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The role of building information modelling in the implementation of sustainable, environmentally friendly, and social infrastructure projects

Abstract. The realities of the 21st century in the context of overpopulation, political changes and economic challenges require the development and implementation of infrastructure projects that ensure the sustainability of resource use and have a minimal negative impact on the surrounding natural ecosystems. The purpose of this study is to substantiate and evaluate the main aspects of Building Information Modelling its possibilities and its advantages in the construction of sustainable infrastructure in the context of energy efficiency, balanced use of resources, implementation of environmentally friendly technologies, improvement of the principles of landscaping and improvement of people's quality of life. A number of general theoretical research methods were used, in particular: the methods of analysis and synthesis, the method of interviewing, the method of deduction and induction. The analysis of scientific articles showed an insufficient number of publications that reveal the features of the use of modern information modelling technologies in the design of environmentally safe, sustainable and socially responsible infrastructure. The study described the overall impact of Building Information Modelling on the environmental aspect of infrastructure activities. The peculiarities of the application of Building Information Modelling technology in environmental impact assessment were substantiated. The social aspect of information modelling of infrastructure projects was also analysed. The importance of building modelling using integrated approaches for safety assessment and management decision-making was emphasized. The problems in the processing of Building Information Modelling model information, which mostly concern socio-technical aspects, were revealed. The structure of the methodology of information modelling of buildings was substantiated in the context of a significant reduction of harmful emissions, energy saving, the use of environmentally friendly technologies and materials. The practical significance of the study lies in the integration of information modelling into the processes of construction, planning, monitoring and risk management in the long term, which allows to ensure the effective implementation of projects and the avoidance of environmental, technical and social problems in the future

Keywords: integrated technologies; ecological monitoring and assessment; energy efficiency; digital innovation; risk and security

INTRODUCTION

With the enlargement of the European Union to include new member states, a wide range of infrastructure network planning has emerged, encompassing areas such as road, sewer, civil engineering, and pipeline construction. These developments are in line with global efforts to make infrastructure projects more sustainable, environmentally

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friendly, and socially responsible. In this context, Building Information Modelling (BIM) plays a crucial role by forming the core of the planning and construction process and enabling comprehensive monitoring of the construction project at all stages. The relevance of this research is driven by the need to educate engineering firms and other stakeholders on the potential benefits, challenges and wider implications of implementing BIM in infrastructure development. Promoting a comprehensive understanding of the synergistic relationships between BIM and Environmental, Social, and Governance (ESG) criteria is extremely important for sustainable infrastructure development.

Digitalization has also become increasingly important in the construction industry since 2010s. As digitalization has progressed, BIM has established itself as a methodology that goes far beyond a simple software program (Prokopenko & Povolotskyi, 2022). Unlike traditional 2D planning, BIM offers the integration of time (4D), cost (5D), sustainability aspects (6D) or facility management information (7D) outside the 3D model, enabling more efficient management construction projects and provides transparency of documentation for decades, as noted by R. Charef *et al*. (2018).

The methodological basis of BIM in the context of a complex process includes the creation and management of digital models of buildings or infrastructure measures according to the rationale of S. Theißen *et al*. (2020). BIM models contain more detailed information such as soil layers, planned pipe layouts, or even specific product sheets for specific components.

Infrastructure planning encompasses a variety of aspects, from the design of large transportation networks to the planning of utility systems, according to data analysis by A. Sharafat *et al*. (2021). These projects are often highly complex and involve a large number of interfaces with other trades, some of which cannot be easily integrated into a BIM model. For example, there is still a lack of options for integrating information on the ground conditions into the BIM model, as soil experts, for example, deliver their results as written reports and not as a visual BIM model.

Old existing underground pipelines are often unreliable and, in some cases, only available as old paper plans. Especially for large linear structures, many BIM software tools are not yet (as of 2024) designed to accurately display global coordinate systems such as Universal Transverse Mercator. Therefore, the integration of BIM methodology into these processes is a complex task that requires adaptation of existing BIM tools and practices according to the research of M.Q. Huang *et al*. (2020). This adaptation should take into account both the specific requirements of infrastructure projects and the existing working methods of the involved stakeholders.

