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Kyrgyz National University named after Zhusup Balasagyn<https://doi.org/10.5281/zenodo.14766578>**Abstract**

This article examines digital technologies used for monitoring and managing construction projects. Key tools are studied, such as project management systems (BIM, ERP), the Internet of Things (IoT), Geographic Information Systems (GIS), as well as the application of big data analytics and artificial intelligence (AI). The article explores methods and approaches that enhance accuracy, safety, and efficiency in construction through the implementation of digital solutions. It also examines the advantages and challenges of integrating digital technologies into construction practices, including reduced project completion times, and cost savings.

Keywords: digital technologies, construction monitoring, project management, Building Information Modeling (BIM), Internet of Things (IoT), Geographic Information Systems (GIS), big data, artificial intelligence (AI).

Introduction

Construction is one of the fastest-growing industries, as this sector actively incorporates various innovative tools. One of the most significant changes is the use of digital technologies for monitoring and managing construction projects. The introduction of such methods substantially increases the efficiency, safety, and quality of construction work. It also contributes to reducing costs and project completion times. The digitization of construction covers varied aspects, from design and planning to the control of construction work execution.

The main digital technologies used in construction include project management systems, the Internet of Things (IoT), geographic information systems (GIS), as well as big data analytics and artificial intelligence (AI) tools. These project management systems help organize work efficiently and track construction progress, since they create a digital model of the project and provide access to it for all participants. The IoT technology allows for the integration of sensors that monitor the physical condition of structures, while big data analytics helps predict and prevent potential risks.

Another important aspect is the use of cloud platforms for data storage and sharing. It increases managerial processes and establishes maximum transparency at all stages of construction project implementation. The introduction of AI and machine learning (ML) into construction processes opens new opportunities for automating and optimizing workflows. These technologies considerably reduce the human factor and improve the accuracy of forecasting and planning. The aim of this study is to analyze the application of digital technologies for monitoring and managing construction projects, as well as to assess their impact on the efficiency and safety of construction.

Main part. Key digital technologies in construction monitoring

The advancement of digital technologies significantly transforms construction monitoring processes. It offers greater efficiency, safety, and precision in managing construction projects. Digital tools are increasingly being adopted to monitor various construction parameters, from structural integrity and environmental

conditions to project timelines and cost management. Research on construction supervision and quality control in prefabricated construction demonstrates that the application of digital technologies results in a high compliance rate, reaching 95.7% [1].

The implementation of Building Information Modeling (**BIM**) is one of the most significant innovations in modern construction. It is a digital representation of a building's physical and functional characteristics. This tool enables the creation of comprehensive 3D models of structures and systems [2]. Models serve as a shared knowledge resource for all stakeholders involved in the project. This can include architects, engineers, contractors, and clients, and allow them to work collaboratively throughout the entire lifecycle of a project.

This method improves the precision of construction plans and facilitates the monitoring of the project's progress. It allows for the tracking of construction turning points, resource allocation, and cost management. This helps in locating potential issues early in the process and prevents costly delays, and optimizes the overall construction process. Various BIM models can integrate data from IoT sensors. It allows for real-time monitoring of a building's structural performance during construction.

The **IoT** has a noteworthy impact in modern construction monitoring, as it supports the integration of smart sensors and devices that collect and transmit data in real-time. This equipment can monitor a wide range of parameters, such as temperature, humidity, vibration, and load-bearing capacity. It provides specific information about the building's structural health. One of the most significant benefits of IoT in construction monitoring is its ability to detect potential problems before they grow into serious issues. Sensors can monitor the stability of scaffolding, alerting workers to any shifts or weaknesses in real-time. These IoT devices can track the wear and tear of construction equipment, thus preventing breakdowns and ensuring the machinery operates efficiently [3]. This digital approach is particularly relevant in the construction sector, as incidents in this field account for one-fifth of all workplace accidents (fig. 1).

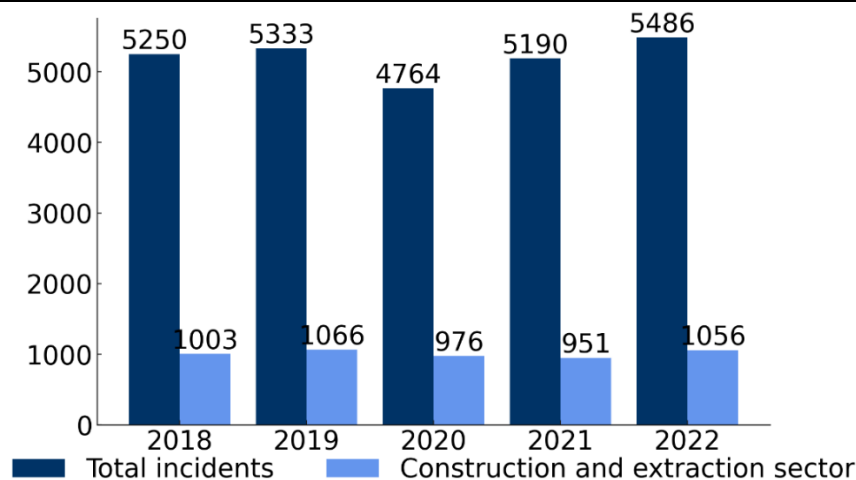


Figure 1. Number of fatal occupational injuries in the U.S. in the period of 2018-2022 [4]

To assemble, analyze, and visualize geographic data related to a construction project, **GIS** are widely utilized. This tool integrates spatial data with various types of information, such as environmental conditions, terrain analysis, and infrastructure details, to help construction teams make informed decisions about site selection, design, and planning. It can also be used to assess environmental impacts. In construction monitoring, GIS provides valuable insights into the progress of construction by comparing real-time data with initial plans. It helps track the movement of materials and workers, monitor construction workflows, and guarantee that safety regulations are being followed on the site.

