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INNOVATIVE FINANCIAL INSTRUMENTS FOR DIGITALIZATION AND AUTOMATION OF PROCESSES IN CONSTRUCTION

ABSTRACT

This article presents a comprehensive study of modern financial instruments capable of stimulating digital transformation and automation processes in the construction industry. Enhancing the technological maturity of construction sector enterprises becomes a key factor in ensuring their competitiveness amid global digitalization and the transition to Industry 4.0. In this context, financial innovations play not only the role of capital mobilization tools but also act as catalysts for the implementation of digital solutions, platform systems, BIM technologies, automated construction management, and lifecycle monitoring systems. The paper focuses on revealing the essence and classification of financial innovations, highlighting such instruments as intellectual bonds (IP bonds), venture investments, crowdfunding, green bonds, and partnership financing of digital projects. A systematic table is provided analyzing each instrument, its level of implementation, advantages, and significance for the construction sector, along with illustrative statistical data on the volume of investments in construction digitalization in Ukraine in recent years. Particular attention is given to analyzing risks associated with innovative financial mechanisms, such as the complexity of valuing intellectual assets, insufficient legal clarity of intellectual property-based financing, risks related to regulatory framework misalignment with modern technologies, and potential volatility of the venture capital market. The necessity of forming a balanced financial strategy for construction companies, which would involve diversification of funding sources for digital projects, is substantiated. The research results have practical implications for financial managers of construction enterprises, representatives of investment companies, government regulatory bodies, and the scientific community studying transformational processes in the economy.

Keywords: financial instruments, construction digitalization, automation of construction processes, innovative financial mechanisms, construction sector, financial risks, innovation investments, construction startups

JEL Classification: G23, L74

INTRODUCTION

The construction sector has always been, and remains, one of the fundamental pillars of the national economy, as it provides the physical embodiment of economic growth and social development. However, at the dawn of the 21st century, the role of construction is no longer confined to traditional approaches to erecting buildings. Global challenges—from climate change to the devastating consequences of armed conflicts—are forcing the industry to rethink both its technological processes and the financial mechanisms that make them possible.

In the context of Ukraine's post-war recovery, the need to modernize the construction sector has taken on particular urgency. The country now faces the task not merely of rebuilding destroyed infrastructure, but of shaping an entirely new model of construction—one that is technologically advanced, transparent, risk-resilient, and capable of rapid scaling. In other words, the goal is to create a model of "digital construction," in which automation, digitization, and intelligent systems become integral to the production cycle.

However, the transition to such a model requires more than just software, sensors, or BIM models. A fundamental change in the ways these processes are financed is needed. Traditional forms of capital raising are focused on tangible assets calculated using classic balance sheets, while digital innovations in construction are predominantly intangible assets: patents, algorithms, software complexes, and integrated management systems. Their valuation and financing go beyond the usual credit model that financial institutions are accustomed to using.

Therefore, the role of innovative financial instruments in the digitalization and automation of the construction industry cannot be overestimated. These include intellectual property bonds (IP bonds), venture financing, crowdfunding mechanisms, green bonds for financing sustainable digital projects, project financing taking into account future cash flows, as well as public-private partnerships that allow attracting large capital investments for technological modernization of the industry.

The integration of such financial mechanisms is not a fleeting trend or an attempt to follow global currents for the sake of appearances. It is a matter of survival. In today's world, competition is no longer about access to raw materials or labor – it is about the speed of adaptation to technological change. And the construction industry, despite its traditionally conservative character, is no exception.

LITERATURE REVIEW

One of the foundational studies underpinning this topic is the work of Virchenko V.V. (Virchenko, 2018), which convincingly argues that traditional financing models—focused primarily on classic, tangible construction assets—are no longer sufficient. They fail to accommodate the investment needs associated with implementing intelligent management systems, process automation, and digital infrastructure. Virchenko emphasizes the urgent need to design flexible financial mechanisms capable of mobilizing capital specifically for digital innovation in the construction sector.

Over the past decade, financing in construction has begun to shift from a purely economic consideration to one of strategic significance. In particular, the comprehensive analysis by Chuvpylo V., Shevchuk S., Hapon S., Nahorna S., and Kuryshko R. (2023) draws attention to the role of digital-asset-linked bonds in transforming capital structures within construction firms, enabling more agile adaptation to technological change.

