Organisational and Economic Tools for Managing Investment Programmes Involving Construction Enterprises Through Digitalisation

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Abstract: In the current realities of business development, internal processes management plays a particularly important role in accomplishing the goals set. With the rapid development of technology, the trend among businesses has been to go digital, i. e. using more and more technology in the operation of the company, to increase management efficiency. Thus, it remains relevant to reflect on how governance and business organisation models have changed or may change, as a result of this process. It was decided to focus on companies in the construction sector and to illustrate the special features of their digitalisation. Thus, the main purpose of this study is to analyse the organisational and economic management tools in the construction industry based on digitalisation methods and the introduction of technologies into the company's operational processes. Analysis was the main method used in the study, as the authors referred to a wide range of sources of information, mainly articles by academics, and drew conclusions on the basis of the processed data. The authors conclude that modern developments in construction companies and their transition to digitalisation have had a significant impact on project delivery. Digital technology allows decision-making to be automated when working on projects, which increases efficiency by eliminating the human factor.

Keywords: Construction Sector; Investment; Entrepreneurship; Management; Technology.
JEL Codes: R53, G32, M21.

1. INTRODUCTION

Digitalisation (or DT – digital transformation) is a change in the nature of production and economic processes whereby humans are no longer the subject of these processes; in other words, digitalisation is a process of changing forces and factors of production in a company (enterprise, country, society) (Yudina, 2017). Most countries have already recognised digitalisation as a priority for a country's development. It is becoming a trend and the basis of a strategy to achieve economic prosperity and increase a country's international competitiveness (at least if the country is able, skilled and willing to use information technology; if it is used effectively as a development resource) (Demura and Putivtseva, 2021; Kozhageldi et al., 2022). The digitalisation trend is observed in absolutely all sectors, but for the purposes of this study, the authors examined how it is being pursued in the construction sector. It is particularly relevant to consider these trends given that DT in the sector has been gaining popularity relatively recently (approximately from the beginning of the 21st century), especially when compared to other sectors. Generally, the concept of digitalisation of the construction industry affects all activities in the industry, ensuring increased efficiency of construction activities and bringing qualitative changes in the technology, organisation and management of construction production (Artyushkin and Plotnikova, 2021; Tukhtamisheva et al., 2020; Lapin et al., 2021). However, it also has its limitations and disadvantages, which are worth bearing in mind when making decisions. They are also discussed below in the study.

A large number of academics have worked on the issue. For example, it is worth mentioning M. Sutrisna and A. Olanipekun (2021), who examine current trends in the digitalisation of the construction industry from theoretical and empirical perspectives. S.S Uvarova, A.A. Panenkov, Ya.L. Sonin (2020) studied changes in the organisational and managerial activities of construction companies during digitalisation, focusing less on the digitalisation methods of the production process. It is also worth acknowledging the scientists who have analysed the current state of the art in the latest technologies that are used directly in project work. P. Gerbert, S. Castagnino, C. Rothballer, A. Renz, R. Filitz (2016) and E.S. Rakhmatullina (2017) looked at the impact of BIM (Building Information Modeling) on company processes and how it has affected the industry. W. Lu, T. Tan, J. Xu, J. Wang, K. Chen, S. Gao, F. Xue (2020) studied how the concept of DfMa (Design for Manufacturing and Assembly) could influence the development of the construction sector. The authors also come to interesting conclusions about how

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revolutionary and different this approach is. C. Zhang, D. Artidi, P. Liu (2021) examined the role of laser scanning in structural engineering and when working on construction projects in general; R.V. Razyapov (2021) analyses the role of AR (augmented reality) and VR (virtual reality) technologies in the modern realities of the construction industry, and the impact of 3D (three-dimensional) printers was considered by D.A. Luneva, E.O. Kozhevnikova, S.V. Kaloshina (2017).

Based on these and other studies, the author's perspective on digitalisation in the construction industry and the recent changes in organisational management is shaped. The focus of the study was on current DT trends in the construction sector (and their prospects for a change) and the implications of digitalisation for companies. The novelty of the study lies in the fact that it not only considers general trends in company performance but also separately in the organisational and performance components.Iit also provides several models that can describe individual changes in the performance of companies in the construction sector during the digitalisation process.

The main purpose of this study is to analyse the organisational and economic management tools in the construction industry based on digitalisation methods and the introduction of technologies into the company's operational processes.

