ESTOA **27** / pp. 257 - 268 / DOI: 10.18537/est.v014.n027.a16

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Research Article
2025 January - June

Digital transformation in the construction industry: Analysing the impact of technological changes on construction processes Transformación digital en el sector de la construcción: Analizando el impacto de los cambios tecnológicos en los procesos de construcción

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ABSTRACT The relevance of the problem under study lies in the rapid development of digital technologies, which provide unique opportunities for optimising and improving the efficiency of construction production. The purpose of the study is to analyse the impact of digital changes on the technology and organisation of construction activities in Ukraine. The methods of literature review, experimentation, and abduction were used. The study determined which digital technologies, such as BIM, IoT, and AI, are most important to construction organisations. A framework of efficiency-boosting tactics, including personnel training, process optimisation, and technology integration, was created. To visualise data on digital priorities and initiatives, an application was developed. The study emphasised the significance of all-encompassing digital transformation plans and the demand for ongoing innovation in the building sector.

RESUMEN La relevancia del problema objeto de estudio radica en el rápido desarrollo de las tecnologías digitales, que ofrecen oportunidades únicas para optimizar y mejorar la eficiencia de la producción en el sector de la construcción. El objetivo del estudio es analizar el impacto de los cambios digitales en la tecnología y la organización de las actividades de construcción en Ucrania. Se utilizaron los métodos de revisión bibliográfica, experimentación y abducción. El estudio determinó qué tecnologías digitales, como BIM, IoT y AI, son más importantes para las organizaciones de la construcción. Se creó un marco de tácticas de mejora de la eficiencia, incluida la formación del personal, la optimización de los procesos y la integración de la tecnología. Para visualizar los datos sobre prioridades e iniciativas digitales, se desarrolló una aplicación. El estudio subraya la importancia de los planes integrales de transformación digital y la demanda de innovación continua en el sector de la construcción.

Received: 08/03/2024
Revised: 06/08/2024
Accepted: 17/09/2024
Published: 31/01/2025

KEYWORDS technical innovations, architectural dynamics, electronic modernisation, repair procedures, use of devices for construction

PALABRAS CLAVE innovaciones técnicas, dinámica arquitectónica, modernización electrónica, procedimientos de reparación, uso de dispositivos para la construcción

Cómo citar este artículo/How to cite this article: Emelianova, O., Tytok, V., Lavrukhina, K., Shatrova, I., & Demydova, O. (2025). Digital transformation in the construction industry: Analysing the impact of technological changes on construction processes. *Estoa. Revista de la Facultad de Arquitectura y Urbanismo de la Universidad de Cuenca, 14*(27), 257-268. https://doi.org/10.18537/est.v014.n027.a16

e - ISSN: 1390 - 9274
ISSN: 1390 - 7263

1. Introduction

The modern construction industry is experiencing a period of rapid technological development, which is leading to dramatic changes in the way projects are managed. Given this dynamic context, the study of digital change in technology and organisational processes in the Ukrainian construction industry is becoming an extremely important task. The issues of the study are that the construction industry, despite its great potential, faces a number of challenges and constraints that significantly affect its development and competitiveness. It is important to address the issue of effective implementation of digital innovations in the Ukrainian construction sector, ensuring a harmonious combination of technical changes and management strategies to achieve optimal results.

For a better understanding of this topic, it is worth reviewing earlier works that address the tasks at hand. For example, the purpose of the study by Voitovych et al. (2023) was to develop a methodology for optimising the work schedule of a construction company. They used the method of processing expert opinions, organisational and technological modelling, and other mathematical approaches. Marchenko and Koliadenko (2023) studied the trends in the development of construction companies in the context of digital transformation, analysing the real estate market and the digitalisation of the construction business in Ukraine. They conclude that the use of digital transformation in the construction business facilitates the collection and analysis of information on residential and non-residential property, which facilitates administrative services in the sector and the fight against corruption. Researchers Dergachova and Koleshnya (2020) systematised the interpretation of the concepts of "digitisation", "digitalisation" and "digital transformation" in domestic and foreign literature, highlighting their differences. The authors offer their own interpretations of these terms and also consider the role of digitalisation and transformation through the prism of market capitalisation of the world's leading companies.