Big Data analytics is affecting construction monitoring through facilitating the analysis of great amounts of data generated throughout the construction process. This data can include information from IoT sensors, BIM models, financial records, labor reports, and environmental data. By examining large datasets, construction managers can identify trends, discern inefficiencies, and make more informed decisions about project execution. The use of Big Data allows for predictive analytics, which can forecast potential problems, such as delays or cost overruns, before they occur. Big Data tools can predict the possibility of delays based on various risk factors. These features contain weather conditions or material shortages.

Additionally, **AI and ML** are progressively being applied in construction monitoring to improve action-planning, optimize processes, and reduce risks. The integrated AI can analyze data from multiple sources, such as IoT sensors, BIM models, and project management systems, to identify patterns and provide actionable insights. Various ML algorithms, alternatively, can continuously learn from the data and adapt to changing conditions. This feature makes them helpful for monitoring and predicting various aspects of construction projects. The AI technologies can be used to forecast the completion time of a project based on real-time data and historical courses. It can also be applied to identify possible safety hazards by analyzing data from sensors and cameras placed on-site. Models of ML can locate anomalies or deviations from planned schedules and workflows.

Drones and remote sensing technologies have become important tools in construction monitoring, allowing for aerial surveillance and data collection in areas that are difficult to access or hazardous. Drones are equipped with cameras and sensors and can capture high-resolution images and video, which can be used to create detailed maps and models of construction sites. These technologies are especially useful for surveying large areas, monitoring progress, and assessing the condition of structures. Experts can also use drones to monitor work safety by providing real-time footage of the site, helping project managers identify potential hazards or safety violations. Remote sensing technologies, such as LiDAR (Light Detection and Ranging), can create precise 3D models of the terrain.

Listed technologies can be used to track the progress of construction, verify the authenticity of materials, and make certain that all experts have access to accurate and most recent information. This level of lucidity helps reduce risks, improve efficacy, and enhance trust among project participants.

Managing construction projects using digital technologies

Digitalization brings revolutionary changes to the management of construction projects. Modern companies increasingly rely on digital tools to optimize workflows, improve efficiency and transparency. Some of the most significant advancements in this area are project management systems, such as BIM and **ERP** (Enterprise Resource Planning), as well as cloud platforms.

Project management systems such as ERP play a central role in organizing and controlling construction processes. These systems allow for the integration of various aspects of a project. It varies from planning and design to resource management and work execution. They provide project participants, including builders, architects, contractors, and clients, with access to a unified data platform, significantly enhancing coordination and efficiency.

Different ERP systems streamline and combine all business procedures linked to construction project management. Modules for financial management, procurement, personnel, and monitoring job performance are included. These systems make accounting, analysis,

and reporting easier, increasing transparency and decreasing the chances of human mistakes. Construction firms can enhance project efficiency, monitor budgets and deadlines, and enhance communication between departments. BIM enables in-depth modeling of construction procedures, simplifying the ability to predict costs, project durations, and reducing mistakes and resource wastage.

Modern construction projects often require the participation of numerous parties, including architects, engineers, contractors, and clients, making effective communication and information exchange crucial. **Cloud platforms** becomes a key tool for improving collaboration in construction with their ability to provide a centralized data repository and real-time access to project information [5]. Cloud technologies allow all project participants, regardless of their location, to work with a single digital model and most recent data about the progress of construction, fostering fast infor-

mation exchange and decision-making. Cloud platforms enable immediate updates to project documents, making the latest changes available to everyone involved, thus reducing the time required for approvals and corrections.

Cloud platforms also establish a high level of data security. They provide centralized storage for project documentation and support data recovery in the event of unforeseen circumstances, such as data loss or system failure. This significantly reduces the risk of losing important documents and increases overall project control.

Digital technologies are transforming construction project management by enhancing efficiency, accuracy, and collaboration across various project stages [6]. However, their application also presents challenges, involving cost, technical complexity, and the need for skilled personnel. Table 1 summarizes the key advantages and challenges associated with the use of digital technologies in this field.

Table 1.

Advantages and challenges of using digital technologies in construction project management [7, 8]

Advantages	Challenges
Improved precision in all stages.	High costs: significant investment required.
Better transparency: Enhanced visibility of project data.	Skill gaps: Need for trained personnel.
Improved collaboration: easier communication and coordination.	Data security: risk of cyber threats.
Optimized resource use: AI and ML improve scheduling and logistics.	Resistance to change: employees may be reluctant to adopt new tools.
Faster decisions: real-time data speeds up decision-making.	System integration: challenges in integrating new tech with existing systems.
Risk reduction: early detection of potential issues.	Maintenance: continuous updates and support needed.

Digital technologies can significantly improve the management of construction projects. The successful integration of these technologies also requires overcoming several technological and organizational barriers, which calls for a comprehensive approach to their implementation in the construction industry.

Conclusion

The integration of digital technologies in construction project management and monitoring offers substantial benefits. This can include enhanced accuracy, improved safety, and increased efficiency. Technologies such as BIM, IoT, GIS, and AI provide tools that enable real-time monitoring, predictive analysis, and effective collaboration among project stakeholders. Despite the challenges of high initial costs, data security concerns, and the need for trained professionals, the advantages of embracing these technologies are undeniable. In the future, construction projects will become increasingly complex, and digital tools will play an important role in minimizing risks, optimizing resources, and supporting sustainable development in the industry.

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