТЕКТУРЕ)

The Industrial Revolution is the restructuring of society under the influence of innovations in technology and technique, which is accompanied by a jump in productivity. Today, the 4th revolution is taking place, which is rapidly changing the landscape of various areas of life, including architecture and the construction industry. The Industry 4.0 revolution connects technologies used in organizations and people's daily lives. It combines physical and digital technologies. But it doesn't develop as a daily simple life in architecture and construction industry like many other industries like as automotive, aircraft, electronic etc. ***The relevance of the study*** *is to study and analyze the stage of the historical event on the industrial revolutions (specially fourth industrial revolution) and his realization in today's construction and architecture industry.* ***Purpose of study****: a comprehensive review of contemporary and historical literature related to fourth industrial revolution, and his realization level in the industry with specific focus on construction and architecture industry. Thus,* ***the main tasks of the study*** *can be distinguished as follows: review of historical literature and basic understanding of the industrial revolutions; understanding of Industry 4.0 and its principles and benefits; reveal and introduce Industry 4.0 in construction and architecture industry; some samples about using Industry 4.0 in construction and architecture industry. The third-part of research is devoted to the implementation of the fourth wave technology idea in construction and architecture. The research used the* ***method of analysis*** *of scientific and historical literature and documents related to the Industrial Revolution (specially fourth industrial revolution) and his achievement in the construction and architecture industry to achieve and formulate conclusions.* ***The conclusion of study*** *is about today's stage of realization of fourth industrial revolution in the construction and architecture industry and his point of view to next industrial revolution which start from 2017. The author believes that the development of the construction and architecture industry now and in the future depends on the attention and use of new industries and professionals in this industry*

Промышленная революция – это перестройка общества под влиянием инноваций в технологиях и технике, которая сопровождается скачком производительности труда. Сегодня происходит четвертая строительная революция, которая стремительно меняет картину различных сфер жизни, в том числе архитектуры и строительной отрасли. Революция «Индустрия 4.0» объединяет технологии, используемые в организациях и в повседневной жизни людей. Она сочетает в себе физические и цифровые технологии. Но в архитектуре и строительстве она не развивается так, как во многих других отраслях. ***Актуальность исследования*** *заключается в изучении и анализе этапа исторического события, связанного с промышленными революциями (в частности, четвертой промышленной революцией), и его реализации в современной строительно-архитектурной отрасли.* ***Цель исследования*** *– это всесторонний обзор современной и исторической литературы, связанной с четвертой промышленной революцией и уровнем ее реализации в отрасли, с особым акцентом на строительстве и архитектуре. Таким образом, основными* ***задачами исследования*** *можно назвать следующие: обзор исторической литературы и базовое понимание промышленных революций; понимание Индустрии 4.0, ее принципов и преимуществ; выявление и внедрение Индустрии 4.0 в сферу строительства и архитектуры; примеры использования Индустрии 4.0 в строительной и архитектурной отраслях. Третья часть исследования посвящена реализации идей технологии четвертой волны в строительстве и архитектуре. В* ***исследовании использован метод анализа*** *научно-исторической литературы и документов, связанных с промышленной революцией (особенно четвертой промышленной революцией), и ее успехи в строительной и архитектурной отраслях для достижения и формулировки выводов.* ***Вывод исследования*** *заключается в сегодняшнем этапе*

*specially IT specialists and technology. **The scientific novelty of the study** is to study, analysis, identify main factors of Industry 4.0, and collection of some samples of realization of this technology (fourth wave technologies) in construction and architecture industry.*

реализации четвертой промышленной революции в строительной и архитектурной отраслях и ее точки зрения на следующую промышленную революцию, которая началась с 2017 года. Автор считает, что развитие отраслей строительство и архитектура сейчас и в будущем зависит от внимания и использования новых отраслей и профессионалов в этой сфере, особенно IT-специалистов и технологий. Научная новизна исследования заключается в изучении, анализе, выявлении основных факторов Индустрии 4.0 и подборке образцов реализации этой технологии (технологии четвертой волны) в строительстве и архитектуре.