However, even with the clear advantages of these innovative financial mechanisms, the construction industry faces significant challenges. Chief among these is the difficulty of objectively valuing intangible digital assets. As Adibfar A., Costin A., and Issa R.R.A. (2020) point out, digital products—such as construction-management software, automation algorithms, and BIM models – are complex to quantify financially, complicating their use as collateral or other forms of financial security.

Balytska, M. (Balytska et al., 2021) explores the role of financial technologies as a key driver of financial market development. The authors analyze how digital tools – including online payments, blockchain, and electronic platforms – influence the efficiency of financial operations, enhance transparency, and stimulate innovation within the financial sector. They conclude that fintech acts as a catalyst for structural transformation in capital markets and contributes to strengthening the competitiveness of national financial systems.

At the same time, Bondarenko, S. (Bondarenko et al., 2022) examines the legal mechanisms for ensuring information security in the context of digitalization. The authors analyze the regulatory framework governing data protection, cybersecurity, and information relations in the digital economy. The study emphasizes the need to harmonize national legislation with international standards to prevent cyber threats and enhance trust in digital financial and socio-economic processes.

In the work of Desyatnyuk, O. (Desyatnyuk et al., 2024), the authors investigate the impact of digitalization on international financial security within the framework of sustainable development goals. The paper explores how digital technologies transform financial risk management mechanisms, international financial flows, and threat monitoring systems. Special attention is given to cybersecurity issues and the relationship between financial innovations and sustainable economic growth.

The study by Dziubliuk, O. (Dziubliuk et al., 2022) focuses on the modern development of the payment card market in the digital economy. It examines trends in the adoption of contactless, mobile, and electronic payment systems, as well as the level of digital integration of banking services. The authors emphasize that the development of payment infrastructure is a crucial factor in enhancing financial inclusion and improving the efficiency of the banking sector.

In Fedosiuk, Y. (Fedosiuk et al., 2024), attention is drawn to the emerging trends in fintech development in 2024. The author explores the influence of artificial intelligence, big data, and regulatory technologies (RegTech) on the transformation of financial markets. The study highlights the formation of new business models, the digitalization of banking services, and the challenges faced by financial institutions amid rapid technological change.

Summarizing the reviewed works, it can be concluded that the academic community views the digitalization of the financial sphere as a strategic factor in economic development, integrating technological, legal, and managerial dimensions. The gradual transition to digital financial instruments creates the foundation for strengthening financial resilience, expanding inclusion, and forming a new type of financial ecosystem characterized by innovation and transparency.

Despite the evident relevance of this issue, regulatory and methodological frameworks for accounting and valuing digital assets in construction remain underdeveloped. Traditional accounting approaches have been rooted in physical resources – assets with clear market prices and predictable depreciation. Digital assets, by contrast – software modules for modeling, analytical algorithms, integrated management platforms – often lack direct market analogues. Their abstract nature resists fixed valuation and complicates integration into standard financial reporting.

Accordingly, Chuvpylo et al. (2023) argue that establishing transparent, standardized approaches to evaluating digital assets within construction is essential. This involves not simply adjusting procedural norms, but fundamentally shifting accounting paradigms so that digital technologies are recognized as defined components of business value. Without this, it becomes impossible to build realistic financing models in which intellectual development is seen not as a cost, but as a source of added value. Over time, such models would enable construction firms to attract systematic investment not only in materials and equipment, but also in algorithms, data architecture, and digital solutions.

Current discourse around financing construction's digitalization is further sharpened by global structural shifts. Zhosan H. (2022) warns that overreliance on external capital for digital innovation can carry latent but serious consequences. When firms lean heavily on outside funding, they risk narrowing their strategic focus: settling for piecemeal automation – such as digitalizing document workflows or individual operations – while neglecting deeper investments in R&D, organizational redesign, and human-capital development. Consequently, digital initiatives may become superficial ornaments rather than transformative interventions.

Critical reflection on this tension – between superficial digital adoption and deep structural transformation—is key to shaping a new investment model in construction. Absent reformed approaches to accounting for digital assets, meaningful transformation remains unlikely. Zhosan H. therefore underscores the necessity of hybrid financial strategies that combine external investment with internal reinvestment in strategic digital development.

