Digital Transformation of the Construction Industry: The Role of BIM, Digital Twins, Artificial Intelligence and Blockchain in Smart Real Estate Ecosystems

Mykola Denysenko[1], Svitlana Breus[2], Oleksandr Levchenko[3], Oleksandr Balymov[4], Yehor Prytula[5]

[1]*Doctor of Economic Sciences, Professor, Doktor habilitovanyi nauk ekonomichnykh, Profesor nauk ekonomichnykh, Professor at the Department of Management and Entrepreneurship, Volodymyr Vynnychenko Central Ukrainian State University, Kropyvnytskyi, Ukraine, ORCID: https://orcid.org/0000-0001-8767-9762*

[2]*Doctor of Economic Sciences, Professor, Professor at the Department of Management and Logistics, European University, Kyiv, Ukraine, ORCID: https://orcid.org/0000-0003-0624-0219*

[3]*Doctor of Economic Sciences, Professor, Head of the Department of Management and Entrepreneurship, Volodymyr Vynnychenko Central Ukrainian State University, Kropyvnytskyi, Ukraine, ORCID: https://orcid.org/0000-0001-5452-7420*

[4]*Postgraduate Student, European University, Kyiv, Ukraine, ORCID: https://orcid.org/0009-0003-4643-9035*

[5]*Postgraduate Student, European University, Kyiv, Ukraine, ORCID: https://orcid.org/0009-0001-9849-3979*

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Abstract. *The digital transformation of the construction industry is becoming an important prerequisite for increasing the efficiency, transparency, and sustainability of real estate asset management. The objective of this study is to determine the role of Building Information Modeling, digital twins, artificial intelligence, blockchain, and related digital technologies in shaping smart real estate ecosystems. The methodology is based on a systematic review of scientific publications, comparative analysis, content analysis, and conceptual generalization of approaches to the digitalization of construction and real estate management. The main results show that the integration of BIM, Digital Twins, IoT, AI, and blockchain improves coordination among project participants, supports real-time monitoring, enhances asset valuation and lifecycle forecasting, automates contracts and payments, and creates the foundation for digital leasing and smart real estate management. At the same time, the study identifies major barriers, including high implementation costs, integration complexity, shortages of digital competencies, and cybersecurity risks. The conclusions emphasize that digitalization is a strategic factor in the modernization of construction and real estate ecosystems, provided that technologies are implemented comprehensively and supported by organizational change. Further research should focus on integrated digital platform models, economic feasibility for small enterprises, and cybersecurity standards.*

Keywords: *Digital transformation in construction; Building Information Modeling (BIM); Digital twin technology; Internet of Things in construction; Artificial intelligence in construction management; Blockchain in real estate; Smart contracts in construction; Digital real estate ecosystems; Construction digitalization; Smart construction management.*

JEL Classification: A10, A11, A19, E22, G11, G17, G19, O10, O30, O40

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Introduction. The construction industry itself is becoming digital, and digital real estate leasing increasingly relies on this transformation. The key premise is that an object created within BIM environments or digital twin systems subsequently becomes an asset in financial leasing models managed through digital platforms, blockchain technologies, and artificial intelligence.

Digitalization in the construction sector involves the implementation of BIM, digital twins, IoT, artificial intelligence, cloud platforms, and automation to optimize all stages of the asset lifecycle. Studies clearly confirm that digital technologies reduce project execution time, lower costs, improve quality and safety, enhance coordination among project participants, and ensure transparency of management processes (Moshood et al., 2024; Nikmehr et al., 2021; Asif et al., 2024; Chowdhury et al., 2019; Alhadi et al., 2025; Shehadeh, 2025; Omrany et al., 2023; Zhang et al., 2024; Eldeep et al., 2021; Zulu et al., 2023). At the same time, achieving maximum effectiveness requires comprehensive integration of digital solutions and the development of digital competencies among personnel (Nikmehr et al., 2021; Stadnyk et al., 2025; Chowdhury et al., 2019; Alhadi et al., 2025; Chacón et al., 2024; Hu et al., 2022).