Keywords: *construction, fourth wave technology, 4IR, Industry 4.0, construction robot, artificial intelligence, augmented reality (AR), virtual reality (VR), extended reality (XR)*

Ключевые слова: *строительство, технология четвертой волны, 4ИР, индустрии 4.0, строительный робот, искусственный интеллект, дополненная реальность (AR), виртуальная реальность (VR), расширенная реальность (XR)*

Introduction

The relevance of the study. The Industrial Revolution is the process of transition from an agrarian economy characterized by manual labor and handicraft production to an industrial society dominated by machine production. The history of human activity related to the invention, design and manufacture of technical products and devices. It is a story of evolution from the handicraft production of single objects to the assembly industrial production of series products [1, 2]. The development of mankind is inextricably linked with the progress of science and technology, which is confirmed by several industrial revolutions. Construction and architecture which appeared in ancient times and as an industry that creates complex technical devices, such as buildings and structures – is also evolving in this direction and went through several stages of evolution.

There are many reasons why construction has not yet evolved into precision housing. Many of these reasons lie in the realm of finance and marketing rather than engineering and technology. Where modern products of the automotive, aircraft, electronic and other industries of mechanical engineering have been phenomenal in reducing product costs through mass production and in increasing sales through clever marketing and distribution, the construction industry has choked. In light of the development of the concept of "Industry 4.0", the term "Construction 4.0" appeared but this term didn't develop in real life of humans like another industries!

Thus, the *research objectives* are as follows:

- basic understanding of the industrial revolutions (see part 1);
- review and analysis of literature about the industrial revolutions specially about Industry 4.0; its principles; main challenges and benefits (see part 1);
- reveal and introduce Industry 4.0 in construction and architecture industry (see part 2);
- search and find some samples about using Industry 4.0 in construction and architecture industry.

Research methodology would be used literature review, pattern recognition, identification and conceptualization method for contribute the results of study. For this occasion, main stages and methodology of this research are like as follows:

Literature review and analysis method: latest scientific literature, interdisciplinary text and documents with a suitable thematic analysis related to industrial revolutions, Industry 4.0, construction and architecture;

Pattern recognition is the ability to see patterns in seemingly random information. The goal is to note the main patterns and concepts in the results of the first step. The second step looks for similarities or patterns in the sample and codes the results by concept;

Identification method: to recognize specific, problems and characteristic of Industry 4.0 and its relation to modern construction and architecture (results of part one and two);

Conceptualization method: in order to find a suitable theoretical connection between the identified concept and its relation to Industry 4.0, urban development, modern construction and architecture.

Main part

The Industrial Revolution is a period of global changes related to industrial production processes, machines and technologies that took place in Europe in the 18th and 19th centuries. This historical period led to tremendous economic, social and technological progress and was one of the most significant in world history. The technological changes that were

taking place at that time gave impetus to innovation not only in industry, but also in many other areas of life. The process of industrialization began with the transformation of agriculture, the mining industry and the textile industry, which improved the lives of millions of people. One of the main industries which effected by industrial revolutions are architecture and construction industry.

Thus, the purpose of this article is to study the history and causes of the industrial revolution, as well as its consequences and effect on the latest industrial technology (4th industrial technology) in construction and architecture. We will review the key facts and events associated with this area, as well as discuss all the changes that it made to the development of mankind especially associated with architecture and construction industry.

Sample application of the fourth wave technology in construction

Building "Mini Sky City" – Changsha, China Chinese builders once again surprise the world with their record speed in the construction of high-rise buildings. They recently completed the construction of a 57-story skyscraper called Mini Sky City, which was completed in the shortest possible time – in just 19 days (fig. 1).

The Mini Sky City skyscraper was built by Broad Sustainable Building Corporation, known for its use of prefabricated house technologies in construction. The secret of this company lies in the maximum possible preparation of all structural elements of buildings at individual factory sites, as well as a perfect and error-free logistics process. The main structures, as well as part of the exterior and interior decoration of this 57-story skyscraper, took only nineteen days. After the final commissioning, Mini Sky City will house 800 residential apartments, as well as office space for 4,000 people. The building will be operated by Broad Sustainable Building itself and will be one of its headquarters. The Mini Sky City skyscraper will differ from other skyscrapers in the city of Changsha by the active use of "green" technologies, including triple air purification both inside the building and outside.