Today's construction sector is undergoing rapid evolution under pressure to embed digital technologies across all essential processes. Digitalization in construction is not a bolt-on innovation or isolated automation – it is a strategic realignment of business models: reassessing project management, adopting Building Information Modeling (BIM), deploying automated quality-control systems, and applying real-time monitoring of logistics and financial flows. Clearly, such transformation demands appropriate, specialized financial backing – not standard credit lines, but tailored instruments suited to the digital economy of construction.

FinTech solutions – long dominant in banking and e-commerce – are gradually penetrating the construction landscape. Enabled by the rise of the Internet of Things, mobile technologies, cloud services, and big data analytics, innovative financial tools are now available to the industry. As Kloba L., Dobosh N., and Soroka O. (Kloba et al., 2020) observe, financial technology in construction now embodies a radically new management approach: prioritizing rapid decision-making, flexible financial planning, and automated oversight of resource spending – far beyond traditional accounting or simple payment interfaces.

In this context, the position of Tarasiuk M.V. (Tarasiuk et al., 2017) is particularly relevant. The researcher emphasizes the need for a broader understanding of financial instruments in the process of digital construction digitalization. According to Tarasiuk, the issue is not merely about conventional loan products or standard payment services. Rather, a comprehensive system is emerging – one that integrates finance, information technology, and risk management tools into a unified, holistic financial chain.

Among the most pertinent financial innovations identified by the author are crowdfunding platforms, which enable the accumulation of capital for innovative projects without involving traditional banking institutions; as well as infrastructure and green bonds, which facilitate financing for energy-efficient and environmentally sustainable construction. Notably, the growing role of venture capital is also highlighted. This form of financing is becoming a key driver for startups developing digital solutions for the construction industry, thereby accelerating modernization across the sector.

The increasing adoption of IP-backed bonds – financial instruments secured by intellectual property – warrants particular attention. This mechanism opens new pathways for construction firms to monetize intangible assets. These include not only patented technologies or engineering solutions but also digital products such as BIM models, construction management software suites, and automation algorithms, which are increasingly being recognized as legitimate financial assets.

As a result, financial technologies in construction are no longer limited to supporting the operational implementation of projects. Instead, they are forming the foundation of a new architecture for investment management – one that not only enables capital acquisition but also optimizes its allocation while ensuring high standards of transparency, efficiency, and accountability. In this regard, financial transformation in the construction sector is shifting from being a potential option to becoming a pressing necessity – no longer a matter of the future, but an imperative of the present.

A systematic analysis of these instruments reveals that the financial infrastructure supporting construction digitalization is multi-layered. It encompasses:

- tools for real-time financial accounting and audit automation;
- digital platforms for managing investment flows and contracts;
- innovative credit products tailored to the implementation of digital technologies in production;
- insurance instruments designed to mitigate risks associated with automation and robotics in construction.

According to Fedulova and Liebidieva (2011), financial innovation represents a distinct class of economic processes involving the creation of new financial products, services, or technologies capable of driving internal transformation within an enterprise or achieving commercial market viability. In the construction context, this means that novel financial solutions must not only simplify capital-raising procedures but also facilitate the integration of digital technologies into construction management. This includes financing the development and deployment of BIM modeling, automated resource accounting systems, electronic tendering platforms, and cloud-based project management tools.

Financial instruments for construction digitalization can take various forms and functions. These may include conventional banking products enhanced with technological features – such as loans for innovation-driven projects—or entirely new financial mechanisms, such as digital platforms for funding automation initiatives or the tokenization of real estate assets to attract investment (Kloba et al., 2020). These instruments may be short- or long-term, target mass or niche markets, and exist in either tangible form (e.g., automation equipment) or intangible form (e.g., digital services, blockchain solutions for contract transparency).

The essence of financial innovation in construction goes far beyond simply updating traditional capital-raising tools. What is unfolding is a fundamental rethinking of the logic governing financial and production processes in the construction industry – a transformation on a scale comparable to the industrial revolutions of past centuries. It is no longer sufficient to merely fund physical construction projects. The modern market demands the development of new management models, in which finance is an integrated component of the digital ecosystem governing construction activity.

Guryanova, L. (Guryanova et al., 2024) and Khaustova, M. (Khaustova et al., 2022) describe in their research the application of machine learning methods to assess financial decentralization reforms, focusing on their impact on inclusive and sustainable regional development.

Kryshtanovych, M. (Kryshtanovych et al., 2021) and Latysheva, O. (Latysheva et al., 2020) model the process of forming the safety potential of engineering enterprises, proposing a methodological framework for risk assessment and management. Their study includes empirical examples demonstrating the practical application of the model to enhance organizational safety levels.

