Digital Technologies and Tools - Drivers of Digitalization in Construction

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Abstract

Construction is a structural sector that creates the infrastructure for the functioning of other sectors, which is why its development is essential for the national economy. For this reason, the digitalization of construction is paramount. It is characterized by great complexity of production processes and typical conservatism, which is why it is known for its difficulties in the transition to digitalization. Digital technologies and tools are the engines of digitalization in construction. The paper explores the importance of some key technologies and tools for its digitization – first, the role of building information modeling, along with the application of virtual, augmented, and mixed reality, mobile technologies, and cloud computing. Sensors and other tools and technologies belonging to the Internet of Things, as well as the use of drones, have great potential for revolutionizing the construction sector. Artificial Intelligence and Machine Learning help analyze large amounts of data in construction and help make timely, accurate and efficient decisions. The study highlights the importance of resources as basis for the digitalization of construction with focus on human resources.

Keywords: Digitalization of construction, building information modeling (BIM), virtual reality, cloud computing, mobile technologies, drones, IoT, sensors

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Introduction

One of the characteristic trends related to the construction sector is its relatively lower degree of digitalization compared to other economic sectors, as well as its greater conservatism in relation to the processes of digital transformation. A number of its features cause it to lag behind in the processes of digitalization. Among them can be indicated different degree of electrification of the many stages in the construction process and the typical greater difficulties in automating the work processes on the work site; specific to the construction sector technical features and challenges that play a negative role in the slow pace of digitization. Construction projects and solutions are being developed for construction sites designed for different sectors that are geographically remote and scattered, and this creates additional challenges.

The need for accelerated digitalization of the construction sector is determined by many factors, which include the large amount of data generated in the sector, in need of storage and appropriate processing, the huge amount of project documentation, which requires timely access, the desire to create environmentally friendly buildings. meeting all current requirements for belonging to “smart buildings”, etc. The authors point out that the processes of increasing labor costs, on the one hand, and the declining cost of technology, on the one hand, are important for stimulating digitalization and the transition to Industry 4.0 (Elghaish et al., 2020; Golizadeh et al., 2018; Newman et al., 2020). As in other economic fields, so in construction, the main driver of digitalization is digital technology. Thanks to significant investments in technological progress, various and increasingly modern and up-to-date digital technologies are available on the market.

The time to reach the market (time-to-market) is constantly decreasing (Urbach and Röglinger, 2018). The whole range of applied digital technologies is very wide and includes on the one hand already established technologies such as mobile technologies, social media, advanced analysis, cloud computing and others. On the other hand, newer technologies are included, such as the Internet of Things (IoT) and blockchain technologies (Fitzgerald et al., 2014).

The introduction of this study outlines some features and trends in the digitalization of the construction sector. The first section examines the main technologies and tools that are drivers for the digitalization of construction. Special emphasis in the second section is placed on some of the leading resources needed for the implementation of digitalization processes in the field of construction. In the conclusion, summaries are made and guidelines for future research related to the research topic are presented.

1. Digitalization of Construction – Key Technologies and Tools for its Implementation

Several key technologies, tools and software are applied to achieve the required level of digital transformation. These include:

1.1. Building Information Modelling (BIM)

BIM has a central position in the digital transformation of the construction sector and is increasingly becoming a leading standard for highly efficient construction. It covers the digitization of the entire construction investment process and the creation and management of building data throughout its life cycle (Andersson, 2016). BIM supports all involved stakeholders by providing them with a digital presentation of the building's characteristics at all stages of its life cycle - from the earliest concept and the start of design to the moment of its demolition. The modeling creates a visually accurate model of the building, and it is accompanied by the maintenance of a database that stores and maintains all the information about the design and construction of its components. BIM allows digital simulation of projects at the earliest stage before a brick is laid. It is essential that BIM can mitigate and overcome planning errors, allow faster calculations, estimate additional costs, and demonstrate the various options for performing part of the work.