A key aspect of using BIM in infrastructure planning, according to the statements A.M.I. Raouf & S.G. Al-Ghamdi (2018), is the consideration of the long-term perspective. Infrastructure projects often have a very long-life cycle, and decisions made during the planning phase have long-term consequences. Therefore, the ability of BIM to cover and model the entire project life cycle is extremely important. This includes consideration of aspects of sustainability, long-term maintenance and operation costs, and adaptability to future needs and technologies.

Thus, BIM plays a key role in the implementation of sustainable, environmentally friendly infrastructure projects. However, there are aspects that require more attention and further research, in particular: integration of energy efficiency in modern engineering and planning solutions, ensuring the principles of inclusiveness in projects, environmental assessment and rational choice of building materials, social responsibility of infrastructure projects. The purpose of the study was to substantiate the BIM and ESG criteria in the context of a balanced partnership and to promote a sustainable, holistic approach to the implementation of infrastructure measures, taking into account the principles of resource conservation, management efficiency, the use of renewable energy sources, improving safety, working conditions and social responsibility.

MATERIALS AND METHODS

A literature review and qualitative expert interviews, which were analysed using the structuring of scientific content, were two main methods in this article. The combination of these methods enables a comprehensive analysis that provides both theoretical knowledge and practical insights into the application of BIM about ESG issues. The research questions guiding this study are:

1. RQ1: How can BIM help to improve the environmental sustainability of infrastructure projects?
2. RQ2: How can BIM be used to promote social aspects such as occupational safety in infrastructure projects?
3. RQ3: How does BIM influence transparency and communication between stakeholders in construction projects?

The qualitative literature analysis followed a systematic approach proposed by A. Fink (2019) and is divided into six steps:

1. Defining the research questions.
2. Selection of suitable databases.
3. Definition of the search terms.
4. Definition of the research period.
5. Definition of selection criteria.
6. Conducting the analysis.

Scopus, Web of Science, Google Scholar, and IEEE Xplore databases were used during the study to create a comprehensive database for deductive qualitative content analysis. The search terms included key concepts such as “BIM”, “infrastructure”, “ESG”, “environmental sustainability”, “occupational safety”, and “transparency” and were used in various combinations to identify the relevant literature (Fig. 1). Particular attention was paid to linking these terms with BIM. In addition, care was taken to ensure that the literature also dealt with the consideration of infrastructure measures.

Keywords 1	Keywords 2	Databases
• Environmental sustainability, environmental impact, green building • Workplace safety, social responsibility • Governance, transparency, stakeholder communication	• BIM and/or infrastructure	• Web of Science • Scopus • Google Scholar • IEEE Xplore

Figure 1. Search string and databases

Source: compiled by the author

The time period for the study was set from 2007 to December 2023 in order to capture the developments and applications of BIM since its introduction in Europe. The sources analysed included primarily scientific articles and project presentations that contained at least one of the ESG keywords. The use of different search strategies – from keyword and free text searches to targeted searches in titles and abstracts – made it possible to capture a broader range of information. This method made it possible to gain deep insights into existing research and to identify patterns and gaps in the current literature, which is essential for answering the research questions.

Qualitative expert interviews were conducted to further deepen and validate the insights gained from the literature analysis. These interviews served to capture current, practice-based knowledge and experiences that may not yet be fully reflected in the academic literature. This approach is particularly valuable in gaining a deeper understanding of the practical application and challenges of BIM in relation to ESG issues in infrastructure planning. The selection of experts focused on experience in infrastructure planning using the BIM method. This included experts from different hierarchical levels in engineering firms – from management level to project engineers – as well as experts from cooperating companies, such as consulting firms and software vendors. Limiting the sample to the areas of transport infrastructure and water supply and disposal enabled a focused and in-depth analysis with regard to infrastructure planning (Huang *et al.*, 2022; von Soest, 2022).