In their work, the authors Akselrod et al. (2021) explored the concepts of Building Information Modelling (BIM) as an innovative direction in an unstable economic business environment. The authors identified the prerequisites and the need to implement the concept of digital transformation in construction organisations, analysing the obstacles and stages of digital strategy formation. The article also discusses BIM technologies as a tool for analysing and managing large amounts of data in the construction industry and identifies the competitive advantages of their use. The study by Tytok and Rasputnyi (2023) highlights the imperatives of managing the development of enterprises in the digital economy, analysing the digital competitiveness index of Ukraine and the development of enterprises in this context. It is noted that digital transformation is a key component of successful enterprise development management, defining parameters and principles, such as structure and detail. In turn, Lipych (2023) emphasised that technological changes inherently affect enterprise management and require a rethinking of the information strategy within the framework of digital transformation. The digital business strategy, as an important component of this process, determines the directions of development, taking into account digital resources and creating competitive advantages through the digitalisation of products, services, and business models.

The above studies highlight key aspects of digital transformation and enterprise development management. However, they do not detail the impact of digital innovations on specific technological aspects of construction production, and not all studies consider aspects of the implementation of digital solutions at different stages of the construction process and their interaction with different aspects of construction production. This study does not only focus on construction production or the execution phase; rather, it also examines the effects of technical advancements and digital transformation on other facets of the construction business.

The purpose of the study is to analyse the impact of technological change on the Ukrainian construction sector.

2. Literature review

Researchers Seyman Guray and Kısmet (2023) used the concept of "Construction 4.0" to define the direction of development of the sector, where digital technologies are playing an increasingly active role. Statsenko et al. (2023) provided a systematic literature review on Construction 4.0 (C4.0) technologies and applications, proposing a framework of C4.0 scenarios. Tanne and Indrayani (2024) focused on the automation, robotics, and BIM aspects of Construction 4.0 technology integration and visualisation. In their study, the authors provided a graphic depiction of how various technologies might be incorporated. Siriwardhana and Moehler (2024) emphasised skill development in order to fill a gap in the literature on the application of Construction 4.0. The authors noted a number of research gaps, including inadequate preparedness assessments from several perspectives, skill shortages in some countries, and a lack of frameworks for successful Construction 4.0 deployment.

Kor et al. (2023) investigated the integration of deep learning and digital twins in the context of Construction 4.0. Their study highlights the potential of these technologies to revolutionize construction processes, enabling real-time monitoring, predictive maintenance, and optimized decision-making. The authors emphasize that the synergy between deep learning algorithms and digital twin models can lead to more accurate project planning and execution, ultimately reducing costs and improving overall project outcomes.

The application of artificial intelligence (AI) and smart vision technologies in construction has been explored by Baduge et al. (2022). Their comprehensive review outlines various machine and deep learning methods that are being employed in the construction sector. The authors argue that AI-powered systems can significantly enhance quality control, safety management, and productivity in construction projects. They also note that the integration of these technologies aligns with the principles of Construction 4.0, fostering a more data-driven and intelligent approach to building processes.

In their systematic review, Begić and Galić (2021) explored the concept of Construction 4.0 in relation to BIM 4.0. Their findings suggest that the integration of BIM with other digital technologies, such as the Internet of Things (IoT) and cloud computing, is crucial for realizing the full potential of Construction 4.0. The authors argue that this integration can lead to more collaborative and transparent construction processes, facilitating better communication among stakeholders and enabling more sustainable building practices.

Sawhney et al. (2020) provide a comprehensive overview of Construction 4.0, describing it as an innovation platform for the built environment. They discuss various aspects of digital transformation in construction, including the use of robotics, 3D printing, and advanced materials. The authors emphasize that Construction 4.0 is not just about technology adoption but also involves a fundamental rethinking of construction processes, business models, and workforce skills.

A system that integrates numerous robots and human agents working together to improve productivity and efficiency in building jobs was developed by Prieto et al. (2024). The study's findings showed that multiagent robotic systems are capable of overcoming obstacles and finishing construction projects quickly. Sonkor and García de Soto's (2024) research focuses on the cybersecurity issues related to ChatGPT use in construction projects. The authors underscore the growing dependence of the construction sector on information and operational technologies to enhance efficiency, precision, and excellence.

In an effort to increase awareness of this new technology, AlBalkhy et al. (2024) provided a thorough analysis of digital twins in the built environment sector. The study suggested DT systems' definition and organisational framework consisting of our main layers. Moshood et al. (2024) explored the potential of digital twin technology to revolutionise the construction industry, which has historically been slow to adopt digital innovations.