3D printing in construction

In 2017, the Irkutsk company Apis Cor for the first time in Russia printed a house on a 3D printer. The building, with an area of only 38 m², was printed at the factory. In 2019, the same company built a two-story building in Dubai using 3D printing [3, 4]. This time the printer was already working on the construction site, and its creators proudly declared that the device does not need rails, since it can be installed on an uneven surface. With this project, Russian builders got into the Guinness Records Book. A house in Dubai has become the first building in the world to be 3D printed on site. Printing took 500 hours (fig. 2).

Another 3D printer project in 2021: the first residential building in Germany to be completely printed on a construction printer [3, 5]. It is believed that 3D printing is mainly for load-bearing structures, but here the printer also made a fireplace, a staircase and a bathtub. The whole house took 13.5 hours. The house is located in the German city of Beckum, its area is 160 m², the contractors were Peri 3d Construction and Heidelberg Cement Group (fig. 3).

Internet of Things (IoT) and Smart Sensors

In the summer of 2021, the Russian company Sitronics introduced the Sitronics Smart Watch, which is designed specifically for construction teams. Among other things, the watch measures the pulse and body temperature and, in the event of critical deviations, transmits an alarm. The foreman can assign tasks to the brigadier through the web interface, and he can send back the status of completion. The foreman and brigadier can see in real time where the workers are.

In 2020, the Canadian company AOMS Technologies developed sensors and software that allow real-time monitoring of the state of concrete: its humidity and temperature in different areas [6, 7]. The information collected from the sensors is processed by a program that builds a curve of curing and evaluates the maturity of the structure. All information is transmitted in real time via Wi-Fi (fig. 4).

Robots and drones in construction

In the village of Danube and the city of Fokino in the Primorsky Territory, drones were used to inspect heating networks. Drones are also used for photogrammetry – creating maps and plans with automatic calculation of volumes and sizes of objects: for this system AutoDesk ReCAP, Pix2Dmapper, Datugram and other software are used.

The Axora Digital Solutions Marketplace in 2021 explored the adoption of innovations in the industry: according to the survey, 73 % of respondents believe that remote control technologies have already become indispensable in metallurgy and mining. Under these technologies, remote operations centers are being created, which are designed to improve production safety and show the social responsibility of companies [8, 9, 10].

Australian robot mason Hadrian X. lays up to 1000 bricks per hour. In December 2021, a robot built 16 townhouses in the village of Villages in Western Australia for local construction company Inspired Homes (fig. 5).

