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BIM technologies adoption and implementation challenges in Eastern European countries analysis

Abstract. The study aimed to assess the level of integration of digital information technologies in the construction industry in Eastern Europe. Quantitative data on the implementation of Building Information Modelling (BIM) services in Eastern Europe was collected, and a comparative analysis of the dynamics of their use in 2020-2023 was conducted. The results of the study show a significant difference in the level of BIM implementation in Eastern European countries, which is closely related to the level of economic development, the state of the construction industry and support from government agencies. Countries with more developed economies and stable regulatory frameworks, such as Poland and the Czech Republic, have demonstrated the highest rates of BIM adoption. In these countries, various BIM services are actively used at all stages of the construction project life cycle, from design and modelling to construction management and facility operation. Government support in these countries includes the development of national standards, the introduction of mandatory requirements for the use of BIM in public tenders and the implementation of educational programmes to improve the skills of specialists, which promotes the active implementation of technologies and increases the efficiency of the construction industry. On the other hand, countries with less developed economies and limited government support have seen a slower process of BIM integration. In countries such as Ukraine, Bulgaria, and Romania, BIM has been applied mostly in individual projects, but the mass adoption of BIM is being held back by the lack of national standards, insufficient skilled personnel, and low awareness among market participants. The findings can be used to identify the key factors that influence the success of BIM implementation in the construction industry and can be used in the future to further develop effective digitalisation strategies in the region

Keywords: information modelling; construction processes; usage dynamics; project management; development strategies

INTRODUCTION

Building Information Modelling (BIM) is an advanced technology that is radically changing the way the construction industry designs, builds and operates facilities. BIM can be used to create three-dimensional digital models of buildings, as it is a comprehensive system that includes all the information needed to manage a project at all stages of its

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life cycle. These models contain data on architectural, engineering and construction components, as well as information on materials, costs, lead times, performance. However, when implementing BIM technology, different countries in Eastern Europe may face several significant challenges due to differences in economic development and other factors. Such differences in the initial conditions for BIM development make it impossible to implement a single universal approach for the entire region and require careful adaptation of the technology to the specific needs and capabilities of each country. The additional resources and effort required for such adaptation can be a serious obstacle for small companies and organisations, limiting their ability to fully take advantage of the benefits offered by BIM technology and implement innovative approaches in their operations.

A study of BIM adoption in Eastern Europe could fill important gaps in understanding the local challenges and potential of this technology in different economic and regulatory environments. This study can help identify effective strategies to overcome the obstacles associated with the implementation of BIM, as well as develop recommendations for creating favourable conditions for the development of this technology. This will not only help to harmonise standards in the region but also increase the overall efficiency of the construction industry in Eastern Europe. One of the main factors influencing the implementation of BIM is the level of technological readiness and economic development. M. Voloshyn & A. Petiakh (2021) analysed BIM technology and noted that this technology opens up wide opportunities for construction but requires significant technological changes for the implementation of BIM. V. Andrukhov & A. Potekha (2023) noted various factors in BIM integration, pointing out the importance of clear methods and technological adaptation for the successful development of the technology. H. Yuan & Y. Yuan (2020) emphasised the economic aspects that affect the adoption of BIM among industry professionals, emphasising their importance for the successful implementation of the technology. Thus, all these studies point to the need for a general and comprehensive approach for the successful implementation of BIM in Eastern Europe, which accounts for all the above factors and drivers.

An important factor in the implementation of BIM technology is the level of training and qualification of personnel in the field of BIM. J. Semaan *et al*. (2021) highlighted the importance of cooperation between educational institutions and industry to ensure the relevance and practical orientation of training. O. Casasayas *et al*. (2021) analysed the impact of government support on the development of BIM and demonstrated that countries with active government policies in the field of construction digitalisation are making much greater progress in implementing this technology. This confirms that for the successful implementation of BIM in Eastern Europe, it is also necessary to address such aspects as improving professional training, intensifying government support and adapting the technology to the specific conditions of each country.

Another factor that can affect the effectiveness of BIM implementation is the integration of the technology into existing infrastructures and processes (Kudabayev *et al*., 2022). K.-Y. Kang *et al*. (2022), in a study on the integration of BIM into traditional construction practices, determined that the adaptation of existing systems to new technologies is a critical success factor in this area. Q. Tushar *et al*. (2021) also investigated the interaction of BIM with other construction management tools, determining that synchronising data between different platforms can significantly increase efficiency. S. Girginkaya Akdag & U. Maqsood (2020), who analysed the implementation of BIM in the specific conditions of countries with different levels of infrastructure development, noted that the lack of standards and the need for individual solutions often slow down the integration process. However, these studies do not always consider in detail the specifics of individual countries and the challenges faced by these countries in implementing BIM, requiring further research to better understand the real opportunities for BIM implementation in different contexts.