Construction is increasingly shifting toward BIM, IoT, digital twins, and smart management, which together create a unified digital representation of a building at all stages of its lifecycle (Shishehgarkhaneh et al., 2022; Khomenko et al., 2025; Obidnyk & Obidnyk, 2025; Banihashemi et al., 2023; Pereginets & Smirnov, 2025). Within the framework of Construction 4.0, BIM and digital twins form the basis of a "digital asset" that can be used in leasing systems. BIM and digital twins serve as a "digital passport" of a building, including structural characteristics, engineering systems, energy efficiency indicators, operational costs, and technical condition within a single data source (Shishehgarkhaneh et al., 2022; Obidnyk & Obidnyk, 2025; Pereginets & Smirnov, 2025). This digital passport can then be directly used for financial decision-making, including valuation, risk assessment, service life estimation, and energy performance analysis, thereby reducing information asymmetry between developers, banks or leasing companies, and investors (Saari et al., 2022; Vigren et al., 2022; Pan & Zhang, 2022; Pereginets & Smirnov, 2025).

Literature Review. In the scientific literature, the digitalization of the construction industry is considered a complex process of integrating information and communication technologies, data-driven management systems, and digital platforms into the processes of design, construction, and operation of real estate assets (Chen et al., 2021; Zhu et al., 2022).

One of the key directions of transformation is the implementation of Building Information Modeling (BIM), which enables the creation of integrated digital models of buildings and improves the efficiency of construction project management (Obidnyk & Obidnyk, 2025; Landim et al.,

2025). BIM forms the basis for the development of digital twins of buildings, which ensure continuous updating of information about the condition of an asset based on IoT sensors and analytical systems (Akanmu et al., 2021; Omrany et al., 2023).

Digital twins are considered a key tool for lifecycle management of buildings and infrastructure assets, as they allow real-time monitoring, technical condition forecasting, and optimization of operational costs (Moshood et al., 2024; Park et al., 2024).

Along with the development of digital building models, the role of Artificial Intelligence (AI) in construction management is actively studied. AI is used to analyze large datasets, forecast project delays, optimize resource allocation, and support managerial decision-making processes (Pan & Zhang, 2021; Piras et al., 2024).

Another important research direction is the application of blockchain technologies and distributed ledger technologies (DLT) in construction and real estate management. These technologies make it possible to automate contract execution, ensure transparency of financial operations, and increase the level of trust among project participants (Li & Kassem, 2021; Ibrahim et al., 2022; Ogungbemi, 2024).

In the real estate sector, blockchain is considered a tool for creating digital asset management platforms that enable automation of leasing and rental operations, digitization of property rights, and optimization of financial flows (Saari et al., 2022; Vigren et al., 2022; Naeem et al., 2023).

Researchers also emphasize the emergence of the digital real estate concept, which combines digital infrastructure, network services, data collection systems, and analytical decision-support platforms (Ullah et al., 2018; Naeem et al., 2023).

At the same time, construction digitalization significantly influences construction productivity, cost reduction, and improvement of lifecycle management efficiency (Oliinyk et al., 2024; Chowdhury et al., 2019; Chen, 2025). Studies also highlight the role of digital technologies in promoting sustainable development in construction and implementing the principles of the circular economy (Banihashemi et al., 2023; Nikmehr et al., 2021; Asif et al., 2024).

Aims. The aim of the study is to determine the role of digital technologies in the transformation of the construction industry and their influence on the formation of digital ecosystems for real estate management. Particular attention is paid to analyzing the impact of BIM, digital twins, IoT, Artificial Intelligence, and blockchain technologies on the development of digital models of construction asset management and financial mechanisms in the real estate sector.

Methodology. The methodological basis of the research is a systematic analysis of scientific publications devoted to the digitalization of construction and the development of digital real estate. The study employs

methods of comparative analysis, generalization of scientific approaches, literature content analysis, and conceptual modeling of interactions between digital technologies in the construction industry.

The analysis of scientific literature made it possible to systematize the main directions of application of BIM, Digital Twin, IoT, Artificial Intelligence, and blockchain technologies in the processes of design, construction, operation, and management of real estate assets.

Results. In the construction sector, distributed ledger technologies (DLT) and blockchain are already being tested for payment systems, contract management, supply chain management, compliance monitoring, and smart contracts (Li & Kassem, 2021; Ibrahim et al., 2022). In the real estate sector, blockchain and smart contracts enable the digitization of property rights, leasing and rental agreements, as well as the automation of payments and contractual obligations (Saari et al., 2022; Hunhevicz et al., 2021; Naeem et al., 2023; Ogungbemi, 2024).

The same technologies allow the creation of a seamless chain "digital construction → commissioning → digital leasing/renting → securitization of financial flows" within a single distributed infrastructure (Saari et al., 2022; Li & Kassem, 2021; Hunhevicz et al., 2021; Ibrahim et al., 2022). Thus, blockchain and smart contracts act as a common technological layer linking construction and leasing systems.