During the interview, the main principles and provisions of the code of ethics were applied. In particular, the diversity of the respondents, mutual respect, the opportunity to express themselves in the language that is most convenient to master, the protection and confidentiality of information in accordance with local and international ethical standards, the avoidance of any forms of discrimination based on gender, race, age, disability or other factors were taken into account factors (Global Code of Ethics, 2021). The interviews were conducted to the point of theoretical saturation, with a total of 19 expert interviews conducted. The interviews were based on a carefully developed interview guide containing ten open-ended main questions in four thematic blocks. These questions served as conversation starters and were supplemented by specific follow-up questions to deepen the discussion and obtain more detailed information. The interviews were recorded and then transcribed to ensure a precise and comprehensive analysis. The interviews were analysed using MAXQDA software (Kuckartz & Rädiker, 2019), which enables efficient and systematic analysis of both the qualitative and quantitative elements of the interviews. While the qualitative analysis focused on summarizing and interpreting the content, MAXQDA also supported the quantitative frequency analysis by making the frequency of certain themes and opinions visible. This combined method of analysis helped to present a more complete picture of the different perspectives and experiences.

The results were presented descriptively and then critically examined to highlight both the potentials and challenges of BIM in the context of ESG in infrastructure planning. The use of MAXQDA ensured a high level of transparency and traceability in data processing and evaluation, which is essential for the credibility and reliability of the study results.

RESULTS

The overall results of the literature research on the influence of BIM on ESG in infrastructure measures are shown in Figure 2. After removing duplicates and a subsequent examination of the abstract and full text, 20 publications were found and thoroughly analysed. The deductive keywords were not discussed directly in the articles found, which is why an inductive categorization was carried out first, in which categories were derived from the texts. The inductive categories were then assigned to the superordinate categories (Table 1).

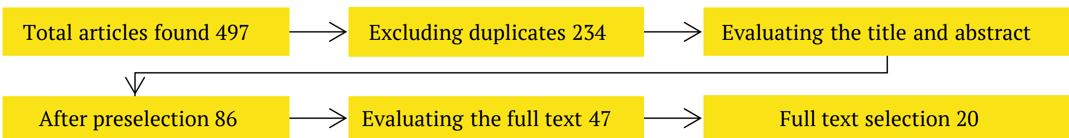

Figure 2. Systematic literature search

Source: compiled by the author

Table 1. Deductive and inductive categorization

Deductive	Inductive
Environmental sustainability, environmental impact, green building	Sustainability in infrastructure projects
	BIM in the context of sustainable buildings
	BIM in environmental assessment
	Digital twin in sustainability assessment
	BIM for energy-efficient construction
	Road design through shadow analysis
	CO_2 savings through sustainable building approaches
	Integration of environmental assessment into the design process
	Material selection and CO_2 footprint
Workplace safety, social responsibility	Factors that influence social collaboration in BIM projects
	Safety in educational institutions
	Prevention of accidents at work
	BIM for safety assessments
	Use of technology for safety in the workplace
	Humanistic approach to infrastructure management
Governance, transparency, stakeholder communication	Data Governance Act
	Adapting to future requirements and uncertainties
	Challenges in the processing of BIM model information
	Communication efficiency through BIM
	Implementation of BIM in communication networks

Source: compiled by the author according to J.Á. Aranda *et al*. (2021), M. McPherson *et al*. (2022), G.T.N. Veerendra *et al*. (2022), A. Laali *et al*. (2022), C.X. Hui *et al*. (2023), Z. Yang *et al*. (2023), N.F. Arenas & M. Shafique (2023)

