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CHALLENGES REGARDING DIGITALIZATION IN CONSTRUCTION

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ABSTRACT

In an era marked by rapid change and accelerated technological progress, the construction industry is already experiencing significant transformations due to the implementation of automation and digitalization. Digitalization in construction is an essential process for increasing efficiency, reducing costs, and improving sustainability. However, this transition faces multiple challenges. Among the main obstacles are the resistance to change by traditional firms, the lack of digital skills among employees, and the high costs of implementing advanced technologies. The difficult integration of digital solutions into existing processes, the lack of interoperability between platforms, and cybersecurity concerns are other major barriers. Overcoming these challenges can facilitate a sustainable digital transformation with significant benefits for productivity and building quality. Thus, digitalization becomes not only an opportunity, but also a necessity for the future of the construction industry. The paper analyses how digital technology is revolutionizing the construction sector, highlighting both the advantages and challenges generated by this technological change.

KEYWORDS: digital technology, construction industry, challenges, digitalization

1. Introduction

The construction industry, one of the fundamental sectors of the global economy, is undergoing significant transformation due to digitalization. Digitalization in construction is the process of integrating digital technologies into all stages of a construction project, from planning and design to execution, monitoring, and maintenance.

This involves the use of modern solutions such as building information modelling (BIM) (Fig. 1) [1], Artificial Intelligence (AI), Augmented and Virtual Reality (AR/VR), process automation, and the Internet of Things (IoT).

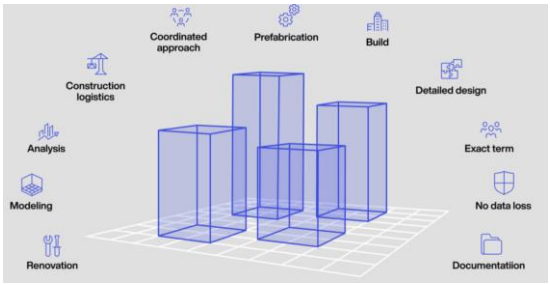

Fig. 1. *BIM project monitoring strategy* [1]

The adoption of these technologies involves numerous challenges, both technical and organizational.

In a traditional industry, where processes are often slow and manual, the transition to a digital model involves overcoming several obstacles. These challenges are not insurmountable, but they require a strategic approach, investment in training, and the adoption of an open mindset to change in order to fully harness the potential of digitalization in construction [2].

2. The importance of using digital technology in construction

The use of digital technology in construction is essential for the modernization and efficiency of the industry, having a significant impact on the way buildings are planned, designed, constructed, and maintained.

The main digital technologies used in construction and their impact on efficiency, sustainability, and safety in the field:

• Computer-Aided Design (CAD) and Building Information Modeling (BIM)

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CAD (Computer-Aided Design) technologies allow the creation of detailed 2D and 3D models of structures, making it easier to view and modify designs before construction. BIM (Building Information Modeling) expands this capability, integrating additional information about materials, costs, and the execution schedule, promoting more efficient collaboration between architects, engineers, and builders [3]. This integration reduces errors and saves time and resources [4].

• Virtual Reality (VR) and Augmented Reality (AR)

These technologies are used for simulations and visualizations of projects before construction begins. Augmented reality can help site staff visualize project information directly in the field, while virtual reality can be used for training and presenting projects to customers (Fig. 2) [5].

Fig. 2. *VR & AR in the Construction Sector* [5]

• Drones and 3D Printing

Drones equipped with cameras and sensors capture aerial images of construction sites, facilitating the monitoring of the progress of the work and periodic inspections. 3D printing technology allows building components to be made quickly and accurately.

This can reduce construction costs and time, and contribute to the creation of innovative structures (Fig. 3) [6].

Fig. 3. *Drone scanning* [6]

• IoT (Internet of Things):

IoT devices are integrated into construction equipment and buildings to collect real-time data, such as the condition of machinery or environmental conditions on the construction site. This data is essential for effective project management.

Due to the complexity that arises in the use of software, hardware, embedded systems, and network ecosystems, it becomes very important to study, understand, and use the appropriate technology for automating a building (Fig. 4) [7].

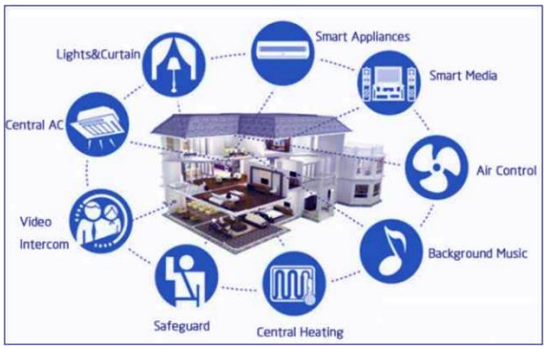

Fig. 4. *Internet of Things applications in buildings* [7]

• Automation and Robotics:

Robots are increasingly being used in construction for tasks such as material handling, welding, or installation, thus reducing working time and exposure to risks for workers [8].

With a fast-paced construction process, the incorporation of robotics technology in construction facilitates construction professionals with quality-assured outcomes and reduced human errors.

• Project Management Software

Digital platforms for project management allow teams to be coordinated, progress to be tracked, resources to be managed, and deadlines to be met, leading to more efficient execution of work [9].

The adoption of these technologies is essential to meet today's challenges and ensure the development of a smarter and more sustainable built environment.

3. Advantages and disadvantages of digitalization in construction

Digitalization in construction brings numerous benefits, including increased efficiency, reduced costs, and improved safety, but it also comes with a few challenges [10]. It is essential that these challenges be managed correctly, through investments in training, infrastructure, and security, in order to reap the full benefits of digital technologies in the sector [11].