The study aimed to comprehensively study the implementation of BIM technology in Eastern Europe and identify the key factors that influence the success of this process. In particular, the study included the task of investigating the existing problems and obstacles that accompany this process. Another important task of the study was to conduct a detailed review of 2020-2023 trends in the use of BIM, as well as to develop recommendations for optimising the implementation of the technology at the national level.

MATERIALS AND METHODS

Initially, a thorough analysis of the available information on BIM implementation in various Eastern European countries was carried out, which identifies the key benefits, obstacles and opportunities associated with BIM implementation. The next step was to create a classification of Eastern European countries according to their level of BIM adoption. This classification was based on several criteria, including the existence of national strategies for the digitalisation of the construction industry, the level of government support, the extent of BIM use in the private and public sectors, and the availability of educational programmes for training in this area. Four groups of countries were identified: leaders in BIM adoption, countries with a moderate level of adoption, countries in the early stages, and countries with a low level of adoption.

For a more detailed analysis, based on open information from the Eurostat Database (n.d.), quantitative data on the use of various BIM services in Eastern Europe, in particular for the periods 2020-2023, were collected. This process included an assessment of the dynamics of the adoption of such services, which cover various aspects of construction projects, from modelling and design to construction management and facility operation, which was used to track how the level of BIM adoption changes over time and identify the main services that are most widely used.

Particular attention was devoted to the analysis of awareness and use of such services among various construction market participants in Eastern Europe. In particular, the dynamics of changes in the percentage of BIM services used, as well as the level of awareness of their capabilities, were studied. The analysis of these data identified general trends in the implementation of BIM, as well as obstacles that hinder the spread of this technology, such as insufficient training, lack of national standards or financial constraints.

A key part of the research was the study of specific cases of BIM implementation in countries such as Poland, the Czech Republic, Hungary, Slovakia, Ukraine, Romania, North Macedonia, Bulgaria, Moldova, Serbia, Latvia, Lithuania and Estonia, which identified both common features and unique approaches to integrating this technology in different environments. This process included researching the identification of BIM projects and initiatives in the selected countries, as well as analysing detailed case studies, such as large infrastructure projects, commercial buildings, or government initiatives that have used BIM at various stages of the construction lifecycle. The study also included specific aspects such as technological infrastructure, staff education and training, and the level of support from the government and the private sector. Thus, the effect of these factors on the effectiveness of BIM implementation in different contexts was analysed, identifying general trends and specific differences in BIM implementation that are critical to the successful integration of this technology. Based on the data obtained, recommendations were developed for further implementation of BIM in Eastern Europe, focused on creating adaptive strategies that consider local conditions and country specifics to maximise the effect of BIM implementation and promote the development of the construction industry in the region.

RESULTS

BIM is an advanced technology that enables the creation of detailed digital models of buildings and infrastructure facilities, providing an integrated approach to their design, construction, operation and dismantling. At the centre of this approach is a three-dimensional model that can be used to display the geometry of the object and contains all the necessary data on its physical and functional characteristics. This includes information about materials, engineering systems, cost and time parameters, as well as data related to the performance and durability of the building.

The process of creating BIM begins with design, when architects, engineers and other specialists develop a three-dimensional digital prototype of the future facility. This model contains detailed information about all building components, including walls, floors, roofs, windows, doors, and utilities such as electricity, water, sewage, ventilation and air conditioning systems. Each element of the model has its unique characteristics, such as dimensions, materials, properties and precise location in the building structure, which can be used to create a visual representation of the building, analysing its behaviour in depth under real-world conditions. BIM is also a source of data for all project participants at all stages of the building's life cycle. During construction, the model can be used for work planning, material management, and quality control. Thanks to the integration of time parameters (4D), the timing of work can be predicted, which optimises resources and negates delays. Cost parameters (5D) can be used to control the project budget in real-time by analysing the costs of materials, labour and equipment (Marzouk & Elmaraghy, 2021).

During the operational phase, BIM is a key aspect of building management. It contains the entire history of the facility, including data on maintenance, repairs, upgrades and system replacements, which provides accurate and quick access to the necessary information for informed decision-making on the operation and further development of the facility. In addition, BIM improves the energy efficiency of buildings by enabling energy consumption to be analysed and the operation of heating, ventilation and air conditioning systems to be optimised. During the dismantling phase, BIM is central in containing data on all materials used and their possible reuse or recycling, which allows for efficient planning of the dismantling process, reducing costs and minimising environmental impact. BIM technology significantly contributes to the improvement of construction practices by introducing process standardisation and improving the quality of construction (Andrukhov *et al.*, 2024). Detailed digital models can be used for more accurate calculations and analyses, resulting in lower material costs, reduced waste and improved environmental performance. Additionally, BIM facilitates deeper integration of modern technologies such as automation, robotics and the use of innovative materials, making construction more flexible and adaptable to new challenges.