A thorough and methodical analysis of the digital revolution taking place in the building construction sector was provided by Naji et al. (2024). Al-Omari et al. (2023) examine the current level of digitalisation adoption in the Jordanian construction industry and identify the key obstacles hindering its implementation. Lim et al. (2024) provided insights on potential improvements for the inefficient companies, which could be valuable for policymakers, investors, and other stakeholders in making informed decisions about resource allocation and investment opportunities in the construction sector.

Table 1 provides a comprehensive overview of the digital technologies discussed in recent research on the construction industry. It shows the range of technologies being studied in the building industry and helps identify which digital technologies are getting the most attention in current research.

	BIM	IoT	AI	AR	VR	Automation	Robotics
Seyman Guray and Kısmet (2023)	x		x				
Statsenko et al. (2023)	x	x	x	x	x	x	x
Tanne and Indrayani (2024)	x			x	x	x	X
Siriwardhana and Moehler (2024)						x	X
Prieto et al. (2024)			x			x	X
Sonkor and García de Soto (2024)			x				
AlBalkhy et al. (2024)		x					
Moshood et al. (2024)		x	x				
Naji et al. (2024)	x	x	x	x	x	x	X

Table 1: Digital technologies in construction industry research. (2024)

3. Methods

The research was conducted using the methods of narrative literature review and experiment, as well as induction and deduction.

The narrative literature review method was used to comprehensively examine existing scientific works on the topic. The strategy used for this approach involved an organised process to find, assess, and compile pertinent studies. Using particular keywords associated with digital transformation, construction technology, and organisational change, important databases and publications were searched. In order to assure the authenticity and reliability of the results, the selection criteria concentrated on peer-reviewed publications, conference papers, and industry reports (Webster and Watson, 2002).

The narrative literature review method helped explore expert opinion processing techniques, organisational and technological models, and various mathematical approaches relevant to the construction sector. The review covered a range of subjects, including the prospects for the development of the construction sector, the role of digitalisation through market capitalisation, BIM concepts, the digital competitiveness index in Ukraine. Additionally, the review analysed a model of digital transformation with virtual reality (VR) and augmented reality (AR) and the creation of a digital transformation model for the maritime industry.

The study assesses the effects of digital transformation in the construction sector using the competitiveness and readiness indices. While the readiness index measures a company's preparedness to accept and use digital technologies, the competitiveness index gauges how well a company can compete with these technologies. These metrics were selected due to their applicability in assessing the stage of digital transformation in construction companies as well as its future potential.

The experiment method was used to create a table of priorities for digital technologies (BIM, IoT, AI, VR/AR, automation, and robotics) for construction companies – Skanska, Turner Construction, and BAM Construct. Priority was determined by assigning a score from 1 to 7, where 1 is the lowest priority and 7 is the highest. The study employed a stratified random sampling method to select participants from these construction companies. A total of 43 participants took part in a survey. Regarding the company distribution, 16 participants were from Skanska, 19 – Turner Construction, and 8 – BAM Construct. A wide spectrum of professionals from the construction industry were represented in the sample: project managers made up 25%, engineers 20%, IT specialists 15%, site supervisors 15%, architects 10%, quantity surveyors 10%, and sustainability experts 5%. The age distribution of participants was as follows: 30% were between 25-34 years old, 40% between 35-44, 20% between 45-54, and 10% over 55. In terms of gender, 70% of respondents were male, and 30% were female.

In addition, a framework for strategies to improve efficiency in the construction industry was developed. It includes criteria such as technology integration, process optimisation, staff training and development, standardisation and regulation, sustainability and innovation, and environmental awareness. A simple application was also implemented using JavaScript, HyperText Markup Language (HTML), and Cascading Style Sheets (CSS) to analyse the data from these tables and diagrams and then visualise them. The code generates interactive graphs that are embedded on the website and show the results of the use of digital technology priorities and strategies in the construction sector. In general, this application is implemented as an HTML page with embedded JavaScript code and uses the Chart.js library to create dynamic charts. The main elements of the code are used to display information about digital technology priorities and efficiency strategies in the construction industry. It uses data for the graph, including company labels and technology priorities, graph settings such as scales and legends. It also uses data for the strategy graph and strategy graph settings. The result is displayed as interactive graphs on a web page.

An abductive reasoning approach was used in the study, which successfully integrates induction and deduction in a cycle of theory construction and data analysis. This strategy enabled a dynamic interplay between theory and empirical facts. Originally, theories and literature on digital transformation in construction were consulted in order to extract possible explanations and hypotheses. This process was known as deductive reasoning. In order to generalise from these particular facts, inductive reasoning was then used. The abductive technique made it possible to continuously improve theoretical claims in response to fresh empirical data and vice versa. This offered a more thorough and adaptable framework for dissecting the various facets of technological advancement in the building industry (Niiniluoto, 2024).