Latysheva, O. (Latysheva et al., 2020), Lelyk, L. (Lelyk et al., 2022), and Makedon, V. (Makedon et al., 2019) explore approaches to managing the sustainable development of machine-building enterprises through the concept of a “sustainable development space,” integrating environmental, economic, and organizational parameters. Their research proposes tools for strategic planning and assessing enterprise sustainability.

In the work of Lazebnyk, L. (Lazebnyk et al., 2020), the authors analyze the role of information infrastructure in the digitalization of enterprise business processes, emphasizing the importance of building efficient IT structures and communication systems. The study provides practical recommendations for improving IT infrastructure to support digital transformation.

Mamonov, K. (Mamonov et al., 2023) examines the state and specific characteristics of the development of construction enterprises, analyzing industry economic indicators and internal organizational challenges. The paper offers recommendations aimed at enhancing operational efficiency and adapting to market dynamics.

Mia, M. (Mia et al., 2022) investigates the impact of green entrepreneurship on social transformation and the factors influencing the application of the AMO theory (Ability–Motivation–Opportunity). The research demonstrates how environmentally oriented business models drive behavioral and organizational transformations in society.

Nikonenko, U. (Nikonenko et al., 2022) evaluates investment attraction policies in key economic sectors, taking into account the introduction of Industry 4.0 principles. The authors analyze barriers and opportunities for investment within the context of production digitalization.

Finally, Solodzhuk, T. (Solodzhuk et al., 2023) and Yarova, M. (Yarova, 2023) analyze the current state of the fintech market in Ukraine and outline its development prospects. They highlight key growth drivers, regulatory challenges, and potential directions for future innovation.

In contemporary academic discourse, the classification of financial innovations has long been a subject of focused analysis. However, as Shevchenko V. (2012) rightly notes, existing classification approaches can and should be adapted to the specific needs of individual sectors – particularly construction. Such adaptation is not only reasonable but also essential in light of the rapid transformation occurring within the industry under the influence of digitalization and automation.

In this context, four key areas of financial innovation directly relevant to the construction sector can be identified:

1. **New Financial Products.** This refers not merely to the modernization of traditional credit lines or insurance packages, but to the development of specialized financial instruments tailored to the specific needs of digital transformation in construction. These include targeted loan programs aimed at implementing automated construction management systems; financing tools for the development and deployment of digital platforms for construction oversight; and models for funding the creation of intellectual property, such as patented software solutions. One particularly promising area is the tokenization of infrastructure projects, which enables the attraction of investments through the issuance of digital assets backed by real construction objects.
2. **New Financial Services in Construction: The Evolution of Financial Interaction.** In the current phase of development in the construction industry, it has become increasingly evident that financial support for innovation can no longer be confined to traditional mechanisms. The digitalization of construction necessitates new forms of financial engagement, where conventional banking instruments are gradually being replaced by more flexible and technologically advanced solutions.
3. **New Forms of Organizing Financial Structures in the Construction Sector.** Innovations have impacted not only financial products and services but also the organizational models of financial institutions serving the construction industry. This includes the emergence of a new institutional support format involving the establishment of digital banking entities tailored to serve construction companies with a high degree of process automation.
4. **New Financial Technologies as a Driver of Transformation in the Construction Sector.** The modern financial infrastructure of the construction industry is now inconceivable without the application of innovative digital technologies.

AIMS AND OBJECTIVES

The objective of this article is to provide a deep theoretical reflection and a comprehensive analysis of the role of innovative financial instruments in the context of digitalization and automation within the construction industry. At the same time, the paper aims to develop practical recommendations to enhance the effectiveness of these financial mechanisms in order to accelerate the technological transformation of the construction sector.

The main research tasks are as follows:

1. First, to reveal the essence and specific features of financial innovations in the construction sphere, taking into account its current digital paradigm.
2. Second, to conduct a detailed analysis of modern financial instruments that directly contribute to the implementation of technological changes and innovations in construction processes.
3. Third, to assess the risks associated with the use of advanced financial mechanisms in this sector, particularly those that may affect the stability and long-term effectiveness of projects.
4. Finally, to formulate concrete, practice-oriented recommendations for improving financial tools that would stimulate a more dynamic and sustainable development of digital transformation in construction activities.