Fig. 1. The Mini Sky City skyscraper, China

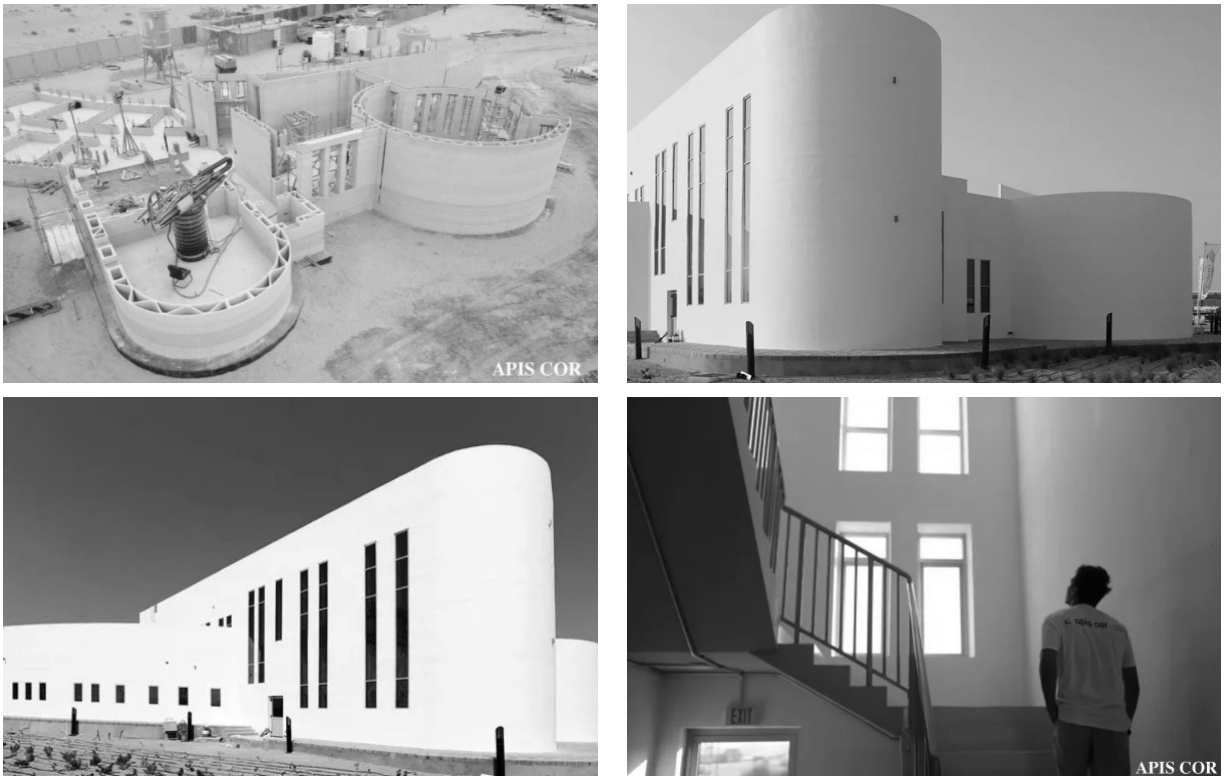

Fig. 2. The two-story building using 3D printing, Dubai

Fig. 3. The residential building construction with 3D printer, Germany

Fig. 4. Smart Sensors and gadget in construction

Fig. 5. Hadrian X. construction robot

Artificial intelligence (AI)

U.S. modular steel construction company ConXtech and AutoDesk Research said in 2021 that they had jointly developed an AI module for bidding analysis. It analyzes steel structure price data, finds profitable options, and even suggests the most economical building configuration for the developer.

Company's ConXtech module with AI allows at the initial stage to estimate the cost of materials and the entire building without the involvement of professional estimators.

In May 2020, during the lockdown, Severstal's Cherepovets site launched a machine vision algorithm that calculates the distance between workers on a rest. More recently, the use of AI has become the norm for factories to control the wearing of respirators and other personal protective equipment (fig. 6).

Virtual and augmented reality

The construction industry uses VR/AR to train operators of complex mechanisms like as cranes, demolition machines, hydraulic lifts and excavators.

Crane Planner software from Liebherr, which is based on virtual reality technologies. The program allows you to reproduce the process of lifting the load. The algorithm contains the parameters of all Liebherr cranes: the program automatically calculates the ground pressure and the position of the center of gravity.

The planitec AR app from Paschal allows you to recreate the formwork project in the real environment and original size directly from your smartphone or tablet. The English app is available for free on the App Store (fig. 7).

Blockchain

A consortium on blockchain in construction has been created in the world. The consortium members managed to integrate the Autodesk Forge platform and the Ethereum blockchain: the actions that the engineers performed in the Autodesk cloud were successfully recorded as transactions on the blockchain. Thus, the blockchain can become a reliable and the only reliable source about all the changes in the construction project that are made by different people and different programs, the researchers conclude, adding that the same integration can be done for AutoCAD and Revit. The general scheme of the blockchain operation: the actions of different teams that can work with different applications are recorded in a smart contract. Integration of the 3D model and the blockchain: the engineer writes a "check depth" comment for the pile, a window opens on the right, where the comment is recorded as a transaction in the blockchain: it is assigned a time and an identifier (fig. 8).