The results of the literature analysis showed an unexpected distribution of the thematic focus of the articles with regard to infrastructure measures. Although the primary aim of the analysis was to identify literature explicitly dealing with infrastructure measures, the study revealed a lack of articles directly focused on this area. Specifically, the analysis revealed that only 35% of the articles analysed dealt explicitly with infrastructure measures. Interestingly, although 25% of the articles contained the keyword "infrastructure", they referred to infrastructure-related building construction, such as hospital buildings. While these articles provided relevant insights, they did not focus primarily on infrastructure in the narrower sense. In addition, 40% of the articles were classified as thematically neutral. These articles covered topics that are relevant to both infrastructure measures and other areas in a broader context. This category of articles therefore offers potential starting points for the application of BIM in different contexts of infrastructure planning and development.

A graphical representation of this distribution is shown in Figure 3. These results illustrate the thematic focus of the articles found in the literature and highlight the need to intensify research in specific areas of infrastructure interventions in order to better understand the application and impact of BIM in this sector.

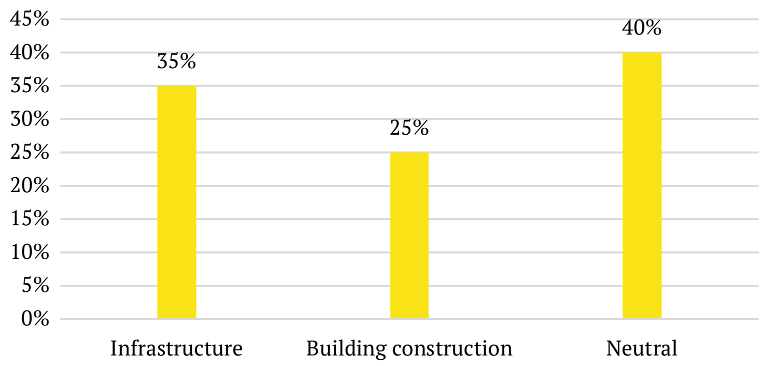

Figure 3. Thematic focus of the literature examined

Source: compiled by the author

Given the thematic limitations identified within the existing literature with regard to specific infrastructure measures, there is a need to broaden the perspective and tap into additional sources of information. That is why qualitative interviews of respondents play a key role in the results of this study. These interviews offer the opportunity to gain practical and detailed insights into the impact of the BIM method on ESG issues in the context of infrastructure projects.

Influence of BIM on the environmental aspect of infrastructure measures. BIM enables significant progress in the context of sustainable buildings. By integrating BIM into the design and construction process, more environmentally friendly materials can be selected and used more efficiently, contributing to a significant reduction in carbon emissions. This is reinforced by the integration of Life Cycle Assessments (LCA) and energy efficiency analysis into BIM processes, leading to a reduction in carbon emissions (Wang, 2022).

BIM has a substantial influence on the environmental aspect of infrastructure measures. The adoption of BIM in infrastructure projects can lead to several environmental benefits and improvements (Fig. 4).

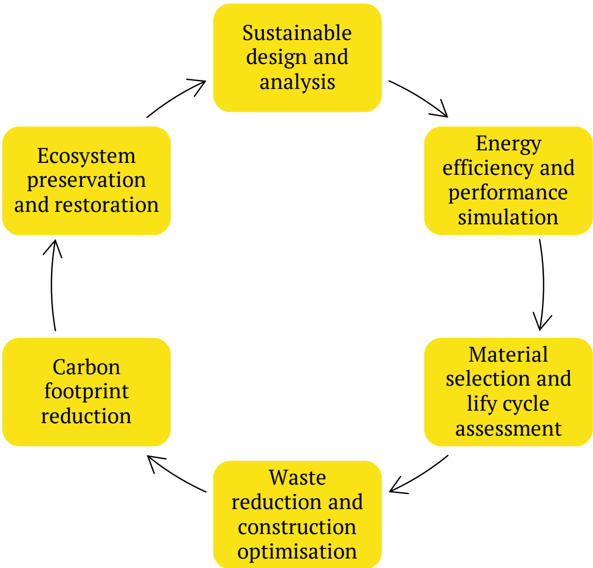

Figure 4. The main aspects of the impact of BIM on the environmental aspect of infrastructure measures
Source: compiled by the author according to Y. Yang *et al*. (2021), A. Rodríguez-Amigo *et al*. (2022), A.R. Nasab *et al*. (2023)