Models that combine digital twins of buildings with blockchain technologies enable the implementation of performance-based contracts, where payments are linked to actual operational indicators (energy consumption, comfort levels, accessibility) in real time (Hunhevicz et al., 2021). This approach directly corresponds to the "building as a service" model and the concept of servitization, where infrastructure is provided as a service and payments are based on performance rather than ownership (Hunhevicz et al., 2021; Pan & Zhang, 2021; Pan & Zhang, 2022).

Overall, the combination of digital twins and blockchain technologies enables the development of performance-based leasing and servitization models. For leasing systems, this implies a transition from fixed payments to flexible models based on data obtained from Digital Twin systems and IoT sensors, including energy service contracts and "green leasing" models (Shishehgarkhaneh et al., 2022; Hunhevicz et al., 2021; Pan & Zhang, 2022; Wong et al., 2025).

Construction enterprises are increasingly forming digital operational ecosystems and adaptive platforms where BIM, Digital Twins, IoT, Artificial Intelligence, and blockchain technologies are integrated for project management, supply chain management, and risk management (Khomenko et al., 2025; Banihashemi et al., 2023).

At the same time, the concept of digital real estate / smart real estate is emerging in the real estate sector. This concept consists of four main components: ICT infrastructure, data collection technologies, network

services, and digital decision-making systems (Owais et al., 2025; Naeem et al., 2023; Ullah et al., 2018).

At the intersection of these two ecosystems, digital financial leasing emerges. This means that leasing companies are connected to the same data-driven platforms as developers, building operators, and urban or energy infrastructures (Khomenko et al., 2025; Vigren et al., 2022; Owais et al., 2025; Banihashemi et al., 2023).

The relationship between construction, digitalization, and leasing is summarized in Table 1.

Table 1. Relationship between construction, digitalization, and leasing

Construction / leasing stage	Digital technologies	Impact on financial leasing
Design / construction	BIM, Digital Twins, AI	Improved asset valuation, risk assessment, lifecycle forecasting
Contracts and payments	DLT, smart contracts	Automation of payments, reduction of transaction costs
Operation	IoT, Digital Twins, AI	Performance-based leasing, flexible payment models
Portfolio management	Platforms, big data	Portfolio optimization, securitization of financial flows

Source: Shishehgarkhaneh et al., 2022; Khomenko et al., 2025; Pan & Zhang, 2022; Pereginets & Smirnov, 2025; Li & Kassem, 2021; Hunhevicz et al., 2021; Ibrahim et al., 2022; Shishehgarkhaneh et al., 2022; Hunhevicz et al., 2021; Wong et al., 2025; Banihashemi et al., 2023; Saari et al., 2022; Fields, 2019; Vigren et al., 2022; Owais et al., 2025.

Thus, the deeper the digitalization of the construction sector (BIM / Digital Twins / IoT / AI / blockchain), the more data-driven, automated, and transparent financial leasing of real estate can become.

Digitalization significantly improves the efficiency of construction processes; however, it requires investment, system integration, and personnel training.

Digitalization improves efficiency through several mechanisms.

1. Increasing productivity and reducing project timelines and costs

- the integrated implementation of BIM, IoT, AI, digital twins, and cloud platforms significantly reduces errors, shortens project implementation time, and increases the accuracy of calculations and resource control (Oliinyk et al., 2024; Emelianova et al., 2025; Piras et al., 2024);
- studies estimate an increase in construction productivity of approximately 30% and a reduction in organizational costs of up to 20% due to the use of BIM, project management systems, and AI (Chen, 2025; Bilov et al., 2025);
- digital technologies such as BIM, LiDAR, UAVs, and augmented reality improve planning, monitoring of construction progress, coordination processes, and reduce labor costs and project delays (Chen et al., 2021; Chowdhury et al., 2019; Landim et al., 2025).

2. Improving quality, coordination, and safety

- BIM and digital twins reduce design and construction errors, improve

coordination among project participants, and decrease the costs associated with rework (Oliinyk et al., 2024; Moshood et al., 2024; Chen et al., 2021; Piras et al., 2024; Omrany et al., 2023);

- IoT sensors, UAVs, cyber-physical systems, and digital twins enhance safety monitoring, allow better control of materials and equipment conditions, and reduce downtime and accidents (Oliinyk et al., 2024; Akanmu et al., 2021; Shishehgarkhaneh et al., 2022; Piras et al., 2024; Zhu et al., 2022).