Analysis of studies by R. Samimpay & E. Saghatforoush (2020) and A. Abobakirov & O. Omonboev (2023) in the field of BIM demonstrates that the introduction of this technology brings significant benefits to construction projects. For instance, one of the key advantages of the technology is the ability to plan and forecast all aspects of a project in detail based on a digital model. The introduction of BIM technology can significantly improve the quality of construction project management and increase the efficiency of all participants, which can be used to determine in advance the best ways to implement the project, considering all technical, material and organisational factors. As a result, projects are implemented with maximum precision and coherence, which increases their efficiency and achieves high-quality standards. The use of BIM facilitates closer interaction between project participants, ensuring effective information exchange and coordination. Each project participant has access to up-to-date information in a convenient digital format, which enables quick adaptation to changes and informed decision-making. This improves the quality of communication and reduces the risk of misunderstandings or delays in the process. BIM also enables more accurate forecasting of project needs, which helps to ensure an uninterrupted supply of materials

and resources. Thus, all project phases can be completed with optimal resource utilisation, increasing productivity and ensuring continuous progress in project implementation. This approach can be used to achieve a high level of customer satisfaction, as projects are implemented on time and with high quality.

An important aspect of BIM is its role in ensuring transparency and compliance with project requirements at all stages. This increases the trust of clients and investors, as they can monitor the progress of the project and be sure that all work is carried out following the established standards and requirements (Mesároš *et al.*, 2020). BIM can be used to control the quality of tasks and adapt to changes in project requirements, which ensures flexibility and adaptability of processes. This makes BIM a significant aspect that is transforming the way construction projects are managed, enabling high quality, efficiency and customer satisfaction. However, despite these advantages, the implementation of BIM is still accompanied by certain problems and obstacles that may hinder its spread in the construction industry. First, there is a significant difference in the level of awareness and interest in this technology among professionals of different specialities. While most architects, engineers and project managers acknowledge the potential of BIM, the level of implementation readiness can vary. This is because many participants in the construction process fear the risks associated with the transition to a new technology and often resist changes that may require significant efforts to adapt to new conditions (Saber & Wali, 2020).

Financial barriers also hold back BIM adoption. The costs of staff training, software and hardware can be significant, especially for small and medium-sized companies. In addition, the need for ongoing updates and support for the technology adds additional costs, which can discourage businesses from investing in BIM. Additionally, technical difficulties, such as compatibility issues between different software products, also hinder BIM adoption. The lack of universal standards and the difficulty of integrating BIM with other systems can create additional challenges for project teams, while insufficient technical support and limited access to specialised training programmes can delay the adoption of the technology (Toyin & Mewomo, 2022). Contractual and legal aspects are also noteworthy. Modern contracts often do not address the specifics of BIM, which can create uncertainty about the liability and ownership of digital models. Issues related to intellectual property and the rights to use BIM can complicate cooperation between different project parties, leading to additional legal risks (Bruggeman, 2020).

Non-technical factors, such as cultural differences and the willingness of project participants to cooperate, also have a significant impact on the success of BIM implementation. Differences in work approaches and different beliefs can hinder effective interaction between project participants. At the same time, a lack of willingness to share information and collaborate effectively can significantly reduce the potential benefits of using BIM. Thus, although BIM has significant potential to improve construction processes, several obstacles need to be overcome for its successful implementation. When analysing BIM technology in Eastern European countries, it should be noted that its implementation is uneven, depending on the level of economic development, government policy, and the readiness of the construction industry to innovate. Based on these factors, Eastern European countries can be classified into several groups, shown in Figure 1, which differ in terms of the level of adoption and implementation of BIM.