Models made with BIM can have several dimensions of design information: 3D BIM, 4D BIM, 5D BIM, and even a subsequent modeling range shared by a number of researchers. The authors emphasize that BIM is not just a replacement for 2D drawings or AutoCAD files. It is a "larger repository of information" that can be further developed and expanded. 3D BIM can be used to assess the structurality of the building before the project. 3D modeling, based on 3 dimensions - length, width, and height, is complemented by a fourth dimension - time / schedule, to form 4D modeling (Lu and Tse, 2018).

4D BIM includes time-related information associated with various components of the information model. As the implementation of the project develops, the components in the information model (e.g., standard floors, suspended walls, etc.) also change. Therefore, the 4D model represents the construction process in dynamics and is especially important for managing the construction project schedule over time. It allows visualization of the building model over time by simulating the construction process. As a fifth dimension (5D BIM), cost information is added (Hasan and Rasheed, 2019; McKinsey, 2016). 5D BIM supports early budget estimates with a high degree of detail and accuracy. McKinsey (2016) views 5D BIM as a five-dimensional representation of the physical and functional characteristics of each project. Some authors (Najjar et al., 2019) add even more dimensions - 3D modeling, 4D (Time), 5D (Cost), 6D (Operation), 7D (Sustainability), and 8D (Safety) (Fig. 1).

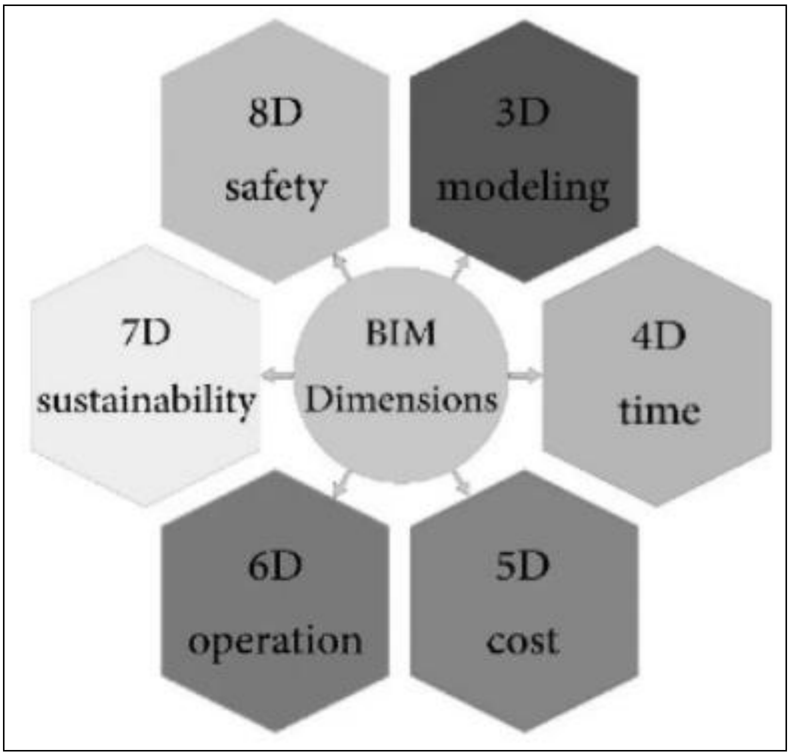

Figure 1. Building Information Modeling dimensions (Najjar et al., 2019)

Currently, according to various authors and their views, BIM modeling can increase its dimensions in addition to 5D, but there is currently no widely accepted definition of BIM with dimensions above 5D (Hasan and Rasheed, 2019). It is offered e.g., 6D BIM to include information on energy consumption in order to achieve high energy efficiency at the design stage.

Special emphasis on the recommendation to use BIM is also required due to the adopted European Union Directive of 2014 (European Parliament Directive, 2014). Article 22 (4) of the Directive recommends the use of BIM as one of the criteria for the award of public contracts. Gradually, the implementation of BIM is becoming mandatory in the various EU member states. Thus e.g., the use of BIM becomes mandatory for public infrastructure projects in Germany from 2020. Similar rules already apply in the Netherlands, Denmark, Finland, and Norway, as well as in the United Kingdom (Roland Berger Global Consulting, 2016).