Overall, the methods used contributed to a deep understanding and study of various aspects of digital transformation in the construction industry. The applied methods allowed for the analysis of innovation, technological progress, and strategic management, as well as the effective implementation of experimental approaches to identify digital technology priorities and develop strategies to improve efficiency in the construction industry. Efficiency-enhancing measures in the construction industry necessitate a multifaceted strategy that includes long-term performance monitoring, qualitative evaluations, and quantitative data. Challenges include addressing complex factors like project scales, regional differences, and evolving regulatory landscapes, and adapting evaluation methods to rapidly advancing technologies.

4. Results

In today's world, the construction industry is entering an era of digital transformation, accompanied by the rapid development of digital technologies. Digital transformation encompasses the introduction of modern technologies and strategies to optimize all aspects of the construction process. This transformation is driven not only by the use of digital tools but also by a rethinking of classical management methods and production processes (Naji et al., 2024).

The advantages of using digital technologies include increased efficiency of production processes, as digital technologies allow for optimisation of workflows, automation of routine tasks, and reduction of lead-time (Ernstsen et al., 2021). Data accuracy and quality are also important, as the use of various digital tools ensures high accuracy and quality of data processing. Electronic systems facilitate the exchange of information between different stakeholders in the construction process, which contributes to better communication and collaboration between teams. Cost savings and resource optimisation are equally important. Digital technologies make it possible to use resources more efficiently, which leads to lower construction and maintenance costs (Voitovych et al., 2023; Bannikov et al., 2019). Opportunities for innovation should also be considered, as digital technologies pave the way for innovative solutions and technical innovations.

On the other hand, the digital transformation in the construction sector is accompanied by certain challenges and disadvantages. Firstly, high implementation costs can be a significant constraint, as the transition to digital technologies requires significant financial outlays. Industry specifics can also complicate adaptation, as the construction sector has unique requirements and processes that may not always interact perfectly with new technologies (Akselrod et al., 2021; Kerimkhulle et al., 2023). Data security issues arise with the increasing volume of digital data. Dependence on technical systems can also be risky, as technical failures or system failures can cause construction work to be suspended and production time to be lost (Xiao et al., 2022; Bollano, 2024). Therefore, both the advantages and disadvantages of digital transformation in construction production need to be carefully considered when developing and implementing strategies to optimise the sector.

An important step in achieving this goal is to analyse the impact of digital changes on technologies and organisations in the construction industry. Since digital transformation leads to the introduction of new innovative solutions and improved process efficiency, it is worth considering certain examples of technologies and construction companies that use digital transformation. For example, BIM is a digital technology that allows for the creation of virtual 3D models of buildings and facilities. BIM also allows for better communication and collaboration between different stakeholders in the construction process (Afzal et al., 2023; Andrukhov et al., 2023). IoT is a technology that allows connecting various devices and sensors to the Internet, which allows collecting and analysing data from construction projects in real time. This helps to identify problems and ensure more efficient management of construction processes (Statsenko et al., 2023). AI can be used to analyse large amounts of data, predict, and optimise construction processes (Marchenko and Koliadenko, 2023). In addition, there is AR and VR. These technologies can be used to visualise construction projects and train workers. They allow creating interactive virtual environments that facilitate the design and construction processes (Naji et al., 2024; Leshchenko and Semko, 2015). Automation and robotics are important as the construction industry uses robots and automated systems to perform routine tasks such as welding, painting, and assembly (Tanne and Indrayani, 2024). These technologies and innovations help to improve productivity, reduce costs, and increase the quality of construction production. They also help to increase workplace safety and reduce environmental impact.

The following construction companies that are embracing digital transformation are also worth considering: Skanska, Turner Construction, and BAM Construct UK. Skanska uses digital technologies such as BIM and IoT to improve the efficiency of construction processes and reduce costs. It also uses BIM and parametric estimation technology to speed up the construction process. In addition, the company uses a concrete strength monitoring system, using the Internet of Things and cloud technologies, to provide real-time data. With the use of these technologies, it is crucial to consider the potential cybersecurity risks associated with increased connectivity on construction sites (Lim et al., 2024). Skanska emphasises that the introduction of AI in construction can improve safety. Although it is important to examine how this might impact human decision-making and accountability in high-risk situations. It is also introducing virtual reality, augmented reality, and mixed reality, from conceptual design to construction and operation. The company is also taking the first steps in the use of robotics, digital manufacturing, and other innovations.