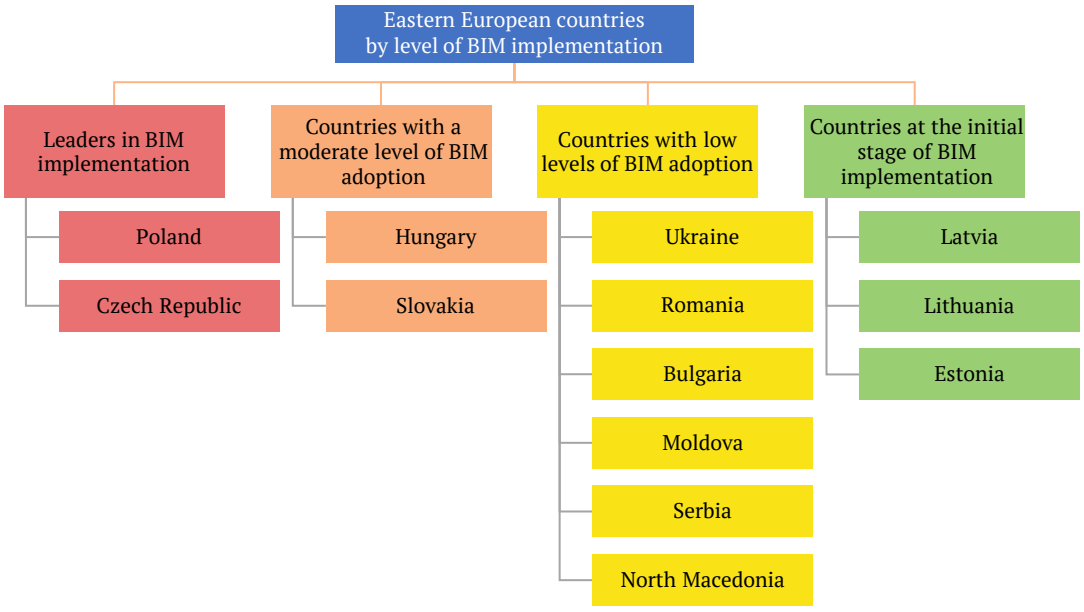

Figure 1. Classification of Eastern European countries by the level of BIM implementation
Source: compiled by the authors based on Eurostat Database (n.d.)

The first group includes countries that actively implement BIM at the state level, supporting its development through regulations and standards. Poland and the Czech Republic, being the leaders in the implementation of BIM technology among Eastern European countries, demonstrate an active approach to the integration of this technology into the construction sector at the state level. These countries recognise the importance of digital tools for improving construction efficiency and are actively working to create regulations and standards that promote the spread of BIM in practice.

The introduction of BIM technology in Poland is systematic thanks to the support of government agencies. The adoption of Directive No. 2014/24/EU of the European Parliament and the Council (2014), which became the basis for the requirements for the use of BIM in public procurement, was an important step. The Polish government launched the project "Digitisation of the construction process in Poland", which ended in 2020 with the development of "A roadmap for the implementation of BIM" (2021). One of the key goals of this strategy is to achieve a level of BIM adoption similar to that of the UK by 2025. Particularly noteworthy is the initiative to introduce MacroBIM in complex or risky public projects with a budget of more than 10 million EUR from 2025, and by 2030 – in all investment projects (Digitization of the Construction..., 2022). In addition, since 2023, Polish citizens have been able to submit electronic applications for a building permit, which was a significant step towards digitising the entire construction process (Decree of the Minister of Development and Technology of Poland No. 45, 2022).

The integration of BIM into public projects in the Czech Republic has also made significant progress in BIM adoption. The responsibility for this process lies with the Ministry of Industry and Trade, which developed a BIM implementation strategy back in 2017 (Concept of introducing the BIM..., 2017). This strategy was subsequently updated to reflect new challenges and opportunities. An important event was the decision to make BIM mandatory for public projects that exceed the threshold set by the EU starting in 2024 (Commission Delegated Regulation (EU) No. 2023/2497, 2023). Therefore, all major public projects in the Czech Republic will be implemented using BIM, which will significantly increase their efficiency and transparency.

The second group includes countries where BIM is being implemented moderately and gradually, mainly as part of private initiatives and without active government support. Hungary and Slovakia are prime examples of such countries. Although interest in BIM is growing in these countries, widespread adoption of the technology is being hampered by several factors, including insufficient government support, lack of clear standards and regulations, and certain inertia in the construction industry. In Hungary, interest in BIM from large construction companies and investors has been observed during 2020-2024 (Szabó, 2023). However, this interest has not yet led to large-scale industry-wide adoption of the technology. The main drivers of BIM development in Hungary are private companies that recognise the benefits of digital tools to improve project efficiency and accuracy. Furthermore, although there were attempts to develop national standards for BIM in the country, they did not receive adequate support from the state. The absence of a legal framework that would regulate the use of BIM in construction is slowing down the process of technology adoption in Hungary. A national strategy that could support BIM is currently under development or discussion. Slovakia is in a similar situation to Hungary, although BIM is already being actively used in large projects, particularly in industrial and infrastructure construction. However, the adoption of this technology on a mass scale is constrained by the lack of clear standards and regulations that would govern its use. For the most part, BIM is used voluntarily, in particular by large companies that have access to the necessary resources and investments. The Slovak government has not yet introduced mandatory requirements for the use of BIM in public projects, which limits the spread of this technology in public procurement and general construction projects.

The third group includes countries where BIM adoption is at an early stage and where there are significant barriers to its spread. This group includes countries such as Ukraine, Moldova, North Macedonia and Serbia. BIM adoption in these countries faces similar challenges, including a lack of a proper regulatory framework, an insufficient number of qualified professionals, and limited financial resources. Ukraine is showing some progress in the implementation of BIM technologies, although the process is still at an early stage. As of 2024, the use of BIM in Ukraine is mainly limited to large investment and international projects where the requirements for modern construction management technologies are part of the contractual terms (Nenastina *et al.*, 2024).