BIM enables the evaluation of materials and components based on environmental criteria LCA tools integrated into BIM software help assess the environmental impact of materials throughout their life cycle, aiding in the selection of more sustainable options (Chen *et al*., 2023; Kalajian *et al*., 2023). The adoption of BIM in infrastructure measures contributes significantly to addressing environmental challenges by promoting sustainable design, optimizing construction processes, and facilitating ongoing environmental monitoring and management. This results in infrastructure projects that are not only efficient and cost-effective but also environmentally responsible and resilient. By using BIM technologies in environmental impact assessment, it becomes possible to enable or optimize the energy-efficient integration of construction measures and materials, which leads to a further reduction in overall energy consumption (Shalbolova *et al*., 2021). BIM thus offers an opportunity for an in-depth assessment of the sustainability and environmental impact of measures, which contributes to the environmentally conscious implementation of infrastructure projects. Also related to BIM is the so-called digital twin, which enables realistic simulation and analysis, providing precise insights into environmental impacts and life cycle costs. This technology not only supports a comprehensive assessment of the environmental impact of projects, but also enables agile adaptation to changing environmental conditions and resource availability (Borjigin *et al*., 2022).

BIM, in combined with a geographic information system, can make environmental impact assessments more efficient, as environmental data and information on existing animal and plant species can be used to optimize the consideration of structure in the environment and assessment options. also, more efficient. For example, when building a new road, one might study how the road should be built to avoid the need to relocate animal species. It may also be possible to study how the integration of a new road will affect the environment in the long term, in which areas compensation measures for animals are needed, or whether compensation measures for plants need to be created (Noor *et al*., 2022; Moudgil *et al*., 2023). By integrating BIM into the design and construction process, energy consumption and CO_2 emissions can be significantly reduced, leading to a more efficient use of resources and a reduction in environmental impact. This methodology supports the development of smart cities by providing intelligent solutions for energy management and resource optimization.

The social impact of BIM in infrastructure projects. As a result of interviewed respondents, in particular engineers, designers, planners, it was established that BIM has a significant social impact on infrastructure projects, affecting various stakeholders and aspects of project development. However, the use of information modelling technologies has both advantages and disadvantages from the point of view of social perception. The social impact in BIM projects is influenced by factors such as management commitment, guidelines, work process manuals and individual willingness to adapt to digital practices. Effective collaboration is promoted through the integration of BIM execution plans.

The respondents describe that it is necessary to create an awareness of BIM, especially at senior management level. The respondents describe that the switch from conventional planning to BIM results in additional work, particularly in the earlier service phases, which also increases the working time of employees in these initial phases. The modelling of the buildings requires more time at the beginning, which must be taken into account by the managers. It is important to make certain internal determinations and to allow more time for the initial planning phases in particular and to communicate this information to all employees and clients. It is also necessary to consider the higher costs of training and software and to be prepared to invest in staff training.

The respondents emphasize the importance of BIM, particularly in relation to safety assessments and decision making. The focus is on using BIM for visualization, understanding and transparency in construction projects, as well as combining it with multi-criteria decision-making methods to incorporate environmental metrics and social factors into the decision-making process. The implementation of BIM-based systems helps to minimize fall hazards and accidents in the construction industry. Early identification of hazards and alternative design recommendations are key elements to increase occupational safety. BIM supports safety assessment and decision-making through visualization and transparency. This includes the integration of LCA and multi-criteria decision methods to systematically incorporate safety aspects into the planning process. In this way, BIM can be used to identify and manage safety risks in construction projects with many interfaces.