1.2. Virtual, augmented, and mixed reality

The implementation of virtual, augmented, and mixed reality technologies is leading to a huge change in the way construction companies use and interact with data. Through them, it is possible for clients and employees to imitate a situation, presenting a situation such as walking and feeling what a property will look like, i.e., they allow the user to be placed in a real environment combined with additional, computer-generated information (Izkara, Pérez, Basogain, and Borro, 2007). Virtual reality is useful mostly during the pre-construction phase, and augmented reality is useful after the project has started. The applicability of augmented reality according to some authors (Rankohi and Waugh, 2013) covers the entire life cycle of the construction project and includes monitoring of the construction process as planned, qualification, dynamic visualization of the construction site, defect detection and integration with different BIM streams.

Other authors believe that a variety of computer devices and automated sensors will allow new paradigms for the human-computer interface to interact with digitally controlled information about the construction project (Dunston and Wang, 2005). They propose the development of mixed-reality computer interfaces, and especially augmented reality systems for the architecture, engineering, and construction industries, and describe the technologies and principles for applying such computer interfaces to support all phases of the project life cycle. According to some authors, the use of augmented reality in combination with other supporting technologies, computer software and hardware offers various quantitative and qualitative benefits that improve construction, engineering, and other related tasks (Bademosi. and Issa, 2019). One of the results achieved by successful construction projects is implementation in the planned period and inclusion in the budget or even the realization of savings in the budget. In order to be able to effectively measure the benefits of the application of augmented reality within the life cycle of construction projects, it is important to categorize them into quantitative units such as schedule / plan and cost reduction.

1.3. Internet of Things and intelligent sensors

Internet of Things technologies and tools are used to support a number of aspects of construction processes on construction sites - to ensure the safety of workers, to reduce costs, to assess quality and achieve energy efficiency, to maintain electronic elements used for forecasting environmental conditions, etc. The Internet of Things is a technology that allows any device or object with a sensor to connect to other machines over the Internet. In the context of construction, this technology may include objects or devices such as trucks, bulldozers, cranes, trucks, as well as the use of wearable sensing devices. Each construction site can become a network of interconnected devices that are easily accessible from the construction office. The use of wearable devices (such as GPS and physiological sensors) can, for example, create several possibilities for managing safety and health in the workplace in physically complex and dangerous building structures, such as tracking. the location of workers in a hazardous work area and monitoring their physiological condition (Choi, Hwang and Lee, 2017).

1.4. Mobile technologies and cloud computing

These two technologies also have a significant impact on the digitalization of construction. Mobile technologies are used in many areas of digital transformation in the construction sector. They are used effectively in the context of all the advantages that can ensure the achievement of an efficient work process in the construction sector. They provide a number of advantages in the design process and construction activities, such as the ability of communication systems to transfer visual data using mobile technologies (Nielsen et al., 2006). The authors derive the regularity according to which the work process applied in the construction sector relies heavily on strong personal relationships and the use of a distributed network of knowledge (Venkatraman and Yoong, 2009). According to them, cooperation tools such as mobile phones, e-mail and fax are not very effective for construction companies. Their research reveals mobile technologies as a suitable tool for collaboration and cites as an example such a tool ClikiFax, which has the potential to perform certain time-critical functions of remote construction sites. In this way, the collaborative communication between the various parties involved in the construction process on or off the construction site is effectively supported.

Regarding mobile technologies, one of the latest surveys of the research company Dodge Data & Analytics among construction professionals shows that 80% of respondents consider them as high-priority technologies, and 4 out of 5 experts say that in currently using some form of mobile technology. Mobile software can improve many aspects of the construction business (eSUB CONSTRUCTION, 2019). Specialists see opportunities specifically for improvement in the management of equipment and fleet in construction, in cost control, as well as accurate and timely collection of data from construction sites.