The first steps towards the implementation of BIM in Ukraine were taken in 2017 when pilot projects were launched with the participation of international companies and government customers (Trach *et al.*, 2022). For example, the Boryspil Airport reconstruction project included BIM elements to improve the management of the construction process. At the same time, BIM is not mandatory at the level of government programmes and regulations, and the technology is being implemented mainly at the initiative of individual companies and international investors. Ukraine lacks a clear national strategy or regulatory requirements for the implementation of BIM, which limits the widespread use of the technology, as many companies continue to use traditional methods of design and construction management. In particular, the lack of standards and an insufficient number of qualified BIM specialists significantly hinder the process of mass adoption.

In 2021, several conferences and seminars on BIM were held in Ukraine, including events organised by the Ukrainian BIM Association and other professional organisations (Levchenko *et al.*, 2022). These events helped to raise awareness among professionals and stimulate interest in

the technology. However, to achieve large-scale adoption, additional efforts are needed to develop national standards, create educational programmes and encourage the public sector to adopt BIM as part of the national strategy for the development of the construction industry.

Romania is gradually moving towards the introduction of BIM in construction processes, although the process remains rather slow. The lack of a national strategy and standards for BIM is one of the main obstacles to the widespread use of this technology. As of 2024, BIM is used mainly in the private sector, in particular in large international projects implemented with the participation of foreign investors. In 2020, the Romanian Ministry of Transport, Infrastructure and Communications initiated several pilot projects using BIM, but so far these are only isolated cases. Education in BIM also needs to be developed, as curricula at Romanian universities are just beginning to include courses on the subject. Bulgaria, similar to Romania, is just starting to implement BIM in its construction processes. In 2020, the government published "Digital transformation of Bulgaria for the period 2020-2030" (2020), which includes plans for the digitalisation of the construction sector, including the introduction of BIM. However, as of 2024, BIM is not mandatory in Bulgaria, and its use is limited to certain large projects, especially those with international participation. Most Bulgarian companies are still using traditional construction methods, and only a few are starting to apply BIM in their work. The lack of qualified professionals and the absence of national standards are among the main challenges the country faces. Moldova has only recently started to consider the possibility of introducing BIM at the state level. There are no specialised programmes or courses to train professionals in this field in the country, which makes it difficult to develop BIM. In addition, most construction companies in Moldova follow traditional approaches to design and construction management, which further slows down the process of transition to digital technologies. North Macedonia and Serbia also face similar challenges in implementing BIM. In both countries, the lack of a clear government policy on the digitalisation of the construction sector and limited funding for research and development make it difficult to widely adopt BIM. Most construction companies in these countries operate using traditional methods, and only a small proportion of large projects involve the use of BIM.

The fourth group of countries with an initial level of BIM adoption includes the Baltic States – Latvia, Lithuania and Estonia. Although these countries are geographically part of Northern Europe, they are historically and culturally closely linked to Eastern Europe. The implementation of BIM in these countries is at an early stage but has its characteristics in each of them. Latvia has begun to introduce BIM into construction processes mainly through private initiatives and international investors. In 2018, a programme was launched to promote digitalisation in the construction sector, including the introduction of BIM (Latvian National Standard (LVS) No. 1052:2018, 2018). However, national standards for BIM have not yet been developed, and the technology remains less popular in public projects. The greatest progress has been made in the commercial sector, where BIM is being used in new investment projects, especially with the participation of international partners. Lithuania is also in the early stages of BIM integration. In 2016, the Lithuanian Ministry of Transport and Communications initiated the Digital Construction project aimed at developing digital technologies in construction, including BIM (Guidelines for Digital Construction..., 2014). As part of this project, several training seminars were held for construction professionals. However, as in Latvia, BIM standards have not yet been introduced at the national level, and most projects using BIM are concentrated in the private sector. Estonia, known for its commitment to digital innovation, is showing greater interest in BIM implementation. In 2019, the Estonian government launched the "E-construction Platform" (Vision of e-construction..., 2018) project, which sees BIM as a key element in the digitalisation of the construction sector. Estonia is also actively developing national standards for BIM, which are planned to be introduced in the coming years. However, as of 2024, BIM is used mainly in pilot projects and initiatives of large construction companies. The dynamics of the rating of the use of various BIM services in Eastern Europe (as a percentage of the total number of projects using BIM) is presented in detail in Table 1. Dynamics of the level of adoption, use, and general awareness of BIM technologies in Eastern Europe in 2020-2023 are shown in Figure 2.