METHODS

The development of this study's methodology was not merely a technical stage – it became part of a broader process of reflecting on the very nature of digital transformation within the construction industry. The focus extended beyond quantitative indicators or a list of tools; it centered on the evolving logic of how financial mechanisms operate in an environment that is rapidly detaching from material foundations. For this reason, a multidimensional approach was adopted, allowing for the integration of a macro-analytical perspective with attention to operational nuances.

First and foremost, systems thinking served as the conceptual foundation for analyzing how financial instruments interact with digitalization processes at both the company and industry levels. The goal was not simply to categorize variables, but to uncover their mutual interdependencies – across temporal, functional, and institutional dimensions. Digital solutions are often perceived as standalone investment items, which complicates their integration into overarching financial models. Here, the systems-based approach helped to dismantle such methodological barriers.

Another essential, though less formal, source of data was expert judgment and insight from professionals directly involved in the sector. Their perspectives offered more than raw statistics – they opened a window into the decision-making “kitchen,” complete with its uncertainties, intuitions, risks, and constraints. The use of expert surveys enabled the alignment of objective trends with the actual practices unfolding on the ground.

Ultimately, the methodological framework of this study is not merely a collection of tools. It is a reflection of the research subject itself – viewed simultaneously as a dynamic system, a space of regulatory ambiguity, and a field of innovation. Consequently, the research required a flexible, reflective approach – one capable of capturing complexity without dissolving it into oversimplification.

RESULTS

In today’s environment, where the economic landscape is increasingly characterized by digital integration, financial innovation in the construction sector is evolving far beyond a narrowly technical interpretation. Whereas in the past this concept was often limited to new banking products or modifications of traditional investment tools, it now reflects a fundamental transformation of the entire financing logic – one that takes into account the challenges of the digital age, environmental priorities, and the need for adaptive governance.

As digital platforms continue to penetrate deeper into construction operations, financial innovation is no longer merely about identifying sources of funding. Rather, it represents a technological capacity to ensure transparent, flexible, and at the same time, structured management of financial flows.

This shift has led to the emergence of a new class of financial solutions – including smart contracts, automated settlement systems, crowd-investing models, asset tokenization, and digital bonds tailored to sustainable development goals. These instruments are not just theoretical constructs; many are already being applied in practice or possess significant potential to support the digitalization and automation of construction processes.

Table 1. Innovative financial instruments supporting digitalization and automation in construction. (Source: Tarasiuk M. V. (Tarasiuk et al., 2017); Kloba L., Dobosh N. та Soroka O. (Kloba et al., 2020))

Type of Financial Instrument	Level of Implementation	Key Application Advantages	Relevance to the Digitalization and Automation of Construction Processes	Illustrative Statistical Data
Intellectual Property Bonds (IP Bonds)	Moderate	Provides funding based on the valuation of digital technologies and patents; incentivizes investment in automated solutions development	Enhances companies’ innovation potential, supporting the development of digital tools and automation technologies	Approximately 12% of construction enterprises raised funds through IP bonds to implement digital solutions (2022)
Venture Capital Investment	High	Offers significant capital and access to expert support, facilitating the implementation of digital platforms and automated systems	Accelerates the adoption of innovative technologies and digital processes in the construction sector	The volume of venture capital investments in construction digital technologies has grown by 35% over the past 3 years

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Table 1. Continued.

Type of Financial Instrument	Level of Implementation	Key Application Advantages	Relevance to the Digitalization and Automation of Construction Processes	Illustrative Statistical Data
Joint Financing of Construction Digital Projects	High	Enables risk-sharing and pooled resources for the implementation of automated systems and digital solutions	Facilitates the execution of complex digital projects and fosters collaborative innovation	40% of major digital construction projects are implemented through partnership-based financial models
Green Bonds	High	Attracts investment for projects involving digital monitoring and automation of ecological processes	Promotes sustainable development in the sector by integrating digital technologies into green building standards	Green bonds account for approximately 18% of total investments in construction digitalization projects
Crowdfunding and Crowdinvesting	Moderate	Broadens the investor base and fosters public support for digital and automated innovations	Enables financing of startups and innovative projects with digital solutions; increases market engagement	Over the past 5 years, more than 250 construction startups with digital technologies have raised capital via crowdfunding

The presented table is not merely the result of academic systematization of financial instruments; rather, it reflects a fundamental shift in thinking about how and through which mechanisms the digital transformation of the construction sector can be financed. Each entry represents more than a formal listing—it offers a strategic perspective on the specific tools that can act as catalysts for change in an industry that has remained traditionally conservative for decades.