Fig. 6. Artificial intelligence implication in construction

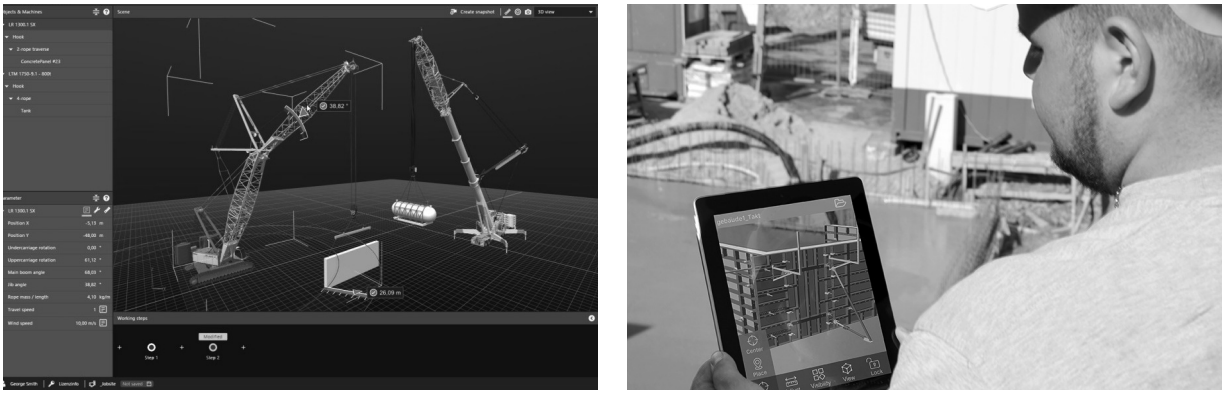

Fig. 7. Crane Planner software and the planitec AR app

Fig. 8. Using blockchain in construction project

Results

Based on the summary of this study, we could draw the following conclusions:

▪ Basic understanding of the industrial revolutions in which describes four main industrial revolutions in the history based on literature review (starts from machine production era (1784) up to days cyber physical system);

▪ Describes the fourth wave technology (or Industry 4.0) and detection of its principles, benefits and main challenges;

▪ There is the concept of the fifth industrial revolution, but so far from its signs in construction and architecture;

▪ Consideration of fourth wave technology in today's construction and architecture shows new initiatives, including: improve communication and data management; planning projects with the help of artificial intelligence and machine learning; construction robots; research drones (drones in construction); advancement of building information modeling (BIM); projects that have been completed virtually before the start of work; computer optimized design;

real-time processing of information with the help of internet of things (IoT); digital twins of designs to optimize the manufacturing process. This research tries to explain all indicated initiatives and shows some realization samples related to these points;

▪ Draw/Shows some sample application of the fourth wave technology in today's construction like as high-speed skyscraper's building; 3-d printing in construction; Internet of Things and Smart Sensors; Robots and drones in construction; Artificial intelligence (AI); virtual and augmented reality; and blockchain.

Conclusion

During the last three industrial revolutions, not only did people's personal and professional lives change over and over again, but sometimes they were even threatened. After each revolution, the world took a new direction. This time, the fourth industrial revolution will change our lives; although the speed and dimensions of this change will be very different and bigger than the changes of the past three industrial revolutions.

We must recall that there is the concept of the fifth industrial revolution, which began from 2017, but as we know this industry is still at the level of definition and development, and the fourth industrial industry has not yet been practically finalized in construction and architecture, a specific feature for its implementation in these branches cannot be seen.

In the coming years, the construction industry can radically change its appearance due to the introduction of IT technologies. Construction will become more transparent and understandable for everyone, which means that the advantage will be given to those companies that are already thinking about their efficiency, reducing costs and developing client work. The fourth industrial revolution and digital technologies in construction are able to increase labor productivity, improve safety at the construction site, ensure the "broach" of any little things throughout the entire construction process from design to operation of the facility. Perhaps now some technologies seem like science fiction or useless dreams, but large developers have already understood the prospects: they are strengthening IT departments and teaching employees' new digital specialties. In the coming years, the construction industry, in addition to the traditional shortage of workers, will face a shortage of IT specialists which would help them for using fourth industrial revolution and technology in construction industry.

REFERENCES

1. Schwab K. The fourth industrial revolution. Currency. 2017.

2. Kashiripoor M.M. *Sovershenstvovanie arhitekturno-planirovochnoj struk-tury malyh gorodov regiona Blizhnego Vostoka na osnove koncepcii ustojchivogo raz-vitija*. Cand, Diss. [Improving the architectural and planning structure of small towns in the Middle East region based on the concept of sustainable development. Cand. Diss.]. Minsk, 2017. DOI:10.13140/RG.2.2.18643.73761

3. Kashiripoor M.M., Garagozov S.B. New trends and innovations in construction: construction with a 3d printer. *Nauka – obrazovaniju, proizvodstvu i jekonomike*: Sat. articles]. Misnk, 2022, pp. 94–99. (In Russian).

4. Kashiripoor M.M., Gayevskaya Yu.N. Basics of understanding BIM technologies in construction. *Nauka – obrazovaniju, proizvodstvu i jekonomike: sb. statej* [Science - Education, Production and Economics "and the 78th student scientific and technical conference of BNTU: Sat. articles]. Misnk, 2022, pp. 89–93. (In Russian).