Authors (Bello et al., 2021) point out that construction sector is associated with intensive data generated from various sources in the implementation of construction projects. In addition, it is also investment intensive, as well as slow in IT adoption. These features of construction correlate with the advantages of using cloud technologies. The creation of an efficient digital infrastructure is very important (Petrov, Radev, Dimitrov, Pasat and Buevich, 2021) especially for construction, this is a complex task. Cloud technologies can be an appropriate solution, as they provide scalable and cost-effective resources based on "pay as you go" pricing model that are particularly suitable for small and medium-sized enterprises. Research analyzes show the relevance of cloud computing to the indicated main technologies in construction - BIM, Internet of Things, virtual reality and augmented reality, mobile technology, and big data analytics.

1.5. Drones

An important characteristic feature of construction projects is their complexity, as well as the tendency to become even more complex. To this are added the requirements for reducing costs and reducing the time for project implementation, while increasing the quality requirements. To meet all these challenges in the construction process, new tools can be applied, such as unmanned Aerial Vehicles (UAVs) - drones. For example, the use of 3D laser technology using drones is suitable for the study of construction land, which is one of the most important tasks in any construction project (Mohammadnia. 2021). In addition to exploring the earth, 3D lasers quickly and accurately locate various infrastructure elements, such as water pipes, power lines, canals, telephone lines, optical cables, and more. This data is captured by the electronic components and entered digital planning tools used by the project manager. The use of drones in the construction process is highly recommended. They automate and optimize a number of important activities, such as land surveys for construction, monitoring of large construction sites, monitoring the progress of construction projects, etc. The authors point out that the application of unmanned aerial vehicles (drones) allows in construction to obtain good results (Konikov and Garyaev, 2021).

Drones are used to conduct aerial surveys and inspections of construction sites and sites, to monitor and inspect workers' health and safety, to generate progress reports, to take photographs, to laser scan and to record thermal images. Drone-based technology contributes to overcoming gaps and difficulties in communication between specialists and workers on construction sites and those working in offices.

3D lasers not only study the earth, but also very quickly identify water pipes, ducts, telephone lines, optical cables, and power lines. They capture all this data and enter it into digital planning tools that are available to the project manager.

1.6. Artificial Intelligence and Machine Learning

Artificial intelligence approach and in particular machine learning as its variety are currently representatives of the latest information technologies and are widely used in many areas of human life and economic sectors - healthcare, telecommunications, financial sector, logistics, retail industry, manufacturing, fast- moving consumer goods (FMCG), digital media, etc. Authors emphasize that intelligent methods and techniques provide an effective computational methods and robust environment for business intelligence in many areas Mach and Salem, 2010; Salem, Revett and El-Dahshan, 2009). This is especially true for construction, thanks to the huge potential of business intelligent techniques to process and analyze data from various sources.

Some authors (Helow and Salem, 2020) point out that the main strength of artificial intelligence methods is associated with its ability to perform tasks that require continuous, around the clock and high-speed expert work. Thanks to artificial intelligence, and machine learning, analyzes are more efficient and scalable, complementing human intelligence and, as a result, supporting timely decision-making.

On the other hand, for some sectors these technologies, incl. robotics can also be seen as a threat, as part of the workforce may become unnecessary. However, such a danger is absent in construction. There is a shortage of workers and specialists in this sector, and the help of artificial intelligence is especially needed there.

In construction industry, machine learning is used to predict risks, assist in making management decisions and select the best option for the construction project, monitoring, maintenance, and avoidance of structural hazards through analysis of experience and more. The main direction in the application of artificial intelligence in the construction sector is the patterns discovery of in large data sets. Even in publications from the more distant past, authors consider the application of artificial intelligence techniques to generate plans for construction projects (Levitt, Kartam and Kunz, 1988). However, researchers from the consulting firm McKinsey predict that the application of artificial intelligence methods in the construction sector is expected to be relatively modest in near future and that construction must catch up, compared to several other sectors Blanco, Fuchs, Parsons and Ribeirinho, 2018).