Turner Construction also uses all of these technologies. The company uses virtual design, construction, and BIM capabilities to provide confidence throughout the project lifecycle for its clients and partners. When it comes to these technologies, it is crucial to evaluate how effective they are in comparison to traditional hands-on experience. While immersive simulations of construction scenarios can be achieved through VR and AR, they do not offer the same tactile feedback or real-world variety as on-site training (Al-Omari et al., 2023). Turner Construction is successfully implementing non-invasive IoT devices on its construction sites. The company's AI experts have introduced a number of best practices and innovative solutions to help employees analyse Turner's vast data, helping to manage risk and

improve access to information. Turner Construction's most recent development is combining innovation and training in AR/VR workspaces. In addition, the company is exploring the capabilities of the Spot robot, to perform various site walkthroughs and automate tasks such as laser scanning and progress monitoring. This introduction raises questions about job displacement and the changing nature of construction work. It is important to think about how the role of human workers will change as robots like Spot become more sophisticated.

Similar to the previous examples, BAM Construct is using various technological innovations such as BIM, robotics, 3D printing, AR/VR, and modular construction. BAM Nuttall used the world's first AI-powered concrete strength prediction engine. But it is essential to take into account the dependability and potential biases of AI systems, which should be rigorously tested and continuously monitored for accuracy. BAM Construct also used IoT to create smart solutions in construction and electronics. This calls for a discussion about data privacy and the risks of relying too much on technology in a field that has historically prized human judgement and experience (Zhang et al., 2023). The increasing interconnectivity of construction sites poses a risk of data breaches and unauthorised access to confidential project information. The sector also needs to find a balance between using IoT insights and preserving the vital role of seasoned experts who can understand data in context and make well-informed judgements based on years of real-world experience.

Although the selected construction companies are implementing a wide range of digital technologies in their operations, it is worth assigning a certain level of priority to each of these technologies. The specific circumstances and strategic requirements of each company mean that some digital technologies may be more significant and strategically important than others. This approach allows for better consideration of the individual needs and characteristics of each company. The most accurate way to determine the priority is to set it on a scale from 1 to 7, where 1 corresponds to the lowest priority and 7 to the highest (Table 2).

Although there are many other technologies and construction companies, these examples are a good indication of how real construction companies are implementing digital transformation to improve their operations and achieve better results. In addition to analysing the technical transformation in the construction industry, a set of strategies proposed by the authors should be implemented to cover the various aspects of digital modernisation and possible challenges (Table 3). The key element is the integration of a range of digital technologies at all stages of the construction process.

These strategies can be adapted and supplemented according to the specific conditions and needs of a construction project or company. In accordance with the tables of digital technology priorities for construction companies and strategies for improving efficiency in this industry, a simple programme can be implemented to visualise and analyse the data from the tables. In other words, the programme code (Appendix 1) generated interactive graphs that can be embedded in a website or used to visualise data on digital technology priorities and strategies in the construction sector. The flowchart in Figure 1 demonstrates the simplified version of the code's action.

This code creates a web page that uses the Chart.js library to create two charts: a bar chart to show digital priorities for three construction companies and a horizontal bar chart to show strategies for improving efficiency in the construction industry (Figure 2).

In the upper graph, the Y-axis represents the priority level. The various coloured parts within each column correspond to different digital technologies, while each column itself represents a building enterprise. The height of each coloured segment indicates the priority level assigned to that particular technology by the respective company. This programme therefore combines the digital technology priorities for the construction companies listed in the table with the efficiency strategies used in the diagram. The result shows that each company (Skanska, Turner Construction, BAM Construct) has a defined priority for each digital technology (BIM, IoT, AI, AR, VR, Automation, Robotics). The graph uses a bar chart where each column represents the priority of a particular technology for each company. The graph also uses a horizontal bar chart to show six strategies to improve efficiency in the construction industry. Each column represents a different strategy (Technology Integration, Process Optimisation, Training and Staff Development, Standardisation and Regulation, Stability and Innovation, Environmental Consciousness).