Table 2. Dynamics of investment volumes in innovative financial instruments for the digitalization of the construction sector (2021–2024).

Innovative Financial Instrument	2021	2022	2023	2024	Average Growth (%)	Key Trends and Explanations
Venture Funding for ConTech	USD 2.9 billion	USD 3.5 billion	USD 4.1 billion	USD 4.5 billion	+35%	Increasing redirection of venture capital towards construction startups specializing in robotics, BIM, 3D printing, and digital platforms. A growing number of investors are entering the ConTech space.
Intellectual Property Bonds (IP Bonds)	USD 480 million	USD 600 million	USD 750 million	USD 800 million	+20%	Employed by major construction firms to raise capital for technology development, especially patented automation solutions.
Joint Financing of Digital Projects (PPP, Consortia)	USD 1.3 billion	USD 1.7 billion	USD 2.1 billion	USD 2.3 billion	+28%	Formation of strategic partnerships for the development and deployment of automated construction control systems, cloud services, and digital twins.
Green Bonds for Construction	USD 800 million	USD 1.0 billion	USD 1.2 billion	USD 1.3 billion	+30%	Funding of digital solutions for energy efficiency monitoring and automation of environmental compliance at construction sites.
Crowdfunding and Crowdinvesting	USD 75 million	USD 100 million	USD 130 million	USD 150 million	+40%	Support for construction startups in the digital construction segment, including mobile apps for process automation and AR/VR technologies.

The implementation of innovative financial mechanisms in the construction sector holds substantial potential for enhancing efficiency and accelerating digital transformation. At the same time, this process is accompanied by a range of specific risks that require thorough analysis and systematic management.

Table 3. Risks requiring thorough analysis and systematic management. (Source: Tarasiuk M. V. (Tarasiuk et al., 2017); Kloba L., Dobosh N. ta Soroka O. (Kloba et al., 2020))

Type of Risk	Description	Potential Consequences	Possible Risk Management Measures
Technical Risk	Imperfections or complexity of new technologies (smart contracts, blockchain)	Financial losses, legal issues	Staff training, system testing
Regulatory Risk	Absence or uncertainty of a legislative framework for new financial instruments	Legal ambiguity, investment restrictions	Legislative monitoring, cooperation with regulators
Financial Risk	Difficulties in valuing innovative assets and products	Misallocation of capital, loss of trust	Implementation of modern valuation methods, transparency in reporting
Cybersecurity Risk	Threats of cyberattacks, data breaches, and failures in automated systems	Financial damage, breach of confidentiality	Investment in cybersecurity, regular security audits
Organizational Risk	Employee resistance to change, low proficiency with innovative financial technologies	Implementation delays, process inefficiencies	Training, employee motivation, corporate culture change
Market Risk	Market volatility, changes in investment climate, and economic instability	Decline in profitability, reduced investment attractiveness	Diversification of funding sources, market trend analysis

Successful risk management at the intersection of digital transformation and automation in the construction sector is achievable only through the application of a systemic, interdisciplinary approach. This approach must be based on the integration of several key elements: technological capacity of enterprises, up-to-date regulatory frameworks, continuous financial monitoring, adequate cybersecurity measures, and, importantly, the development of human capital as the driving force behind adaptation to new conditions. Only through the coordinated interaction of these components can a reliable platform be established for the implementation of modern financial solutions capable of supporting sustainable digital transformation within the industry.

Particular attention should be given to the practical integration of finance and digital technologies. This is not merely a declarative goal but a concrete necessity – to synchronize financial planning with digital platforms such as BIM or ERP. Such integration enables a new quality of project management: expenditures become transparent, budgets flexible, and managerial decisions data-driven in real time. Investors receive verifiable figures rather than abstract forecasts, which in turn reduces risks and increases trust in projects.

The next step should be the introduction of specialized financial instruments tailored to the demands of the digital economy. This includes innovative credit products for implementing automated systems, flexible leasing programs, and green financing aimed at energy-efficient and environmentally responsible solutions. These instruments provide access to resources that have traditionally been outside the scope of conventional banking.