3. Improving lifecycle management efficiency and sustainability

- the implementation of digital twins and BIM throughout the lifecycle enables better planning, operation, maintenance, and energy efficiency, which increases the overall performance of assets (Akanmu et al., 2021; Moshood et al., 2024; Piras et al., 2024; Asif et al., 2024; Omrany et al., 2023; Park et al., 2024);

- several studies indicate the potential for 20–30% improvement in overall project performance and 30–50% reduction in building energy intensity due to the application of digital technologies (Chen, 2025; Asif et al., 2024).

The key effects in lifecycle management are presented in Table 2.

Table 2. Key effects in lifecycle management

Technologies	Main effects for processes
BIM, Digital Twins, CPS	Fewer errors, better coordination, real-time management
IoT, UAVs, sensors	Monitoring, improved safety, reduced downtime
AI, analytics, cloud platforms	Delay forecasting, optimization of logistics and resources

Source: Oliinyk et al., 2024; Akanmu et al., 2021; Moshood et al., 2024; Piras et al., 2024; Omrany et al., 2023; Shishehgarkhaneh et al., 2022; Chowdhury et al., 2019; Zhu et al., 2022; Chen, 2025; Emelianova et al., 2025; Pan & Zhang, 2022; Dagou et al., 2025.

Studies also emphasize several barriers to digitalization, including high initial investment costs, complexity of system integration, lack of digital competencies, and cybersecurity challenges (Oliinyk et al., 2024; Moshood et al., 2024; Chen et al., 2021; Emelianova et al., 2025; Khomenko et al., 2025; Asif et al., 2024; Bilov et al., 2025; Fonseca et al., 2024; Park et al., 2024).

Digitalization significantly improves construction efficiency but requires investments, integration of digital platforms, and staff training.

The main directions of the impact of digitalization include:

- BIM and digital twins – enable precise modeling of construction objects, reduce errors and rework, and improve coordination among project participants (Moshood et al., 2024; Asif et al., 2024; Chowdhury et al., 2019; Chacón et al., 2024; Omrany et al., 2023);
- IoT and sensors – allow real-time monitoring of the condition of materials and equipment, increasing safety and responsiveness (Xu et al., 2025; Fonseca et al., 2024; Shehadeh, 2025);

- AI and analytics – optimize resource planning, forecast delays, and automate risk management (Alhadi et al., 2025; Shehadeh, 2025; Emelianova et al., 2025);
- automation and robotics – increase productivity in manufacturing and installation of construction structures (Xu et al., 2025).

Positive results include:
- reduction of organizational costs by up to 20% and an increase in productivity by approximately 30% with the implementation of BIM, digital twins, and AI (Asif et al., 2024; Malykhin, 2025);
- reduction in the duration of certain construction operations by up to 47% due to automation and digital platforms (Zulu et al., 2023);
- reduction in the number of design changes and RFI requests by 11–25% when BIM is used as a lean management tool (Eldeep et al., 2021);
- improved quality of construction work due to the reduction of the human factor and automated quality control systems (Moshood et al., 2024; Shehadeh, 2025);
- improvement of building energy efficiency by 30–50% due to the application of digital technologies in design and operation (Asif et al., 2024).

The main barriers include:
- high initial cost of technologies;
- the need for personnel training;
- complexity of integration of various digital platforms;
- cybersecurity and data protection issues (Nikmehr et al., 2021; Stadnyk et al., 2025; Chowdhury et al., 2019; Alhadi et al., 2025).

Studies confirm that comprehensive digitalization (BIM/Digital Twins /IoT/AI) can significantly improve the efficiency of construction processes - from planning to building operation (Moshood et al., 2024; Nikmehr et al., 2021; Asif et al., 2024; Chowdhury et al., 2019). The greatest effect is observed when several technologies are integrated simultaneously, for example BIM + IoT + AI (Shehadeh, 2025; Omrany et al., 2023).

However, to fully realize this potential, investments in staff training and organizational culture transformation are required (Nikmehr et al., 2021; Stadnyk et al., 2025).

An important advantage is the possibility of flexible resource management even under unstable supply conditions or complex market environments, which is particularly relevant for modern Ukraine (Oliinyk et al., 2024). At the same time, barriers such as implementation costs, shortage of qualified personnel, and cybersecurity risks remain significant limiting factors.

