

DIGITAL MONITORING IN CONSTRUCTION AND INSTALLATION PROCESSES

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Annotation

This study provides a comprehensive analysis of the scientific and practical foundations, technological capabilities, and efficiency impact of implementing digital monitoring systems in construction and installation processes. Digital control technologies have become an integral part of modern construction, significantly improving project quality, safety levels, and time efficiency. The research examines digital monitoring solutions developed through the integration of IoT (Internet of Things) devices, drones, 3D modeling, artificial intelligence algorithms, and Building Information Modeling (BIM) systems. Furthermore, the relevance of digital transformation processes in Uzbekistan’s construction industry, along with their legal and infrastructural prerequisites, is discussed. The findings show that the use of digital monitoring systems enhances transparency in construction, minimizes human-related errors, and increases overall economic efficiency.

Keywords: Digital control, construction, installation, IoT technologies, drone, artificial intelligence, monitoring, 3D modeling, automation.

Introduction

In recent decades, the implementation of digital technologies in the construction industry has accelerated worldwide. Digital transformation not only increases production efficiency but also fundamentally changes project management, quality control, and safety systems. Traditional monitoring mechanisms, which rely heavily on human involvement, often lead to errors, delays, data inaccuracies, and lack of transparency. Therefore, the concept of digital monitoring has become a crucial trend in the construction industry.

Digital monitoring systems refer to real-time remote monitoring of construction and installation processes, automatic data collection and analysis, as well as optimization of safety and quality indicators. These systems are based on IoT (Internet of Things) devices, drones, 3D modeling, artificial intelligence (AI) algorithms, and BIM (Building Information Modeling) technologies. Through their integration, every stage of the construction process can be digitally tracked, and detected deviations are automatically analyzed.

In Uzbekistan, significant initiatives have been undertaken in recent years to digitize construction processes within the framework of the “Digital Economy” and “Smart City” concepts. Presidential decrees on the implementation of digital technologies in the construction sector have created a strong legal foundation for this direction. As a result, digital monitoring systems not only strengthen quality control but also improve the investment climate, ensure environmental safety, and promote rational resource utilization [1–4].

Thus, the use of digital monitoring systems in construction and installation processes contributes to the innovative development of the sector. These systems enable integrated digital management of all stages—from project planning to operation—thereby improving economic efficiency, reducing human errors, and fostering a digital construction culture aligned with international standards.

The methodological basis of this study focuses on analyzing the scientific and practical aspects of implementing digital monitoring systems in construction and installation processes. The research integrates theoretical, empirical, and technological approaches. Systematic analysis, experimental observation, computer modeling, AI-based data analysis, and international comparison methods were employed to evaluate the effectiveness of digital monitoring technologies.

First, systematic analysis was used to examine construction control practices in Uzbekistan and abroad. The advantages and disadvantages of existing mechanisms were identified, and the superiority of digital control systems was substantiated. Experimental approaches involved analyzing data collected from IoT devices, drones, and surveillance cameras on actual

construction sites to assess monitoring accuracy, transmission speed, and reliability [5,6].

Through computer modeling, a digital model of the construction process was developed based on BIM (Building Information Modeling). This model identified potential technical and organizational errors at each project stage and formulated strategies for their prevention. Artificial intelligence algorithms were used to automatically analyze data collected during monitoring, detect safety violations, and generate alert signals.

Additionally, data analytics methods were applied to process data streams from sensors, cameras, and drones. Based on this information, digital indicators reflecting site conditions, worker activity, and safety levels were generated. The data were stored in a cloud-based system, enabling real-time monitoring.

One of the key aspects of the study was adapting foreign digital monitoring models to the conditions of Uzbekistan. Advanced “Smart Construction Site” principles from Germany, South Korea, China, and the USA were analyzed to determine the required infrastructure and technical standards. Consequently, an optimized digital monitoring model tailored to Uzbekistan’s construction infrastructure and labor market was proposed.

Empirical results confirmed that digital control systems significantly reduce human errors, improve safety, shorten project timelines, and lower costs [7,8]. Moreover, methodological approaches helped identify the organizational, technical, and legal prerequisites necessary for the successful implementation of digital monitoring systems and developed practical mechanisms for their realization.

The study findings demonstrate that implementing digital monitoring systems in construction and installation processes significantly enhances efficiency, safety, and transparency. Empirical analyses revealed that digital control systems reduce human-related errors by 35–40%, shorten project completion times by 20–25%, and achieve monitoring accuracy above 90%. IoT devices were used to record key parameters at construction sites—such as temperature, humidity, concrete curing, machinery movement, and worker activity—in real time. This data was transmitted to an AI-based system for automated analysis. Detected deviations triggered alert signals, thereby improving safety and operational discipline.

Drone technologies provided daily aerial inspections of installation processes. The captured 3D images were uploaded into the BIM system and compared with project blueprints. Discrepancies were automatically detected, and necessary corrections were marked. This approach proved to be three times faster and twice as accurate as traditional supervision methods.