2. MATERIALS AND METHODS

In most countries, the construction sector is a significant contributor to GDP and the economy of a country, which makes the transition to high-tech production methods even more relevant (Rakhmatullina, 2012). Most market players in Western countries have already digitalised or are on their way to becoming digitalised. New companies operate digitally from the start. However, there are still companies that, despite the obvious benefits of transformation and the high demand for it, use digital technologies only partially (without fully integrating them into the daily operations of the company) (Koscheyev, 2019; Issabayev and Issabayeva, 2020). Therefore, they are not getting all the benefits of digital technology. This significantly reduces the financial and economic indicators of such companies. The transition to the use of DT among companies is progressing unevenly but actively. The COVID-19 virus has significantly affected the development of the industry. It has forced companies to change their operating approaches and devote more time to their resilience in the face of crises. This has inevitably led companies to focus more on digitalisation, embedding technology into all enterprise processes (Five ways..., 2020). This applies not only to the actual process of project production, design and construction but also to the company's internal processes.

In fact, the digitalisation process can be roughly divided into two components: digitalisation of management processes and digitalisation of production processes. This is described in more detail by the authors in the study below. Thus, it is important to clarify that this study is mainly concerned with the impact of digitalisation on production processes because they are specific to the industry (in the context of the construction sector it is the design process of projects and their direct implementation, whereas in other industries the production process is most often associated directly with the production of finished products for sale). However, such changes cannot but affect the fundamentals of management and organisation of the company. Therefore, they too are addressed in the study. There are a number of models that help to understand how digitalisation in the construction industry affects its internal processes.

The main method used in developing the study was analysis. It was used to process data on the current state of digitalisation in the construction industry. Through forecasting, the authors have shaped the possible future trends of DT companies in the sector. At the same time, the historical method has allowed for an examination of how the digitalisation of the sector took place in previous years. The modelling method played a particular role as, when working on the study, the authors used models to explain some of the changes in companies in the construction sector due to digitalisation processes. The most important of these is the model of company earnings change during DT, as it helps to explain the current trends in this area. The second model worth looking at is the Automated Management Model for the Construction Investment Project, which shows how management processes can be changed using digital technology. Another important method of writing was deduction, which the authors used to justify the main reasons for the current trends in digitalisation in the industry. The induction method was also used throughout the study, however on a much smaller scale.

This investigation can be divided into several stages. The first stage looks at general trends in the world's construction industry, and its role in the world's economies, given the role of recent world events. The second stage analyses the impact of modern technology used in the construction industry on project preparation and implementation. This section of the study describes in detail the role of the main methods used in this process (BIM, DfMA, AR, VR and others) and their impact on the company: the main benefits and losses from their implementation in the long and short term are described. The third stage is the consideration of changes in the management and organisational principles of companies in the construction sector related to digitalisation and other working methods in project implementation; a model for the operation of an automated project workflow management system is described.

3. RESULTS AND DISCUSSION

The process of digitalisation of the construction industry can be divided into two components. The first is to change the management processes. This component can be called the modernisation of the company at the administrative level, that is, in the processes of the administrative staff. This type of digitalisation is typical for all industries; therefore, most companies (the construction sector and more) have gone through this phase of digitalisation. The second component is a change directly in the models and methods of working on the project (modelling, planning and actual construction). This component has characteristic features in the construction sector. The most common technologies that are used and incorporated into the company's manufacturing process are: BIM, AR/VR, laser scanning, robotics, 3D printing, prefabricated structures and DfMa platforms, analytics software,

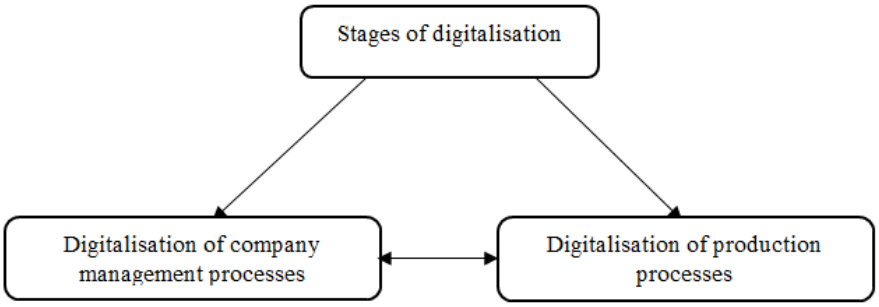

Fig. (1). Allocation of the Digitalisation Process to the Constituents in Companies in the Construction Sector.