Table 1. Dynamics of BIM services usage in projects in Eastern Europe

BIM service	2020	2021	2022	2023
Building modelling	22%	29%	36%	41%
Construction process management	-	-	31%	33%
Project coordination	-	-	24.5%	30.3%
Expenditures analysis	12.5%	15%	18.4%	22.8%
Information management	12%	18%	22%	27%
Technical support	10.5%	12%	15.9%	19%

Source: compiled by the authors based on P. Fiamma & S. Biagi (2023)

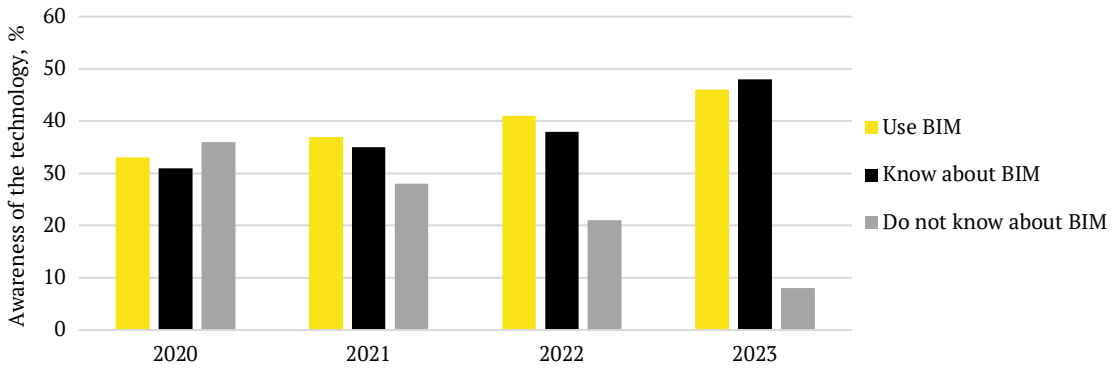

Figure 2. Implementation of BIM technology in Eastern Europe
Source: compiled by the authors based on P. Fiamma & S. Biagi (2023)

In general, the implementation of BIM in Eastern Europe is a complex and heterogeneous process that depends on many factors, including economic development, government policy, availability of skilled personnel and the readiness of the construction industry to change. While some countries, such as Poland and the Czech Republic, have already made significant progress in implementing BIM, most countries in the region are still in the early stages of the process and require additional efforts to overcome existing obstacles. An analysis of the experience of developed countries has made it possible to identify a comprehensive approach for the successful implementation of BIM technology in countries with a low level of its use, which includes several key stages, as shown in Figure 3.

Figure 3. Scheme of successful implementation of BIM technology
Source: compiled by the authors

Thus, the first step for the successful implementation of BIM is to create national standards and regulations that would govern the use of BIM in the construction industry. This should include the development of official guidelines for the design, construction and operation of facilities using BIM technologies. Standardisation is key to ensuring that all market participants can use the same methodology and technology. Educational campaigns and training programmes for BIM specialists are an important aspect. It is necessary to develop and implement educational programmes in higher education institutions, as well as organise refresher courses for already working professionals, which will increase the level of awareness and knowledge of the technology among architects, engineers, project managers and other participants in the construction process. To attract interest in BIM technologies, it is necessary to create financial and other incentives for companies that are willing to invest in the digitalisation of construction processes. This could include tax breaks, research and development grants, and support from government agencies in the form of subsidies.

One of the most effective ways to stimulate BIM adoption is to require its use in public construction projects. This can set an example for the private sector and create demand for the technology. In addition, it is important to ensure interoperability and compatibility of the various software solutions used for BIM to avoid technical obstacles. It is also necessary to regularly monitor the BIM implementation process and evaluate progress to identify problems and address them promptly, which may include periodic updates to standards, analysis of the impact of BIM implementation on the construction industry, and assessment of the cost-effectiveness of the technology. Thus, the introduction of BIM in Eastern Europe is an important step towards the modernisation of the construction industry. Despite the existing challenges, this process offers significant opportunities to improve the efficiency, transparency and quality of construction. In the future, the development of BIM in the region could become the basis for a more sustainable and innovative approach to construction project management, contributing to economic growth and strengthening international competitiveness. The full implementation of BIM will require efforts from both the government and the private sector, which will be key to creating a modern, digitally oriented infrastructure in these countries.

DISCUSSION

This study examined the implementation of BIM technology in Eastern European countries, which was used to identify significant differences in the level of its development and application. The results of the study showed that in countries with developed economies and progressive

regulatory systems, such as Poland and the Czech Republic, the level of BIM adoption is significantly higher, which is reflected in the active use of various BIM services at all stages of the project life cycle. At the same time, in countries with less economic development and less government support, BIM implementation faces numerous challenges, such as the lack of clear national standards and a lack of qualified professionals. The study emphasised the importance of developing and implementing local standards and training programmes, which can help reduce the technological gap between countries in the region and ensure more efficient use of resources in the construction industry. M. Xing *et al*. (2023) also addressed the impact of public policy on BIM adoption, showing how different approaches to regulation and financing can affect the speed of technology integration. L. Wang *et al*. (2020) analysed educational programmes in the field of BIM, revealing significant gaps in the training of specialists in different countries, as well as the need to update curricula to meet modern requirements. A. Ganah & G. Lea (2021) studied the impact of international initiatives and standards on the development of BIM, which indicated the importance of harmonising national practices with international standards to achieve a greater level of integration and efficiency. Thus, the results of this study, alongside the results of the above-mentioned works, emphasise the importance of considering the specific conditions of each country when implementing BIM. They indicate that successful integration of the technology requires an analysis of existing practices and standards, as well as consideration of local economic and educational factors that influence its development.