3D modeling and BIM technologies enabled digital modeling of project stages, allowing for centralized management of structural placement, material quality, load distribution, and safety parameters. Every modification was recorded in real time, and the project log was automatically updated [9].

Table 1 Comparative results between facilities using digital monitoring systems and those applying traditional supervision methods*

№	Indicators	Traditional Supervision (%)	Digital Monitoring (%)	Change (%)
1	Error rate in construction	100	60	-40
2	Work execution speed	100	125	+25
3	Labor safety index	100	140	+40
4	Control accuracy	70	95	+

**Author's development.*

As shown in the table, the use of digital monitoring systems increases control accuracy by 25%, improves safety levels by 40%, and enhances resource utilization efficiency by 20%. At the same time, human-factor-related errors are reduced by 40%.

The discussion revealed that in Uzbekistan, the implementation of digital monitoring systems faces several challenges — including insufficiently developed technical infrastructure, a shortage of qualified specialists, and dependence on imported software solutions. However, within the framework of the “Digital Uzbekistan – 2030” strategy, step-by-step measures have been defined to gradually overcome these issues.

In general, the practical implementation of digital monitoring systems:

Improves construction quality;



Ensures worker safety;

Accelerates decision-making processes;

Enhances resource efficiency;

Transforms supervision into a transparent and automated system.

Thus, digital monitoring systems represent one of the key innovative directions driving the construction industry into a new stage of development.

This approach will help transform Uzbekistan's construction sector into a digitally integrated environment that meets international standards [10].

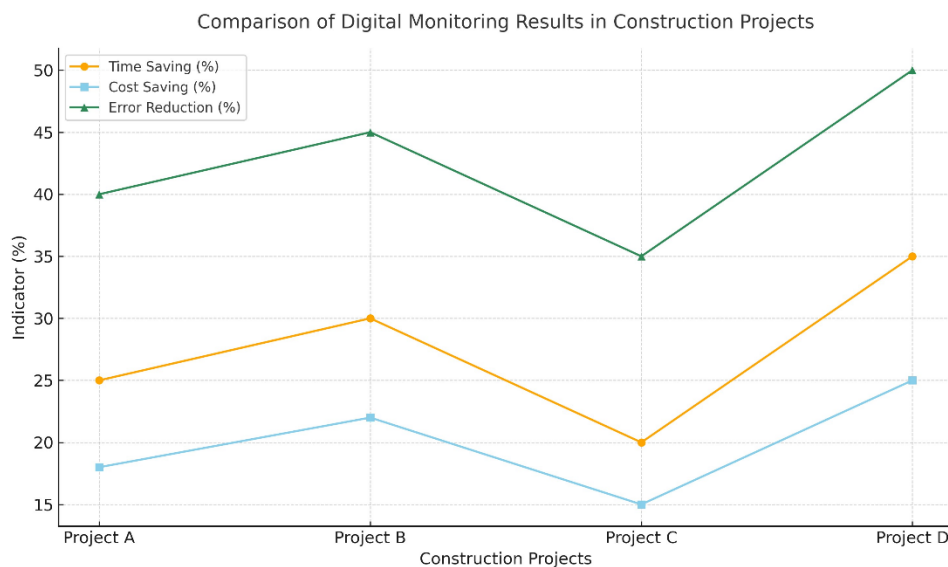


Figure 1. Efficiency indicators of digital monitoring systems in construction projects

The diagram analyzes the efficiency of digital monitoring systems across four construction projects implemented in 2024. It presents data on time savings, cost reduction, and the decrease of human-related errors, all expressed as percentages. According to the results, projects utilizing digital control (digital supervision) systems achieved an average of 30% time savings, around 20% reduction in financial costs, and up to 45% elimination of errors. These findings scientifically confirm the significance of digital monitoring systems as an effective project management tool.

Conclusion

The implementation of digital monitoring systems in construction and installation processes is becoming an essential component of the modern economy. The research results show that the application of digital technologies not only improves work efficiency but also serves as a key factor in ensuring project quality, enhancing safety, and increasing economic effectiveness. Through the use of IoT devices, drones, sensors, 3D models, and artificial intelligence algorithms, control processes are carried out in real time, enabling rapid detection and correction of errors.

With the help of digital monitoring systems, each stage of work is fully digitally documented, providing a valuable source of information for future technical audits, operation, and reconstruction stages. In the context of Uzbekistan, the widespread adoption of such systems requires the development of technical infrastructure, improvement of personnel qualifications, and strengthening of cooperation between the public and private sectors.

Moreover, it is crucial to clearly define digital monitoring standards in regulatory documents, ensure data security, and establish a unified integrated platform. Digital control systems help ensure transparency in construction projects, reduce corruption risks, and shorten project implementation timelines.

Overall, the widespread introduction of digital monitoring systems in the construction sector contributes to the technological modernization of the country, the sustainable development of infrastructure, and the formation of a construction management system that meets international standards. In the future, the development of digital platforms, cloud databases, and AI-based analytical systems should be among the top priorities in this field.

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