	Skanska	Turner Construction	BAM Construct
BIM	7	5	3
IoT	6	4	1
AI	5	1	7
AR	2	6	4
VR	4	7	5
Automation	1	2	2
Robotisation	3	3	6

Table 2: Priority of digital technologies for construction companies. (2024)

Strategies to improve efficiency in the construction industry					
Integration of technologies	Process optimisation	Staff training and development	Standardisation and regulation	Sustainability and innovation	Environmental awareness
Ensuring full integration of digital technologies into all stages of the construction process.	Analysis and optimisation of each stage of the construction cycle to reduce time and resources.	Providing staff with training and development opportunities in digital technologies and the latest construction methods.	Creating and implementing standards for the interaction between different technologies and companies.	Improving and stabilising existing technologies.	Implementation of green technologies and energy-efficient solutions to reduce the environmental impact.
Improving the interaction between digital platforms to optimise information exchange.	Implementation of Lean principles to eliminate unnecessary resource consumption and minimise waste.	Development of programmes for advanced education and exchange of experience.	Regulate and enforce the use of digital technologies.	Promoting innovation and the introduction of new technologies to continuously improve efficiency.	Developing and encouraging the use of materials and technologies based on the principles of sustainable construction.

Table 3: Structural diagram of strategies for increasing efficiency in the construction industry. (2024)

Taking into account all the results, it can be concluded that the identified priorities and strategies represent an important step in the development of the digital transformation of the construction industry, promoting the introduction of the latest technologies and improving efficiency in all aspects of the construction process.

5. Discussion

5.1. Analysis of the digitalisation in the construction industry of different countries

There are many studies on digital transformation in the construction sector, so it is worth considering some of them. For example, in the work by Tytok et al. (2022), the authors focus on construction companies, looking at their digitalisation and the introduction of technology into operational processes. Using an analytical approach and data from a variety of sources, the study found a significant impact of digitalisation on the delivery of construction projects. The priorities for digital technology that have been established are extremely relevant to the construction sector in Ukraine. The building industry in Ukraine has been slower than in certain Western European nations to adopt digital technologies, which is why digitalisation is so crucial. The implementation of digital technology to enhance management efficiency has the potential to yield substantial benefits for Ukrainian construction enterprises, including the ability to narrow the technical divide with their global counterparts (Serdyuk, 2023; Bieliatynskyi et al., 2022).

The authors Chathuranga and Siriwardana (2023) examine the construction industry in Sri Lanka, which lags behind in the adoption of digital technologies. This study develops a self-assessment model of the Sri Lankan construction industry's readiness to adopt digital technologies. Using a multidimensional approach, the study identifies 15 indicators of readiness and reveals two key groups of indicators: Environment, Leadership, Workforce Attitude, Organisational Performance and Technology, Organisation, Technical Knowledge. The developed model integrates these aspects for a comprehensive assessment of readiness, and the self-assessment puts the model into practice, allowing organisations to identify their strengths and weaknesses in terms of digital transformation. The model also considers the implementation of automation technologies, such as automated project management systems, to enhance efficiency in construction processes. The self-assessment model for digital readiness could be particularly valuable for Ukraine's construction industry. Construction organisations could gain a better understanding of their current digital capabilities and areas for improvement by tailoring this approach to the Ukrainian setting.

In their work, Zhu et al. (2023) emphasise that due to the rapid development of digital transformation in Chinese construction companies, there is a need to assess their level of digitalisation and identify problems in the transformation process. This could be especially useful for the Ukrainian construction industry, given its current uneven state of digital adoption. The authors have developed a model for assessing the maturity of digital transformation for construction companies based on six indicators, including strategy, technology application, and management changes. The model also considers the rising use of robotisation technologies in contemporary building processes, such as drones for site inspection and autonomous construction robots. Although the aforementioned work is specific to Chinese companies, adapting this model to the specific context of Ukraine's construction sector could provide a roadmap for companies seeking to enhance their digital capabilities and competitiveness in the global market.