The study also examined in detail the advantages and obstacles to implementing BIM technology. In particular, the Main benefits of BIM were found to include significantly improved coordination between the various stakeholders in a construction project through a single digital model, which reduces the likelihood of errors and conflicts in project data. BIM technology also helps to improve design accuracy and optimise construction costs by enabling early detection of potential problems and conflicts (Piddubna *et al*., 2024). These aspects highlight the importance of BIM implementation to improve the quality and efficiency of construction projects. However, the study also identified several significant obstacles that hinder the widespread adoption of BIM in the region, including the lack of uniform national standards and regulations for BIM, insufficient number of qualified professionals, insufficient attention to training and professional development, and limited government funding and support for the implementation of BIM in building infrastructure, which delay the modernisation process. Y.Y. Al-Ashmori *et al*. (2020) also studied in detail the benefits of BIM, including increased design accuracy and improved coordination between project participants. A. Pidgeon & N. Dawood (2023) analysed the main aspects that provide the benefits of BIM technology, showing that the use of BIM significantly increases the efficiency of processes in construction, which is an important factor for successful implementation. At the same time, K.M. Tönis & H. Voordijk (2023) analysed technical shortcomings, such as the lack of common standards for data exchange and problems of integration of different BIM systems. Comparing the results of these studies with the results of the present study, it should be emphasised that the present study provided a more comprehensive overview of the advantages and disadvantages of BIM implementation. While the aforementioned works are aimed at studying specific cases in the use of BIM, this study included both the study of positive aspects and analysis of obstacles to the implementation of the technology, which was used to better understand the complexity of the problems and develop more effective strategies to overcome them.

The analysis of the dynamics of the use of various BIM services over the years noted a significant increase in their implementation and popularity. A steady increase in the use of building modelling services was noted, indicating the growing importance and prevalence of this technology. Cost analysis also showed growth, highlighting the growing recognition of the importance of accurate cost management in construction projects. Additionally, information management and technical support services also showed positive trends, reflecting an overall improvement in the awareness and use of BIM technologies in various aspects of the construction process. In terms of overall BIM awareness, the data showed a significant increase in both the level of knowledge of BIM and the actual use of the technology. This indicates a positive trend in the adoption of the technology and a decrease in the number of people who are unaware of BIM. Thus, the results indicate the growing popularity and understanding of BIM technologies, which, in turn, may contribute to their wider adoption in the future. A.O. Baarimah *et al*. (2021) also analysed the dynamics of growth in the use of various BIM services, showing a steady increase in the integration of technology into construction projects. X. Chen *et al*. (2021) analysed the effectiveness of using various BIM services, revealing significant variations in the way they are used depending on the goals and objectives. R. Alshorafa & E. Ergen (2021) studied the effectiveness of implementing BIM services in large projects, which revealed a positive impact on the overall level of technology adoption and awareness of BIM. Comparing the results of this study with the results of the above-mentioned works, it should be emphasised that, unlike other works that investigated the use of BIM in other regions, this study confirmed the general growth trends in the implementation of BIM services, and allowed to detail specific aspects of the dynamics of their use in Eastern Europe. This provided a better understanding of the implementation mechanisms and effectiveness of different approaches, which is important for the further development and optimisation of the BIM implementation strategy in the construction industry in the region.

This study proposed a methodology for successful BIM implementation that includes several key steps: developing national standards, training and awareness raising, stimulating innovation, integrating into public projects, and monitoring and evaluation. Establishing formal standards and guidelines is critical to ensure consistency and quality in the application of BIM at all levels of the construction process (Dmytrenko *et al.*, 2024). The development of standards creates clear guidelines for market participants and reduces misunderstandings and errors that can arise from the lack of uniform rules. Training and awareness-raising through the introduction of educational programmes in higher education institutions and courses is another important step to ensure that professionals develop the necessary skills and knowledge. Stimulating innovation through financial incentives and support encourages investment in technology and facilitates the faster introduction of innovative solutions into the construction process. Integration of BIM into government projects, including through the requirement to use the technology in government tenders, ensures widespread use and demonstrates the government's commitment to modernising construction infrastructure (Kramskyi *et al.*, 2023). Monitoring and ongoing analysis of progress allow for rapid response to changes and adaptation of strategies to meet new requirements and trends. Together, these elements form a comprehensive approach to BIM implementation that ensures efficiency, quality and sustainability in the development of the construction industry. S.M.N. Sakib (2020) considered the aspects of developing standards for BIM, emphasising the importance of clear regulations for the successful implementation of the technology in different countries. M. Xie *et al*. (2022) also focused on the study of the process of standardisation of BIM technology, showing that it is critical for successful development and contributes to the faster implementation of BIM. The results of the current study, together with the mentioned works, present a holistic approach to the implementation of BIM, focusing on the need for an integrated approach. This allows for an effective framework for the widespread adoption of BIM, which in turn ensures higher quality, reduced costs and improved management of construction projects.