2. Impact of Resources on Digitalization in Construction

Resources are crucial in the use of technologies, tools, and software to increase digitalization and digital transformation of the construction sector. To achieve a successful digital transformation, construction companies need to build a digital vision and strategy, as well as create an information architecture that determines the choice of technologies and make full use of IT investments. Several paramount situations need to be considered. To begin with, it is necessary to determine the digital maturity of the company's construction business at present (Wernicke, Stehn, Sezer and Thunberg, 2021), as well as to set the company's vision for the future state of digitalization. It is also necessary to identify gaps and define the actions and resources needed to address these gaps in several key areas - people, processes, technology, content (Earley Information Science, n.d).

Companies are now also offering the opportunity to online assess the digital maturity of construction businesses through the Construction Digital Maturity Ladder (CDML) (LetsBuild, 2021). An important part of the challenges facing the implementation of digitalization is the alignment and management of appropriate support resources and teams to focus on digital processes, the adoption of a vision of digital innovation, building digital enthusiasm among middle management (Ezeokoli, Okolie, Okoye and Belonwu, 2016; Solis, 2014; Capgemini, 2017).

Special emphasis is placed on the human resources on which digitalization relies. The importance of the management, experience, expertise, and capacity of the people involved in digitalization is paramount. The implementation of a digitalization strategy depends to a large extent on the motivation and abilities of the team of specialists. If the team includes appropriate members who work well together, in an appropriate organizational structure, then productivity and performance may be higher (Kraewing, 2017). In a growth-oriented digital strategy, special attention needs to be paid to the accompanying development of team skills and abilities. Practice shows that the best processes and the most expensive tools will not contribute to adequate digitalization if the company does not have the appropriate specialists.

The importance of human capital is also emphasized in the Manifesto of the European Construction Industry for Digitalization (CECE, 2018) from mid-2018, initiated by the Committee for European Construction Equipment (CECE) and most of the largest European construction associations. The manifesto pays special attention to the digital skills of professionals and workers and in particular to the need to identify and assess skills needs in the field of digital construction, support for quality training, retraining and retraining, support for industry in its initiatives. to attract young talent on the one hand, and to avoid job losses on the other.

The Manifesto of the European Construction Industry emphasizes the financial resources that should be used at European Union level to support the acceleration of the digital transformation process and to mitigate the impact of the initially low return on investment. To this end, it is proposed that the multiannual financial framework for the period after 2020 focus on financial support for the development of the above-mentioned digital skills of the people, as well as on research and development and IT infrastructure. The idea is to set aside the necessary resources for well-designed, intelligent, and connected assets that ensure the implementation of optimal infrastructure for high-speed internet (CECE, 2018).

Conclusion

A distinctive trend for the construction sector is its relatively lower digitalization compared to other economic sectors. This trend reflects its greater complexity, as well as its characteristic conservatism. During the construction there are difficulties in automating the work processes on the work site. These features, as well as the factors identified because of the study play the role of motivating forces in the processes of digitalization.

The research in this paper brings out the main technologies and tools that are the drivers of the digitalization of construction. Among them, Building Information Modeling stands out in the first place. which is established as a leading standard for highly efficient construction. The application of virtual, augmented, and mixed reality technologies is changing the way construction companies prepare construction work and use and interact with data. Mobile technologies complement construction communication systems and effectively support collaborative communication between participants in the construction process. The study also found that the Internet of Things technologies and tools have huge potential that can be developed to support construction business processes. In turn, Unmanned Aerial Vehicles or Data called Drones and the 3D laser technology used can contribute to reducing costs and reducing the time to implement construction projects. Finally, is the importance for the construction of Artificial Intelligence and Machine Learning. For construction, which is characterized by labor shortages, the use of technologies and tools related to AI, Machine Learning and process robotics can be particularly useful. This lag of the sector in their implementation should be made up.

As a result of the analysis, this paper identifies some of the key resources needed to achieve successful digitalization and transformation of the construction sector. Special emphasis is placed on the need to determine the digital maturity of the construction business of the company. Human resources are mentioned as of paramount importance for digitalization.

Future research may study challenges associated with the implementation of some of these technologies and tools in the construction company. The creation of a methodology for assessing digital maturity, especially for companies in the construction sector is planned.

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