Source: compiled by the authors.

blockchain, digital twins, the Internet of Things (IoT) concept and machine learning solutions across the life cycle of the assets created, e. g. at project, organisation and industry level (Singh, 2019; Borisova et al., 2020; Korzhyk et al., 2017). For the purposes of this study, a few of them will be considered. The digitalisation process in companies is always complex. Thus, it is unlikely that a company is engaged in the digitalisation of only one of the components. Overall, the digitalisation process in enterprises can be illustrated as follows (Fig. **1**).

As can be seen from Fig. (**1**), when introducing qualitative changes to a company's management mode of operation, one cannot possibly avoid introducing some changes to production processes and vice versa. Below is a brief overview of some of the technologies that are enabling the digitalisation of production processes in construction companies. First among them is BIM technology, which has attracted a lot of attention from the beginning and has been one of the drivers behind the mass digitalisation of construction companies (Ibem and Laryea, 2014; Dobroserdova and Rakhmatullina, 2016). BIM is a technology that is essentially a software package for modelling, which greatly reduces the cost and simplifies the process of visualising a future object (Uskov, 2013; Suleimenov et al., 2022). The technology allows achieving full control over the project within one package of programmes and reduces the cost of construction, which increases the likelihood of its competent delivery. At the moment, the technology is used by about 40% of companies in Western Europe and 80% of companies in North America (Rakhmatullina, 2017). The technology also makes it possible to calculate at an early stage the cost, timing of the work, exact quantities of materials and construction equipment needed, risk calculations, etc. Another advantage of the technology is that it allows detailed project information to be stored digitally (creating a digital copy of the object), which can be used when designing similar projects, or other projects in the area. This is especially true if the work is commissioned by state or local authorities (Erofeev et al., 2021; Mukanov et al., 2018).

The technology is most often connected to the company's unified file system. This simplifies the process of interaction between specialists to collect and process information about the project. Nevertheless, the high role of information in production significantly increases the requirements for the quality of input information. Although the programme automates the process of most calculations, it obliges specialists to carefully check all the data they enter into the system. Because there may be as many as several hundred specialists, it is still very difficult to avoid mistakes. Incorrect data inputs can lead to additional implementation costs and a delay from the intended project release date. As the technology cannot detect errors and inconsistencies autonomously, system administrators are obliged to find and solve them manually, which complicates the implementation process.

However, BIM has other disadvantages. For example, to start working in BIM, massive retraining of staff will have to be carried out together with departmental synergies. This process can be quite time-consuming, making it difficult to maintain existing projects, while also resulting in additional costs in the short term. The complexity of the staff retraining problem is unique to each company because of the varying willingness of managers and employees to learn and change in the process of working for the company. Unfortunately, in most cases, the staff has a negative attitude to such changes and is unprepared for them or unwilling to take on new loads and new responsibilities. It is also costly to purchase appropriate software products, which will have a negative impact on the company in the short term (although it does result in long-term savings) (Naumenkova et al., 2022). In addition, at this stage, companies feel a severe shortage of specialists. Globally, this is due to the fact that educational institutions have not had time to adjust to new trends in the construction industry and to train the right number of highly qualified personnel (Ibragim et al., 2020). Nevertheless, over time, this particular problem is becoming less and less pronounced. Sometimes, the software may not work entirely correctly. More often problems arise directly when creating models and exporting them to other devices or software products. This is due to a lack of compatibility with other programmes. Therefore, at the initial stage, employees are tempted to do all the work on 2D software rather than spend their time searching for and correcting data migration errors, which can also be a problem when introducing technology into production processes (Nazemi et al., 2015; Kudabayev et al., 2022).

Below are examples of other types of digital technology that can make working on a construction project much easier. Thus, AR and VR technologies also help to simplify the process of running a project. With these technologies, it is possible to create three-dimensional (3D) models, while the latest models include 4D, 5D and 6D models. Some key benefits of these technologies are: simplification and acceleration of the construction sector training process, the ability to test the performance of structures in virtual reality, to create holographic mock-ups of objects being created, to discuss prob-