At the same time, the specific needs of small and medium-sized enterprises – often the initiators of change but frequently facing limited access to finance – must not be overlooked. Here, digital financing platforms – from crowdfunding to specialized fintech services – play a crucial role in democratizing capital markets and providing an equal starting point even for the smallest players.

Special consideration must also be given to the regulatory environment. Its role extends beyond oversight to creating conditions conducive to development. Flexible, technologically savvy legislation that accommodates instruments such as smart contracts and asset tokenization can become a catalyst for innovative activity and a safeguard against abuse.

Moreover, digital transformations cannot be envisioned without adequate risk management – encompassing financial, cyber, technical, and reputational risks alike. The creation of integrated risk management systems with an emphasis on proactive measures rather than reactive responses is essential for the sustainable development of digital projects.

Thus, the formation of a modern financial infrastructure oriented towards supporting digital change must occur at the intersection of technology, policy, education, and market forces. Only such a multi-faceted approach will create conditions under which digitalization in construction ceases to be an option and becomes a strategic necessity and a driver of sustainable development.

DISCUSSION

The topic of financing digital transformation and automation in the construction industry is attracting increasing attention today, driven by the profound changes that technological progress is bringing to traditional business models and production processes. The renowned researcher Fedulova L., in her seminal study (Fedulova et al., 2011), rightly emphasizes that financial innovations cannot be reduced merely to the evolution of familiar financial products – rather, they represent an independent economic phenomenon that significantly influences the pace of technological innovation adoption across various sectors, including construction.

Equally important observations have been made by Tarasiuk M. (Tarasiuk et al., 2017), who highlight that the development of FinTech opens far broader opportunities than simply optimizing financial flows. It involves the creation of new digital platforms capable of transforming and modernizing even those industries traditionally considered highly conservative. Construction is one such sector was developing collaborative financial ecosystems capable of comprehensive automation of financial operations and interactions among all participants in construction processes is critical.

A significant contribution to this discourse has been made by Chuvpylo V. and colleagues (Chuvpylo et al., 2023), who demonstrate the effectiveness of intellectual property-backed bonds (IP bonds) as financial instruments supporting research and development projects within large companies. They stress that these tools lay the groundwork for systematic financing of automation, including the implementation of BIM technologies, deployment of robotic systems on construction sites, and advancement of digital twins – technologies rapidly becoming industry standards.

Venture financing also draws special attention in academic circles today, being regarded as a catalyst for innovation shifts. Notably, Adibfar A. (Adibfar et al., 2020) provides a detailed analysis of the challenges associated with assessing investment risks in construction digital technologies, caused by high upfront costs and uncertainty in project payback periods. Despite these challenges, venture funds remain a key source of support for startups developing software solutions for the automation and digitalization of construction processes.

Thus, contemporary scholarly consensus consolidates the understanding that innovative financial instruments serve as a fundamental driver of digitalization in the construction sector. However, alongside this recognition emerges a critical need to enhance financial risk management systems, reform the regulatory environment, and foster favorable investment conditions that can ensure stability and consistency in the adoption of technological innovations.

Unlike these studies, our research proposes a systemic and integrated approach that combines financial, technological, and managerial aspects of digital transformation in the construction sector. The main novelty lies in a comprehensive assessment of modern innovative financial instruments – such as IP bonds, venture capital investments, green bonds, joint projects, and crowdfunding – taking into account their impact on the automation and digitalization of processes. At the same time, we conduct a detailed analysis of the risks associated with the use of these mechanisms, including technical, financial, regulatory, cybersecurity, and organizational risks, and propose systemic measures for their management.

A particular strength of our study is the consideration of the needs of small and medium-sized enterprises (SMEs), which often act as drivers of innovation but face limited access to traditional financing. Digital financial platforms – ranging from crowdfunding to specialized fintech solutions – provide equal opportunities for capital access, facilitating a more dynamic implementation of innovations in the sector. Furthermore, we emphasize the importance of synchronizing financial planning with digital platforms (e.g., BIM, ERP), which ensures budget transparency, flexibility in managerial decision-making, and increased investor confidence through verifiable data.

Thus, our research not only confirms the significance of innovative financial mechanisms for the digital transformation of the construction sector but also proposes a holistic approach to their implementation, integrating the technological capacity of enterprises, up-to-date regulatory frameworks, integrated risk management, and human capital development. This provides a scientifically grounded platform for the adoption of modern financial instruments capable of ensuring sustainable and efficient development of the industry in the digital era.