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Advantages of digitalization in construction:

• Increased efficiency

Digitalization helps to increase efficiency at all stages of the construction process. Digital tools, such as BIM (Building Information Modeling) software, allow the creation of detailed project models, optimizing planning and execution. This reduces working time and reduces the risk of errors.

• Cost reduction

While initial investments in technology can be high, in the long run, digitalization can help reduce costs. Automating processes and monitoring projects more effectively lead to material savings, reduced risks, and better resource management.

• Improving safety

Real-time monitoring technologies, such as drones, can be used to inspect risk areas and ensure safety on the construction site. At the same time, digital models allow the simulation of construction scenarios and the identification of potential problems before the start of work, preventing accidents.

• Improved collaboration

Digital platforms allow for better collaboration between all actors involved in a construction project (architects, engineers, builders, and customers), facilitating the rapid exchange of information and reducing the risk of misunderstandings or miscommunication.

• Sustainability and impact reduction on Environment

Digitalization can contribute to a more efficient management of resources, such as building materials and energy [12, 13]. For example, BIM solutions allow for detailed analysis of a project's energy consumption, identifying solutions to reduce environmental impact.

• Access to advanced data and analytics

Digitalization allows data to be collected and analysed in real time. Thus, project managers can make decisions based on accurate and up-to-date information, which can help to better manage the project and identify possible problems early.

Disadvantages of digitalization in construction:

• High upfront costs

The implementation of digital technologies requires considerable investment in software, equipment and staff training. This can be a barrier for small companies or those that do not have large budgets.

• Resistance to change

In many cases, employees and management teams of construction companies may be reluctant to adopt new technologies, preferring to keep traditional ways of working. This resilience can delay the digitization process and reduce its benefits.

• Lack of qualified personnel

Digital technologies in construction require a specialized workforce, and this requires continuous training. Many workers in the industry lack IT skills, and attracting qualified personnel can be difficult.

• Interoperability issues

The different software solutions used in construction may not be compatible with each other. Lack of standardization can lead to difficulties in integrating data and applications, and this can reduce the overall efficiency of the construction process.

• Cybersecurity

As more data is stored and processed digitally, cybersecurity risks become a major issue. Cyberattacks can compromise sensitive project and client information, and protecting them becomes essential.

• Dependence on technology

Digitalization can create a dependency on technology, and in the event of a technical failure or an interruption of the internet connection, the entire construction process can be blocked. In addition, the existence of errors in the software or incorrect data can lead to serious problems on the construction site.

Digitalization in construction offers multiple benefits, but also significant challenges. To maximize the advantages and minimize the disadvantages, careful planning, investment in training, and the development of an organizational culture open to change are essential.

4. Trends for the future of construction from the perspective of digital technology

There are several examples of buildings that use digitized technologies to improve energy efficiency, occupant comfort, and infrastructure management.

• The Edge, Amsterdam, Netherlands

This is one of the smartest office buildings in the world. It uses technologies such as the Internet of Things (IoT), lighting and temperature sensors, and mobile apps that allow employees to adjust their work environment, find available desks, and optimize their routes through the building. The air conditioning and lighting systems are automatically controlled according to the presence and activity of occupants in the rooms (Fig. 5) [14].

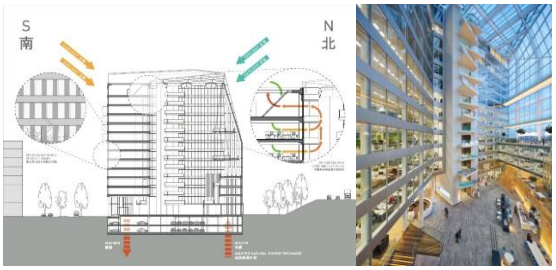

Fig. 5. *The Edge (Amsterdam, Netherlands)* [14]

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• Bosco Verticale, Milan, Italy

These buildings are an example of digitized and sustainable urbanism. Although best known for integrating vegetation into the facade, they are equipped with smart technologies that monitor and regulate water and energy consumption, as well as indoor environmental conditions (Fig. 6) [15].

Fig. 6. *Bosco Verticale (Milan, Italia)* [15]

• Marina Bay Sands, Singapore

This complex uses digital technologies to efficiently manage lighting, air conditioning, and access to different areas of the building. In addition, security systems are digitally managed, and the use of sensors to monitor the flow of visitors helps to improve their experience. (Fig. 7) [16, 17].

Fig. 7. *Marina Bay Sands (Singapore)* [16, 17]

• The Office, Cluj-Napoca

This office building uses smart technologies for energy management and climate control [18]. The lighting systems are automatically adjusted based on occupancy and available natural light, and the energy consumption is monitored in real time through a BMS system (Fig. 8) [19].

Fig. 8. *The Office, Cluj-Napoca* [19]

These buildings are some examples of how digitized technologies can transform the urban environment to optimize the economic and ecological performance of buildings.

6. Conclusions

Digitalization in the construction industry brings multiple benefits, such as streamlining processes, reducing costs, and improving safety on site. However, the deployment of digital technologies faces significant challenges, including resistance to change, high costs, lack of skilled personnel, and interoperability issues between different software solutions [20].

To overcome these obstacles, a well-defined strategy is essential, including:

• Investments in vocational education and training, for the development of employees' digital skills.

• Adoption of standards and regulations that facilitate the integration of new technologies.

• Collaboration between companies, educational institutions, and authorities, to accelerate the digital transition.

• Implementation of cybersecurity measures, to protect data and digital infrastructure.

In conclusion, digitalization is the future of the construction industry, and companies that manage to adopt and integrate new technologies will have a significant competitive advantage.

The transition requires time and resources, but the long-term benefits are considerable, both in terms of operational efficiency and sustainability of construction projects.

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