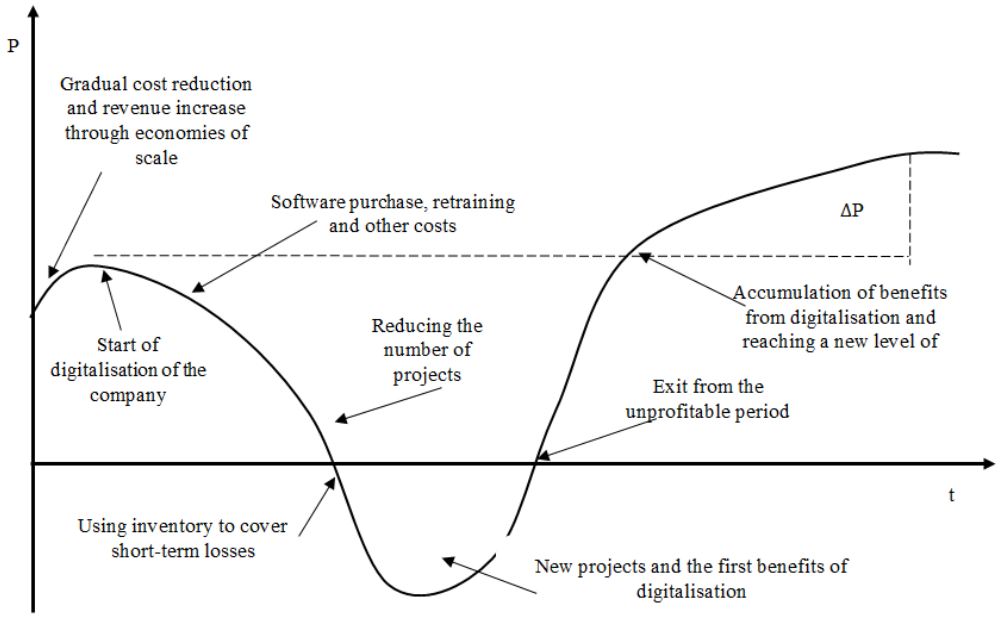

Fig. (2). A model of income changes over time in construction companies during the digitalisation process

Source: compiled by the authors.

lems with colleagues in real-time via video link, to identify installation problems of building structures (for example, allowing engineers to use virtual reality glasses to identify problems in fixing building elements) (Razyapov, 2021; Peleshenko et al., 2017; Lapin et al., 2023). An example of the use of augmented or real reality technology is GA Smart Building, which applied Trimble Connect to the construction of an office building in Toulouse, allowing the company to avoid construction delays and cost overruns (Polinenko, 2018; Suleimenov et al., 2020). In addition, 3D printing is common and offers accurate quantities of materials to produce the required parts, volume models or even entire buildings (or parts thereof) (Luneva et al., 2017; Issabayev et al., 2022). Such printers make it possible to create unusual shapes of designs (which would be difficult to replicate by hand) and also make the construction process waste-free. Laser scanning is also widespread, but its application is actually only possible when other technologies are used. For example, laser scanning can significantly improve the quality of models created using BIM technologies, simplifies design and makes it faster and easier to visualise certain objects (Zhang et al., 2021; Chernets et al., 2008; Syrmanova et al., 2021).

The DfMA approach is also indicative. One thing to note is that this is not a method used in the design of buildings, but an entire concept. Its application within the industry is only at an early stage. In fact, companies are learning first-hand which strategies for using the concept can and cannot work. Notably, most examples of applications of the concept have been successful. Some scientists consider this concept as a global panacea for all problems in the construction sector, but others believe that this is far from the case (Lu et al., 2020; Cherunova et al., 2021). Overall, DfMA methods and approaches have been used in the industry for quite some time, but it is now that they are becoming the most relevant, and therefore most popular among most companies due to the global trend towards digitalisation. As part of the concept, the design should be developed with the simplest possible process for making the components and assembling the final product from those same components. Furthermore, the project team should make the product structure as simple and reduce the cost of manufacturing and assembly as much as possible. Thus, the practice of applying the concept often consists in identifying, quantifying and eliminating losses or inefficiencies in product design.

The main approaches and methods discussed above for the automation and digitalisation of construction processes play a huge role in changing the principles of the functioning of the industry. However, the organisational and economic approaches to management must evolve with them. As mentioned, current management trends in construction companies are based not only on their need for new digital operating principles but also on the global environment. Therefore, the process of changing the financial policies of companies in the industry started already at the beginning of the COVID-19 crisis: restrictions during the pandemic effectively halted and/or delayed company projects; besides, the debt burden on companies began to increase and the number of new orders decreased (Korostelkina and Voronkova, 2021; Mishchenko et al., 2021). This has led companies to increase stocks to be prepared for a new shock. The principles of the supply chain, which were also affected by the restrictions imposed by governments during the crisis, have changed: companies have started to diversify the number of supplies while reducing the number of suppliers. Above, the study described the features that the company experiences in the case of the introduction of the principles of digitalisation in the production and management process. A major concern, however, has been the high price of products, which significantly increases costs in the short term while reducing the profitability of other projects. Fig. (**2**) shows a graph that describes the likely changes in the income of a company in