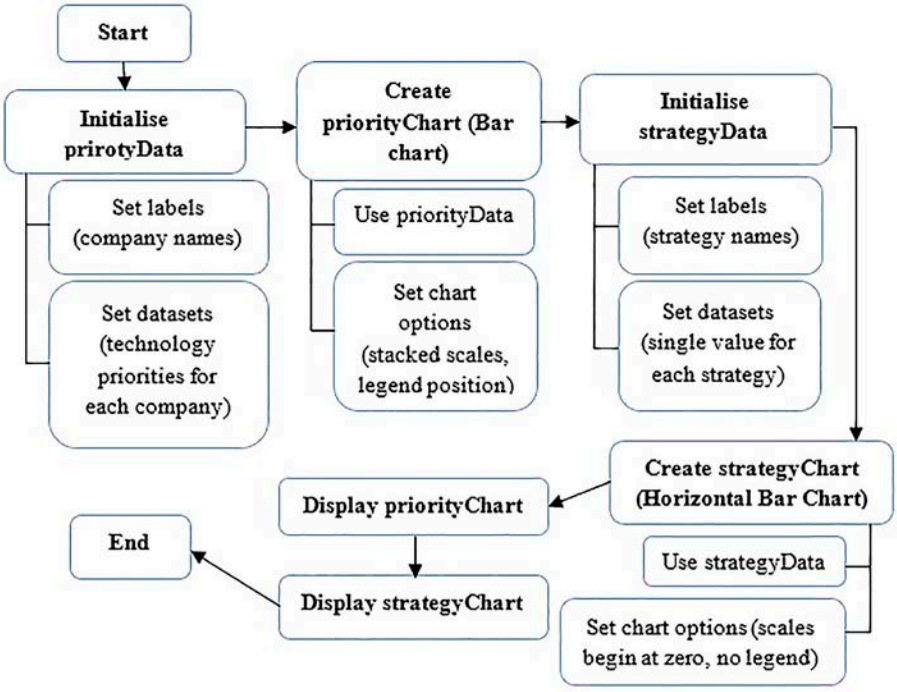

Figure 1: Digital technology priority and strategy visualisation process. (2024)

5.2. Case studies in digital transformation strategies for construction firms

The aim of the study by Cao et al. (2023) is to examine how project-based firms implement digital transformation strategies in the pre-digital revolution environment. The exploratory case study of a large construction company in China identified three key aspects of digital transformation strategies: adaptation to organisational and environmental conditions, business transformation, and organisational transformation. The study also emphasises how AI technology may improve risk assessment, predictive maintenance, and decision-making processes in construction projects, underscoring the necessity for businesses to include AI initiatives in their plans for digital transformation. Given the particular difficulties the construction industry in Ukraine faces, such as unstable economic situations and the need for quick modernisation, the emphasis on adjusting to organisational and environmental conditions is especially relevant.

The study by Olanipekun and Sutrisna (2021) is based on a literature review and 36 scientific publications from 2016 to 2020. The authors propose an inductive model of digital transformation in construction. Using the methodology of grounded theory, they identified strategic considerations to promote transformational effects and suppress barriers. These insights could be particularly relevant in addressing the challenges faced by Ukrainian construction companies in their digitalisation efforts.

5.3. Factors affecting the digitalisation processes

Zhang et al. (2023) conducted a study of the digital transformation of construction enterprises in China and identified seven factors that significantly affect this process. The study confirms that top management support and policy support are key factors for the successful digital transformation of construction enterprises in China. The work by Ernstsen et al. (2021), based on interviews with construction industry professionals, puts forward three key criteria for the digital transformation of the sector: efficient construction, user-driven construction, and value-based computational design. These are highly applicable to Ukraine's construction industry. Focusing on them could help Ukrainian construction companies modernise their practices and increase their competitiveness.

The study by Xue et al. (2023) identifies the key factors and their interactions that influence the habits of using smart building technologies in the construction industry. Applying the Technology-Organisational-Environmental (TOS) framework, the study finds that Strong Sustainable Building Habits are driven by configuration conditions rather than a single determinant. Four configuration conditions favourable for increasing TOS among construction workers were identified. Additionally, the study looks into how VR/AR technologies might be integrated into smart building systems to improve building management, maintenance procedures, and the overall user experience in finished buildings. These

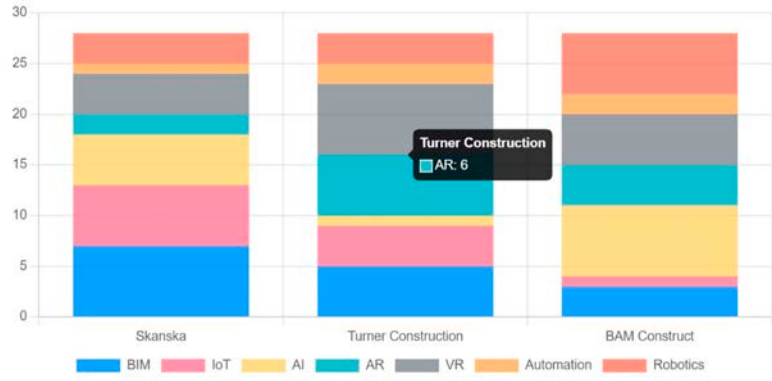

Figure 2: The result of the programa. (2024)

findings can serve as a valuable guide for Ukrainian construction companies for developing strategies aimed at supporting the implementation of smart building technologies and achieving the digital transformation of the enterprise.