Digitalization has demonstrated its ability to significantly improve the efficiency of construction processes – from design to operation – provided that integrated implementation and the development of personnel competencies are ensured.

Further research should focus on:

- developing methodologies for integrating different digital platforms;
• assessing the economic feasibility of digital technologies for small enterprises;
• developing cybersecurity standards, particularly considering the following barriers to digitalization at the enterprise level:

- small enterprises often lack resources for large-scale implementation, which requires evaluation of investment payback;

- the expansion of IoT, BIM, and cloud platforms increases the risk of data leakage, which requires stronger information security standards;

- the shortage of qualified personnel slows digital transformation, making it necessary to develop effective training formats for different categories of employees.

Discussion. The obtained results confirm that the digital transformation of the construction industry is a complex process that involves the integration of information technologies, data-driven management systems, and digital platforms across all stages of the lifecycle of construction assets. The analysis of scientific sources indicates that a key role in this process is played by technologies such as Building Information Modeling (BIM), Digital Twins, the Internet of Things (IoT), Artificial Intelligence (AI), and blockchain technologies, which form the foundation for the development of integrated digital ecosystems in construction.

The results of the study are consistent with the conclusions of numerous scholars who emphasize that the use of BIM and digital twin technologies enables the creation of a unified information model of a building that accompanies the asset throughout its entire lifecycle – from design to operation (Shishehgarkhaneh et al., 2022; Omrany et al., 2023). Such an approach ensures continuous data exchange, increases the accuracy of managerial decisions, and contributes to more efficient management of construction resources.

An important aspect of digitalization is also the application of the Internet of Things and cyber-physical systems, which enable real-time monitoring of building conditions, control of operational parameters, and optimization of maintenance costs (Akanmu et al., 2021; Moshood et al., 2024). In combination with analytical systems and Artificial Intelligence algorithms, such technologies form the basis for the development of intelligent building management systems and improve the efficiency of infrastructure management (Pan & Zhang, 2021; Piras et al., 2024).

Particular attention in academic research is devoted to the use of blockchain technologies and smart contracts in the construction and real estate sectors. Blockchain technologies make it possible to increase the transparency of financial transactions, automate contract execution, and ensure reliable storage of data related to property rights and transactions (Li & Kassem, 2021; Ibrahim et al., 2022). In the context of the real estate market, these technologies contribute to the development of digital asset

management platforms, which provide more efficient management of leasing and rental operations (Saari et al., 2022; Naeem et al., 2023).

At the same time, the results of the study indicate that construction digitalization has not only technological but also organizational and economic dimensions. The implementation of digital technologies requires the transformation of management approaches, the development of digital competencies among personnel, and the adaptation of organizational structures of enterprises to new operating conditions (Khomenko et al., 2025; Stadnyk et al., 2025).

Furthermore, researchers emphasize that digital technologies create prerequisites for the transition of the construction industry toward sustainable development models and the circular economy, as they enable optimization of resource use, improvement of building energy efficiency, and reduction of the negative environmental impact of construction activities (Banihashemi et al., 2023; Asif et al., 2024).

At the same time, despite the significant potential of digitalization, there are several barriers to its implementation. These include the high cost of implementing digital technologies, the complexity of integrating different information systems, the shortage of qualified specialists, and cybersecurity risks. These factors may slow down the pace of digital transformation in the construction industry, particularly in countries with transition economies.

Thus, the results of the study confirm that construction digitalization is a multidimensional process that encompasses technological, organizational, and economic aspects of industry development. Future research should therefore focus on developing integrated models of digital construction project management, as well as exploring the potential use of platform-based business models and digital financial instruments in the real estate sector.

Conclusion. Overall, digitalization represents a key factor in improving the efficiency of construction processes, provided that a strategic approach to its implementation and the development of human capital are ensured (Denysenko, Breus, Levchenko, Prytula, Balymov, 2024; Denysenko, Breus, 2021; Denysenko, Breus, 2023; Denysenko, Breus, Balymov, 2024; Denysenko, Breus, Prytula, 2024). Digital transformation has demonstrated its capacity to significantly increase the efficiency of construction processes – from design to operation – when implemented comprehensively and supported by the development of personnel competencies.

Under conditions of integrated implementation and appropriate training, digitalization significantly improves the efficiency of construction processes – from planning and construction site management to building operation. Further research should focus on the development of methodologies for integrating various digital platforms, assessment of the economic feasibility of digital technologies for small enterprises, and the development of cybersecurity standards.

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