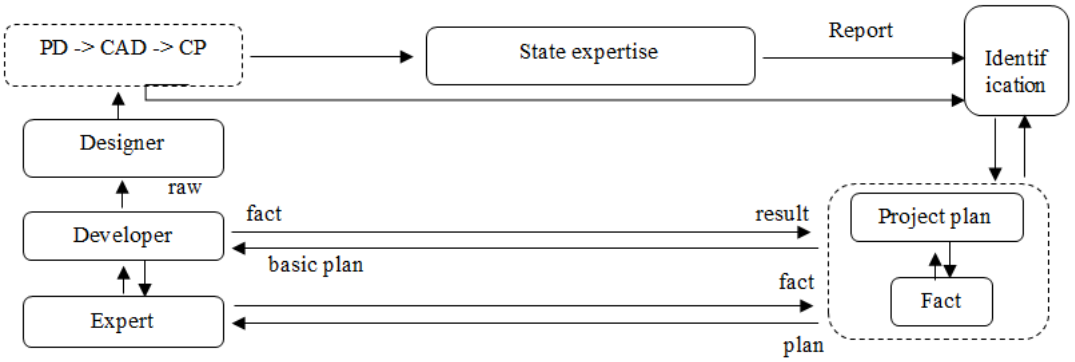

Fig. (3). Schematic diagram of an automated investment and construction project management system.

Source: S.S. Uvarova, A.A. Panenkov, Ya.L. Sonin (2020).

the construction sector that is switching to digital principles of operation.

In Fig. (**2**) P is net profit, and it is time. The value in ΔP shows the difference between the company's revenues before digitalisation and after it. Further, it should be noted that this model is only an approximation; thus, it is not necessary that all companies in the sector go through the same process of digitalisation. Fig. (**2**) shows that the company is likely to face a significant increase in costs at the start of its paradigm shift, which will be reinforced by a decrease in revenue. While the reasons for the increase in costs are fairly obvious and have been described in the study above, revenues are not quite as clear. The authors suggest that the company expects a decrease in revenue due to increased employment, which will lead to postponed projects and fewer new orders. Another factor is changes within the company as a whole and, in particular, the rotation of specialists (hiring some and firing others). Naturally, the decline in income can in theory be either negligible or none at all in the case of good management. However, most companies cannot avoid this.

A change in the company's operating paradigm is likely to lead it to short-term losses, forcing it to spend its savings. This is especially true for smaller companies, as the price of software is about the same for everyone, which means that the smaller the company, the greater the strain it will face. Thus, the company must accumulate sufficient funds to survive this phase before it starts the transformation (it is also likely to do so in the period after the exit from the unprofitable period). Only once the company has digitised sufficiently will it be able to take on a sufficient number of new projects. Thus, it can emerge from an unprofitable period even if there are still transformation processes taking place within the company. Finally, the company will be able to make a long-term additional profit ΔP, which consists of the benefit of lower cost per project and an increase in the number of projects due to the company's increased competitiveness in the market (Baymuratov et al., 2018). Thus, digitalisation is likely to lead to an increase in companies' stocks over time. In addition, it affects control systems. More precisely, it allows the creation of ACSs (automatic control systems), one of which can be used in the investment activities of the construction sector. S.S. Uvarova, A.A. Panenkov, Ya.L. Sonin, (2020) demonstrated one of these schemes, which is also shown in Fig. (**3**).

The scheme in Fig. (**3**) allows for automation of the interaction between the parties involved in an investment and construction project: it provides the necessary data between the investment actors while the software generates the documentation and makes the necessary calculations to run the project. The practical application of this automated model allows not only to reduce the complexity of the project, but also to perform input control over documentation, purchases, deliveries and other business operations. Although the scheme may seem simple enough, it is in fact an arduous task to establish communication between all the actors working on the project (of which there may be hundreds). In this context, it is not surprising that digitalization has significantly increased the requirements for managers in terms of knowledge (they must deeply understand what and how employees do on their jobs. Also, they need to understand how the installed software works) and skills (be able to compose a large number of interactions between specialists in a qualitative way).