The respondents also describe that with the BIM methodology, the number of workers required on the construction site can be determined more efficiently, and the exact knowledge of the areas and masses required on the construction site can also be used to more accurately check how many workers are required on the construction site. The timeline of the construction project can also be tracked in the long term and potential safety gaps and problems can be identified so that problems can be addressed at an early stage and, for example, additional employees can be provided so that the project does not have to be overloaded or postponed.

In one of the case studies, the use of virtual fences to prevent accidents at work using Bluetooth Low-Energy is being used. To prevent accidents, the areas on the construction site are evaluated according to the safety aspect and it is determined which areas may not be entered during certain construction phases. Such system can be integrated cost-effectively and easily into the BIM method (del Carmen Rey-Merchán *et al*., 2021). In addition, C.M. Chang *et al*. (2023) emphasize the humanistic approach in infrastructure management. This approach expands the focus of BIM beyond technical and environmental aspects to also consider social factors in the planning and execution of infrastructure measures. BIM supports efficient coordination and communication between the various employees, promotes transparency and enables the participatory design of projects that are both environmentally friendly and socially responsible.

3D modelling makes it easier for employees to read the plan. It is no longer necessary to display three different plans from three different perspectives. In infrastructure planning in particular, it is becoming increasingly common for employees to find it difficult to understand longitudinal plans in particular, because collisions are not always immediately recognizable in conventional 2D plans. In addition to improving understanding, BIM modelling also provides greater transparency, as all employees can access the same model and can highlight any problems or errors directly in the plan.

DISCUSSION

This study examines the role of BIM in the implementation of infrastructure measures, with a focus on the integration of ESG criteria. The results show that BIM plays a key role in promoting sustainability, which is confirmed by the articles analysed. Thus, BIM can help to achieve ESG goals in infrastructure development. It not only promotes environmentally friendly and social construction practices, but also strengthens governance structures in construction projects. The integration of BIM into construction and planning processes can make a significant contribution to achieving sustainable goals. When examining the impact of BIM on governance, particularly in the area of data governance, the integration of BIM has a significant impact on the management and regulation of data in construction projects. The article by B. Weber *et al*. (2023) provides insights into the evolving legal framework for data sharing in BIM processes. At the same time, the impact of the European Data Management Act on common data environments is important, which requires a reassessment of existing data exchange models in the construction industry. In addition to the role of BIM in data governance, as described by the authors, BIM plays an essential role in adapting to future requirements and uncertainties.

According to these research results, it is followed the view that small and medium-sized engineering companies can find it difficult to manage large amounts of data. However, there is a downside to managing large volumes of data for large infrastructure projects, as they typically require much more storage space than smaller buildings. In infrastructure planning, projects are often 40 km long, whereas in building construction, buildings are often limited to much smaller areas. Data protection is also a major concern for information modelling professionals; guidelines and specifications are needed to define how data should be shared with other parties involved in the project. In addition, it is necessary to clearly regulate the procedure for transferring data if planning is transferred to another office or the performing construction company at a later stage in the provision of services. The challenges in processing BIM model information relate in particular to the socio-technical aspects, as highlighted by P.N. Gade & K. Svidt (2021). Their research shows that lack of flexibility and transparency in BIM systems can lead to difficulties in practice. This highlights the importance of developing BIM systems that are not only technically advanced but also adaptable in terms of user needs and ever-changing project requirements. This also makes it clear that governance in the BIM context must include not only data management, but also the consideration of socio-technical dynamics.

The present research results highlight the importance of the statement of S. Gaur & A. Tawalare (2021) and also describe the need for adaptability when applying the BIM method. They describe that not every BIM tool can be used for every infrastructure measure. For example, software that is also used in building construction can be used for smaller projects, such as Revit software for transforming bus stops. On the other hand, other measures, such as retrofitting longer highways, require different software systems. Therefore, it is necessary to be flexible, especially when planning infrastructure, and not just use closed BIM. In addition, the transformation of infrastructure measures involves working together with cities, municipalities and many other municipal institutions, as well as with utility companies that are responsible for various lines (Sidliarenko, 2023). These stakeholders often do not have access to all software systems. Engineering firms must be willing to be transparent and communicate so that all stakeholders can access this information. Also, if these requirements are met, BIM can bring greater added value to the infrastructure, since the experience shows that there is a more frequent and intensive exchange of information, which leads to a faster reduction in the number of errors (Sakr & Sadhu, 2023).