5. Kashiripoor M.M., Kukhareva I.V. Innovations in construction: construction of houses from waste. *Nauka – obrazovaniju, proizvodstvu i jekonomike: sb. statej* [Science - Education, Production and Economics "and the 78th student scientific and technical conference of BNTU: Sat. articles]. Misnk, 2022, pp. 100–103. (In Russian).

6. Kashiripoor M.M. Application of metaverse in cities, its concept, pre-property and disadvantages. *Gradostroitel'stvo i arhitektura* [Urban planning and architecture], 2023, vol. 13, no 3, pp. 168–173. (in Russian). DOI: 10.17673/Vestnik.2023.03.21

7. Kashiripoor M.M. Metaverse city: definition and direction of development for urban planning and architecture. *Vestnik Brestskogo gosudarstvennogo tehnicheskogo universiteta* [Bulletin of Brest State Technical University], 2023, vol. 3, no. 132, pp. 2–10. (in Russian) DOI: 10.36773/1818-1112-2023-132-3-2-10

8. Noskov I.V., Noskov K.I., Tinenskaya S.V., Ananiev S.A. Drone technology in construction − modern solutions and capabilities. *Vestnik evrazijskoj nauki* [Bulletin of Eurasian Science], 2020, vol. 12, no. 5, pp. 27. (in Russian)

9. Kashiripoor M.M., Boreyko V.M. Automatic monitoring for complex structures and infrastructure of the city. *Dorozhnoe stroitel'stvo i ego inzhenernoe obespechenie: materialy III Mezhdunarodnoj nauchno-tehnicheskoj konferencii* [Road construction and its engineering support: materials of the III International Scientific and Technical Conference]. Minsk, 2022, pp. 90–94. (In Russian).

10. Kashiripoor M.M., Al-Sayyab A.A. Proper methodology for automated monitoring during construction. *Nauka – obrazovaniju, proizvodstvu i jekonomike: sb. statej* [Science - Education, Production and Economics "and the 78th student scientific and technical conference of BNTU: Sat. articles]. Misnk, 2022, pp. 84–88. (In Russian).

БИБЛИОГРАФИЧЕСКИЙ СПИСОК

1. Schwab K. The fourth industrial revolution. Currency. 2017.

2. *Каширипур М.М.* Совершенствование архитектурно-планировочной структуры малых городов ре-

гиона Ближнего Востока на основе концепции устойчивого развития: дис. … канд. арх-ры. Минск, 2017. DOI:10.13140/RG.2.2.18643.73761.

3. *Каширипур М.М., Гарагозов С.Б.* Новые тенденции и инновации в строительстве: строительство с помощью 3d принтера // Наука – образованию, производству и экономике: сб. статей. Минск, 2022. С. 94–99.

4. *Каширипур М.М., Гаевская Ю.Н.* Основы понимания BIM-технологий в строительстве // Наука – образованию, производству и экономике: сб. статей. Минск, 2022. С. 89–93.

5. *Каширипур М.М., Кухарева И.В.* Инновации в строительстве: строительство домов из отходов / Наука – образованию, производству и экономике: сб. статей. Минск, 2022. С. 100–103.

6. Kashiripoor M.M. Применение метавселенной в городах, её понятие, преимущества и недостатки // Градостроительство и архитектура. 2023. Т. 13, № 3. С. 168–173. DOI: 10.17673/Vestnik.2023.03.21

7. *Каширипур М.М.* Город метавселенной: определение и направление развития для градостроительства и архитектуры // Вестник Брестского государственного технического университета. 2023. Т.3, №132. С. 2–10. DOI: 10.36773/1818-1112-2023-132-3-2-10.

8. *Носков И.В., Носков К.И., Тиненская С.В., Ананьев С.А.* Дрон-технологии в строительстве − современные решения и возможности // Вестник евразийской науки. 2020. Т. 12, № 5. С. 27.

9. *Каширипур М.М., Борейко В.М.* Автоматический мониторинг для сложных сооружений и инфраструктуры города // Дорожное строительство и его инженерное обеспечение: материалы III Международной научно-технической конференции. Минск, 2022.С. 90–94.

10. *Каширипур М.М., Аль-Сайяб А.А.* Надлежащая методология автоматизированного мониторинга в процессе строительства // Наука – образованию, производству и экономике: сб. статей. Минск, 2022. С. 84–88.

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