Digitalization is useful not only for direct project participants but also for investors, as it allows them to constantly monitor and control the implementation of investment and construction projects. Savings in resources and time increase investors' interest in construction projects and confidence as to whether these can generate profits and be completed on time. In addition, digital technology will allow projects to be monitored after they have been built (during direct operation). In the long term, this could translate into the creation of entire 'smart cities' whose information systems enable online monitoring of infrastructure conditions and operational management impacts (Uvarova et al., 2020; Ivanov et al., 2021). Thus, digitalization is an excellent tool for increasing the manageability and control of the project at the production stage and after it. It also increases the investment attractiveness of projects because of reduced uncertainty during production. Thus, it can be seen that the impact of digitalization in the construction industry has long-term positive effects and short-term negative effects. Figure 2 shows that, in the long term, the positive effects outweigh the short-term negative ones. This is due to a significant increase in the income of construction companies in the case of a successful transition to digital principles of work. To estimate the amount of savings, it is worth referring to the figures of one of the studies: in 2016, researchers predicted that the use of digital

technology will save around $1.2 trillion in the residential real estate industry alone by 2025 (Gerbert et al., 2016). However, it raises the question of why, then, not all companies, even in highly developed countries, have yet gone digital.

According to the authors, the main reason for the relatively slow spread of digital technologies among construction companies is their high cost and complexity. It is likely that smaller companies and companies with funding constraints are unable to undertake such activities, or are forced to postpone them until better times. Certainly, proper implementation of these technologies can simplify the process, but in any case, the company will experience serious difficulties for the time being (Sutrisna and Olanipekun, 2021). The recent COVID-19 crisis had an ambiguous impact on this trend. On the one hand, the crisis forced companies to become more stress-resistant, which also affected their desire for digitalisation. In fact, it has made it somewhat of a necessity, as companies have been forced to provide remote communications between specialists. On the other hand, the crisis has been a major blow to the industry. Its impact has been indirectly addressed in the study: companies have been forced to suspend their projects while paying salaries in full. This led to a forced decrease in stocks and an increase in the debt burden. On average, large companies managed to survive the period more easily than relatively small companies; moreover, the crisis probably led to the bankruptcy of a certain number of small companies.

4. CONCLUSIONS

The study looked at the main trends in the level of digitalisation amongst companies in the construction sector worldwide. Throughout the investigation, the authors conclude that there is a worldwide trend in the number of companies with massive adoption of technology at all levels of their operations. It has also been shown that digitalisation is primarily undertaken by large companies, which is attributed to the specific process of implementing these changes in enterprises. The authors have found that the long-term impact of changing company principles has a positive effect on the company's revenues and also on its resilience to various kinds of crises. The main disadvantage is the high costs of purchasing equipment and retraining staff, which may be overwhelming for the company that eventually cause it to go bankrupt. The larger the company, the easier it is on average to bear these costs, while relatively small companies are reticent to digitalise their business processes.

The use of new technologies in the sector, namely BIM, DfMA, AR, VR, and others, has influenced the investment and financial management processes of companies. The findings show that construction companies are likely to accumulate their cash reserves shortly for several reasons: the impact of the COVID-19 crisis, the trend towards digitalisation, and the threats posed by new crises. As part of the management processes, some changes were also made that made it possible to form an automated scheme for the project. Based on new technology, it enables all relevant information to be transmitted and processed, provided this information is properly entered and is of high quality. Looking ahead, the authors expect an increase in digitalisation among companies in the construction sector, driven by rising competition among companies and a gradual decrease in the cost of implementation. Furthermore, the technologies used in project development must be updated over time, as there are still many serious drawbacks that complicate the operation of the company.

It can be concluded that the pandemic has led to an increase in the level of digitalisation among companies in the construction sector. However, this trend is generally traced only among large companies. At the same time, small companies will be forced to postpone their plans for digitalisation indefinitely. Therefore, full digitalisation of the industry is not expected in the near future, although increased competition will force companies to switch to these operating principles or exit the market. As for the digitalisation methods of construction companies, there is a demand for further refinement.

As mentioned, the systems remain unaffordable for some companies, suggesting a demand to make them more budget-friendly. In addition, problems arise during their operation due to faulty software. The big disadvantage is that it is impossible to determine exactly where an error has occurred if it is detected, which makes the work of system maintenance staff more difficult. In turn, along with software evolution, workplace process management models need to improve if companies are to increase their project deliverables. It is therefore crucial to keep exploring the most effective ways of managing companies in a digitalised environment.

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