The use of BIM in infrastructure projects has a significant impact on environmental sustainability. By integrating BIM, the planning, construction and maintenance of infrastructure projects can be made more efficient and environmentally friendly. The BIM method enables detailed monitoring and assessment of environmental impacts throughout the lifecycle of a project (Schults *et al.*, 2016). This includes the selection of sustainable paving surfaces and associated materials as well as resource optimization. BIM thus not only promotes environmentally conscious project design, but also contributes to the long-term reduction of environmental impacts and increased economic efficiency. The role of BIM in the early phase of project design is particularly noteworthy, where simulation-based analyses can be used to identify and implement environmentally friendly solutions. This makes BIM an indispensable tool for the realization of sustainable and environmentally friendly infrastructure measures (Oreto *et al.*, 2023).

The results of this study indicate that BIM in infrastructure has a positive effect on the accurate determination of mass. This gives a great advantage in the field of movement of the earth's mass, and also allows not only to accurately calculate the cost, but also to effectively plan the necessary masses on the construction site (Kutia *et al.*, 2023). This leads to a better optimization of resources, as material deliveries can be coordinated with the required quantities. But optimized for more than just cobblestone or gravel surfaces, precise materials can be determined early on, such as the exact size of sewer pipes to avoid collisions. However, some scientific reports contain concepts that characterize the BIM method, which has not yet progressed to the point where the exact position of existing routes can be traced, which is still a problem when it comes to determining the optimal quantities and laying of pipes (Correa & Santos, 2021).

S.H. Khahro *et al.* (2021) describe that a significant reduction in energy consumption and CO_2 emissions can be achieved by using BIM in conjunction with sustainable construction. Especially in the planning and construction of healthcare facilities, BIM supports efficient use of resources and promotes the implementation of energy-efficient solutions, which leads to a significant reduction in negative environmental impacts and costs. The integration of environmental assessment into the planning process using BIM can therefore improve sustainability. It turns out that BIM offers a structured method for assessing the environmental impact of infrastructure projects as early as the design phase. This makes it possible to systematically record environmental impacts and incorporate them into the planning and decision-making process at an early stage, leading to a more effective and environmentally friendly design of infrastructure projects (van Eldik *et al.*, 2020). In 2020, the construction sector was responsible for 36% of global energy consumption and 37% of energy-related CO_2 emissions (Energy-related emissions…, 2024). BIM can assist in the selection of materials to actively contribute to the reduction of the carbon footprint in construction projects. This leads to more sustainable construction decisions and a reduction in overall CO_2 emissions from construction activities, which is particularly important in the development of sustainable infrastructure.

The results of this work present characteristics of how BIM can be used to check which equipment can be used on a construction site. In traditional planning, it often happens that certain equipment is ordered to a construction site, and then it is discovered that it is too large and does not meet the existing conditions for use on the construction site. In such cases, additional work is required, resources are used unnecessarily and CO_2 emissions increase, which can be avoided by using the BIM methodology. BIM allows you to check the position and movement of certain equipment on a construction site using a 3D model for position and height. This is often particularly useful when expanding infrastructure activities, as infrastructure is often built within existing buildings and surrounding structures need to be taken into account during construction work.

CONCLUSIONS

BIM plays an extraordinary role in increasing environmental sustainability in infrastructure projects. By significantly increasing design accuracy and effectively optimizing resources, BIM makes a significant contribution to minimizing the environmental impact of construction projects. It actively promotes the implementation of green building practices and supports the use of sustainable materials.