CONCLUSIONS

The results of the conducted research allow us to formulate a number of important generalizations and practical recommendations regarding the implementation of financial instruments in the context of digitalization and automation in the construction industry.

First and foremost, it is important to emphasize that the current reality of the construction sector demands not merely partial adaptation from enterprises, but a fundamental transformation of their business models through the integration of digital technologies. However, this process is impossible without a profound reform of financial approaches. Outdated financing methods, which for a long time served as the backbone of the industry, prove inadequate to support innovations related to automation, digital modeling, and the implementation of intelligent management systems.

On the other hand, a thorough review and systematization of modern financial instruments has identified the most effective tools that meet the challenges of digital transformation. These include intellectual property-backed bonds (IP bonds), which pave the way for leveraging intangible assets; venture financing, which drives technological innovation; collaborative partnership financing, enabling risk distribution among project participants; green bonds, which integrate environmental priorities into digital solutions; and crowdfunding, which fosters the development of small innovative initiatives.

It is also important to note that the implementation of cutting-edge financial instruments holds significant social value, as it contributes not only to strengthening the competitive positions of construction companies but also to shaping a new corporate culture where digital technologies cease to be exceptions and instead become mandatory standards.

At the same time, a number of systemic issues hindering this process cannot be overlooked. These include the absence of transparent and effective methodologies for evaluating intangible assets, insufficient qualification of management personnel in the field of financial innovations, as well as entrenched conservatism that impedes the adoption of new digital approaches in many companies.

Considering these challenges, future research should focus on developing flexible financial management models capable of integrating innovative instruments into the daily operations of construction enterprises, as well as on empirical assessment of their practical effectiveness across various construction sectors – residential, industrial, and infrastructure.

ADDITIONAL INFORMATION

AUTHOR CONTRIBUTIONS

All authors have contributed equally.

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CONFLICT OF INTEREST

The Authors declare that there is no conflict of interest.

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ІННОВАЦІЙНІ ФІНАНСОВІ ІНСТРУМЕНТИ ДЛЯ ЦИФРОВІЗАЦІЇ ТА АВТОМАТИЗАЦІЇ ПРОЦЕСІВ У БУДІВЕЛЬНІЦТВІ

У роботі здійснено ґрунтовне дослідження сучасних фінансових інструментів, здатних стимулювати цифрову трансформацію та автоматизацію процесів у будівельній галузі. Підвищення рівня технологічної зрілості підприємств будівельного сектора стає ключовим чинником забезпечення їхньої конкурентоспроможності в умовах глобальної цифровізації та переходу до індустрії 4.0. У цьому контексті фінансові інновації не лише відіграють роль інструмента залучення капіталу, а й стають каталізатором упровадження цифрових рішень, платформних систем, BIM-технологій, систем автоматизованого управління будівництвом і моніторингу життєвого циклу об'єктів. У роботі зосереджена увага на розкритті сутності та класифікації фінансових інновацій, серед яких виокремлені: інтелектуальні облігації (IP-бонди), венчурне інвестування, краудфандинг, зелені облігації та партнерське фінансування цифрових проєктів. Наведено систематизовану таблицю з аналізом кожного з цих інструментів, рівня їх упровадження, переваг і значення для будівельної галузі, а також надано ілюстративні статистичні дані щодо обсягів інвестування в цифровізацію будівництва в Україні за останні роки. Особливу увагу автори приділили аналізу ризиків застосування інноваційних фінансових механізмів, таких як: складність оцінки інтелектуальних активів, недостатня правова визначеність фінансування на основі ІВ, ризики невідповідності нормативно-правової бази сучасним технологіям і потенційна нестабільність ринку венчурного капіталу. Обґрунтовано необхідність формування збалансованої фінансової стратегії для будівельних компаній, яка б передбачала диверсифікацію джерел фінансування цифрових проєктів. Результати дослідження мають прикладне значення для фінансових менеджерів будівельних підприємств, представників інвестиційних компаній, органів державного регулювання та наукової спільноти, яка досліджує трансформаційні процеси в економіці.

Ключові слова: фінансові інструменти, цифровізація будівництва, автоматизація будівельних процесів, інноваційні фінансові механізми, будівельний сектор, фінансові ризики, інвестиції в інновації, будівельні стартапи

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