5.4. BIM technology in digitalisation

In their study, Sumer (2023) emphasises that the digital revolution is shaping the future in all industries, including construction and real estate, although the speed of transformation is different. The study, conducted in Turkey, reveals that experts consider the use of BIM, AI, and big data to be key to the future management of construction projects. The adoption of these technologies in Ukraine is currently limited compared to some other countries, which recognise their importance. And the recommendations for change management for digital transformation in the real estate and construction industries add practical value. These recommendations could provide valuable guidance for Ukrainian construction companies.

In turn, Afzal et al. (2023) consider BIM technology, which significantly modernises the construction sector, affecting the low level of innovation. The introduction of digital twin technology allows addressing the dynamic aspects of construction processes and using real data to improve productivity. Although the use of BIM is expanding in Ukraine, it is still relatively new, and digital twin technology is in its early stages. Ukraine's construction industry may benefit greatly from these technologies' potential to increase efficiency and enable digital transformation. The authors Heisel and Hebel (2023) use the principle of "Building Better – Less – Different", which explores the fundamental aspects of sustainability by proposing innovative methods and developments. The transition to clean energy and digital transformation is a necessary component of circular construction (Anisimov et al., 2018). Digital technologies allow rethinking the use of natural building materials and reducing resource consumption, contributing to a profound transformation in the construction and engineering industry (Nussibaliyeva et al., 2024; Bieliatynskyi et al., 2016). The emphasis on lowering resource consumption using digital technologies may be especially helpful for the building sector in Ukraine, which struggles with resource efficiency, especially given the ongoing war.

5.5. Cross-industry insights in digital transformation

Unlike previous researchers, So et al. (2023) consider digital transformation specifically in the shipbuilding and maritime industry. The study proposes a model of mutually beneficial cooperation for large and small companies that takes into account the digital transformation in the shipbuilding industry. The study analyses the progress and challenges of digital transformation in German and Korean medium-sized enterprises and develops a standard model for improving cooperation between large companies and suppliers, taking

into account the specifics of the industry. Effective collaboration is essential for the digital transformation of the construction sector in Ukraine, as it is characterised by a combination of small and medium-sized firms and major organisations. Adapting the proposed model of mutually beneficial cooperation to Ukraine's construction industry context could help accelerate digital adoption across the sector.

Finally, Xiao et al. (2022) explore the path to creating smart cities. The study is based on the technological-organisational-environmental framework and examines the factors that determine the digital transformation of local governments in China. Based on the results of a questionnaire survey and a structural level model, it was found that technological readiness, organisational efficiency, public service delivery, citizen expectations, and pressure from higher authorities are key factors in this transformation. The study highlights the critical role that IoT technology plays in the development of smart cities. It shows how IoT enables the connection of different urban systems facilitates the collection of data in real time, and improves decision-making processes. The application of these factors can serve as a guide for the successful digital transformation of local governments and contribute to the construction of smart cities in Ukraine.

To summarise, the study of various aspects of digital transformation in the construction industry shows the importance of innovation, technological progress, and certain strategies to achieve efficient and sustainable development in this sector. The variety of approaches and emphases in the research provides a comprehensive view of the challenges and prospects of digital transformation in the construction industry.

6. Conclusions

This study on the impact of digital technologies on the construction industry has made a significant contribution to understanding and defining strategies for digital transformation in this sector. One of the main conclusions is the significance of comprehensive digital transformation strategies addressing every phase of the construction cycle. Through the use of the prioritised technology evaluation and formulated strategy framework, companies may more successfully adopt digital solutions. The programme for data analysis and visualisation is a useful tool for tracking the application of strategies and their productivity impacts. The suggestions include carefully evaluating digital innovations at every stage, from conception to implementation; enhancing employee competencies via training; and promoting collaboration between construction firms and academic institutions to exchange best practices. The study concludes that digital transformation has significant potential to improve construction industry efficiency.

Limitations of this study include its focus on a specific geographic context, which may limit generalisability. The constantly changing landscape of digital technology may necessitate regular updates to conclusions. Furthermore, due to the study's limited scope, not all relevant technologies or their long-term effects could be thoroughly examined. Future research should focus on longer-term effects of digital adoption through longitudinal studies and a closer examination of certain digital technologies and how they affect different stages of the construction process.

Conflict of Interests. The author declare no conflict of interests.

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