In the field of social stability, BIM contributes to strengthening work safety. By providing improved risk reduction tools, BIM significantly contributes to safety on construction sites. In terms of governance aspects, BIM plays a key role in promoting transparency and effective communication between stakeholders. By providing real-time information, BIM supports clear and informed decision-making and facilitates intensive data sharing. In summary, it can be seen that BIM not only increases technical efficiency, but also makes a significant contribution to the achievement of ESG goals. Integrating these principles into the BIM process is a crucial step towards more sustainable, responsible infrastructure development.

The results of this study showed that there is a lack of specific scientific articles on the use of BIM in infrastructure planning with a particular focus on ESG issues. This indicates a research gap that should be addressed in the future to provide a deeper understanding of the complex demands of modern infrastructure development. In particular, during the implementation of this study, the transformational role of BIM in infrastructure planning was substantiated, not only increasing the efficiency and economic efficiency of projects, but also making a positive contribution to the environment and society. Thus, the integration of ESG principles into the BIM process is a crucial step towards more sustainable and socially responsible infrastructure development.

Based on the understanding that BIM has a significant impact on the sustainability, environmental and social aspects of infrastructure projects, it is worth forming new models and optimization systems that will meet the modern requirements and needs of consumers. Areas of further research in this context may include integration with modern technologies, improvement of environmental aspects, social interaction and public participation, standardization and improvement of BIM standards, ensuring interoperability with the legal and regulatory framework, effective land use management and assessment of the impact of technology on climate change. These areas of research can contribute to the further development of BIM in the context of sustainable, green and social infrastructure projects, providing more comprehensive and balanced project management for the benefit of society and the environment.

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CONFLICT OF INTEREST

None.

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Роль інформаційного моделювання будівель у впровадженні сталих, екологічно чистих та соціальних інфраструктурних проектів

Анотація. Реалії XXI століття в умовах перенаселення, політичних змін та економічних викликів вимагають розробки та реалізації інфраструктурних проектів, які забезпечують сталість використання ресурсів та мають мінімальний негативний вплив на навколишні природні екосистеми. Метою даного дослідження є обґрунтування та оцінка основних аспектів інформаційного моделювання будівель, його можливостей та переваг при будівництві сталої інфраструктури в контексті енергоефективності, збалансованого використання ресурсів, впровадження екологічно чистих технологій, удосконалення принципів благоустрою територій та покращення якості життя людей. Використано низку загальнотеоретичних методів дослідження, зокрема: методи аналізу та синтезу, метод інтерв'ювання, метод дедукції та індукції. Аналіз наукових статей показав недостатню кількість публікацій, які розкривають особливості використання сучасних технологій інформаційного моделювання при проектуванні екологічно безпечної, сталої та соціально відповідальної інфраструктури. У дослідженні описано загальний вплив інформаційного моделювання будівель на екологічний аспект інфраструктурної діяльності. Обґрунтовано особливості застосування технології інформаційного моделювання будівель в оцінці впливу на довкілля. Також проаналізовано соціальний аспект інформаційного моделювання інфраструктурних проєктів. Підкреслено важливість побудови моделювання з використанням інтегрованих підходів для оцінки безпеки та прийняття управлінських рішень. Виявлено проблеми в обробці інформації моделей інформаційного моделювання будівель, які здебільшого стосуються соціально-технічних аспектів. Обґрунтовано структуру методології інформаційного моделювання будівель в контексті суттєвого зменшення шкідливих викидів, енергозбереження, використання екологічно чистих технологій та матеріалів. Практичне значення дослідження полягає в інтеграції інформаційного моделювання в процеси будівництва, планування, моніторингу та управління ризиками в довгостроковій перспективі, що дозволяє забезпечити ефективну реалізацію проектів та уникнути екологічних, технічних і соціальних проблем у майбутньому

Ключові слова: інтегровані технології; екологічний моніторинг та оцінка; енергоефективність; цифрові інновації; ризик та безпека