Thus, all such studies are critical to understanding and successfully implementing BIM technologies. By providing a comprehensive analysis of existing practices and identifying the main benefits and obstacles, such studies help to formulate effective strategies for BIM implementation. They contribute to the development of optimal approaches that consider the specifics of different countries and their needs, which in turn increases the efficiency of construction projects, reduces costs and improves quality. This creates an important basis for the successful modernisation of the construction industry and the introduction of the latest technologies, which will contribute to its sustainable development.

CONCLUSIONS

This study analysed the level of BIM adoption in Eastern European countries and found that this level varies significantly and depends on many factors, including government support, the availability of national standards, educational programmes and the overall readiness of the construction industry to adopt digital innovations. The study showed that some countries, such as Poland and the Czech Republic, are at the forefront of BIM adoption, demonstrating active government support and strategies aimed at digitalising the construction industry. These countries are actively working to create national regulations for BIM, which allows the technology to be integrated into large infrastructure projects. Other countries in the region, such as Hungary and Slovakia, are at a moderate stage of BIM adoption, with the main burden of implementation falling on private companies and individual projects. In these countries, there is interest in using BIM, especially in large construction companies, but widespread adoption of the technology is limited by a lack of systematic government support and clear standards. The third and fourth groups of countries, which include Ukraine, Bulgaria, Romania, the Baltic States and other countries, are at a low and early stage of BIM implementation. In these countries, there is a low level of BIM use, which is associated with a low level of government support, a lack of national standards, and a shortage of qualified personnel. In Ukraine, in particular, BIM technologies are used in large international projects where it is a requirement of investors, but the technology has not yet become widespread at the national level.

The study determined that several obstacles need to be overcome for the successful implementation of BIM in Eastern Europe, the most important of which is the lack of a clear regulatory framework, an insufficient number of specialists, and low awareness of the benefits of using BIM among a wide range of construction stakeholders. An important condition for the successful implementation of BIM is close cooperation between the state and the private sector, the development of national standards, and active support for educational programmes aimed at training specialists in this field. Notably, this study has certain limitations, including limited coverage of regional and sectoral specifics of BIM implementation in individual countries, as well as the lack of a detailed analysis of the impact of economic crises and political changes on the implementation of this technology. For further research, it is recommended to focus on conducting more in-depth case studies in countries with different levels of BIM adoption, as well as on studying the role of various factors in the process of technology integration.

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CONFLICT OF INTEREST

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Аналіз проблем впровадження та адаптації BIM-технологій у Східній Європі

Анотація. Метою дослідження була оцінка рівня інтеграції цифрових інформаційних технологій у будівельну галузь у країнах Східної Європи. Зібрано кількісні дані щодо впровадження сервісів інформаційного моделювання будівель (BIM) у країнах Східної Європи та проведено порівняльний аналіз динаміки їх використання у 2020-2023 роках. Результати дослідження свідчать про значну різницю в рівні впровадження BIM у країнах Східної Європи, що тісно пов'язано з рівнем економічного розвитку, станом будівельної галузі та підтримкою з боку державних органів. Країни з більш розвиненою економікою та стабільною нормативно-правовою базою, такі як Польща та Чехія, продемонстрували найвищі темпи впровадження BIM. У цих країнах різні BIM-сервіси активно використовуються на всіх етапах життєвого циклу будівельного проєкту – від проєктування та моделювання до управління будівництвом та експлуатації об'єкта. Державна підтримка в цих країнах включає розробку національних стандартів, введення обов'язкових вимог щодо використання BIM у державних тендерах та реалізацію освітніх програм для підвищення кваліфікації фахівців, що сприяє активному впровадженню технологій і підвищенню ефективності будівельної галузі. З іншого боку, в країнах з менш розвиненою економікою та обмеженою державною підтримкою процес інтеграції BIM відбувається повільніше. У таких країнах як Україна, Болгарія та Румунія, BIM застосовується переважно в окремих проєктах, але масове впровадження BIM стримується відсутністю національних стандартів, недостатньою кількістю кваліфікованого персоналу та низькою обізнаністю учасників ринку. Отримані результати можуть бути використані для визначення ключових факторів, що впливають на успіх впровадження BIM у будівельній галузі, і можуть бути використані в майбутньому для подальшої розробки ефективних стратегій діджиталізації в регіоні

Ключові слова: інформаційне моделювання; будівельні процеси; динаміка використання; управління проектами; стратегії розвитку