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The use of Artificial Intelligence in Building Information Modelling: Document-based bibliographic analysis

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Abstract: A strong connection to the architectural, engineering and construction network, with access to technologies such as BIM, leads to increased industrial productivity. The use of BIM can be implemented by using many programs and systems that provide knowledge and quick solutions. Combining BIM with artificial intelligence (AI) methods can provide even greater software benefits. This article examines the use of AI methods coupled with BIM in scientific research. The main objective of the research is to learn about trends in the use of artificial intelligence in BIM research in the context of construction management. This was achieved through bibliometric and scientifically accessible searches and mapping with text mining. Data on artificial intelligence in BIM research has been collected by reviewing and using articles from the Scopus database. The paper will contribute to the access of literature and trends in AI and BIM research.

Keywords: artificial intelligence, BIM, construction management, hybrid AI, knowledge based reasoning, machine learning, metaheuristics

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Introduction

BIM modelling is currently one of the best known and fastest growing modern information technologies in the construction industry. However, after the initial euphoria, there has been a slowdown in the pace of development and a search for new ways to use BIM technology. One possibility, and a very promising one, seems

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to be the possible combination of the use of artificial intelligence (AI) and Building Information Modelling (BIM).

Artificial intelligence (AI) is a branch of computer science that deals with developing intelligent machines and computer systems with human-like reasoning, learning and problem-solving capabilities (Zhang et al., 2022). The use of artificial intelligence in the construction industry can relate to many issues, in particular supporting engineering analysis such as structural, thermal, airflow or energy efficiency, to predict the behaviour of structures under different conditions and propose optimal solutions.

However, the aim of this article is to explore the use of artificial intelligence supported by BIM models in the area of construction management. The scope of such support may include, for example, costing, scheduling, health and safety, human and material resource management, quality control, etc. In the case of the planning and execution of construction works, AI offers, among other things, the possibility of analysing a wide range of data that can be used for predictive analyses to support the costing and scheduling of construction works, and the identification of possible risks, etc. According to Bassir et al. (2023), artificial intelligence can be used to manage a construction project in a number of ways, such as using geospatial data, real-time data and historical data. It could be useful for all the key players in a project: the architect, the engineer, the contractor and the owner. By using large amounts of data, AI makes it possible to create forecasts and optimise construction schedules. AI also offers the opportunity to improve the design process based on previously developed (realised) projects, and to create more detailed computer visions, as well as summaries and various types of analysis (Zima & Wieczorek, 2024).

The author analysed trends in the development of AI currently used in BIM modelling in the construction industry, with a particular focus on the area of construction project management. The research was mainly based on bibliometric analysis, as well as scientific analysis and a text mining approach to mapping. Data on artificial intelligence in BIM research was collected by reviewing and checking selected articles from the Scopus database. This was followed by the use of VoSviewer, a bibliometric network construction and visualisation software tool that also provides text mining functionality, which can be used to construct and visualise co-occurrence networks of key terms extracted from a body of scientific literature.

1. Can artificial intelligence help the development of BIM worldwide?

After a great leap forward for the construction industry over the last few decades with the integration of BIM systems, enabling the automation of design processes and coordination between disciplines, it has become apparent how easily engineers adapt to new, innovative systems (Burzyńska, 2019). Artificial intelligence is a technology that has been slowly gaining ground in the construction industry over the past

few years. Combined with BIM technology, AI can contribute to the rapid growth of the construction industry, an overarching goal for the industry in the coming years. At the outset, it is important to consider the current state of development in BIM technology within the construction industry. According to the results of the review by (Fonseca & Shafique, 2023), it can be assumed that Building Information Modelling (BIM) is a powerful tool with capabilities that improve environmental and sustainable approaches in the design and construction phase of green buildings. Building Information Modelling (BIM) is a methodology and tool that can help the construction industry achieve environmental goals and enables life cycle assessment (LCA) to be carried out at every stage of a project.

The problems and barriers to development have been similar in many countries for years. Based on a survey of 224 participants from 42 different companies, the authors (Yılmaz et al., 2024) received 160 reliable responses. The results indicate that "Deficiencies of Infrastructure and Lack of Qualified Personnel (DIP)" constituted the most significant barrier to development, followed by the "Lack of Documentation and Specifications (LDS)", "Deficiencies of Case Studies and Project Drawings (DCP)", and "Lack of Motivation and Resistance to BIM (LMR)". In turn, the authors (Grzyl et al., 2016) in their publication cite the following as problems of BIM development: problems of data exchange, lack of a single and complete construction classification system, lack of state support, lack of specialists and educational neglect, and negative attitudes to change. One of the conclusions of the presented research is that the development of information technology significantly affects all industries. The construction industry must also adapt and adopt new possibilities. The BIM concept is a compilation of existing experiences, covering various aspects of the construction investment process (time, cost, technology, quality, use of the building), into a compact digital model.

So, with such seemingly fundamental problems in the industry related to reluctance to change, cost, lack of knowledge and access, etc., does it make sense to develop BIM further and move towards AI? The answer is "yes". Systems that support the construction process will facilitate the use of BIM. In addition, the drivers of the construction market are large companies, and they are already looking for many solutions to simplify the work of their employees.

By mapping the most common phrases alongside 'BIM' and 'future', the author in (Borkowski, 2024) observed strong links with other technologies and systems. Researchers and practitioners are looking to combine BIM with other methods/techniques/tools/systems to provide even more value to AECOO stakeholders. Looking at the strong links between the acronym 'BIM' and the word 'future', there is an unchanging direction - integration with: ML, AI, IoT, Blockchain or VR. The phrases "Artificial Intelligence" and its associated terms "Big Data," "Business Intelligence," and "Machine Learning" have shown a rise in queries over the past decade (2010--2019). "Business Intelligence" used to be the most prevalent term, but its use has steadily declined as analytics and other descriptive analytic solutions have grown more commonplace in businesses (Prasanth et al., 2023). According to Pan & Zhang (2021),

the various AI approaches can ultimately achieve the following three main functions that benefit CEM in terms of automation, risk mitigation, high performance, digitisation and computer vision:

1. Modelling and pattern recognition: Modelling is the process of creating conceptual models in a standard, consistent and predictable way.
2. Prediction: AI-powered analysis based on machine learning is typically a prediction task, learning from given sets of historical data to make accurate predictions for new observations.
3. Optimisation: Optimisation can be seen as a decision-making process for finding and delivering practical, sustainable solutions for the construction project. By maximising the expected effects, optimisation can make a process conform perfectly to a set of criteria and constraints.

2. Analysis of the use of AI methods with BIM in construction

2.1. Research methodology

In their bibliometric study, the authors in (Zhang et al., 2022) reviewed articles published between 2010 and 2020, indicating that BIM-AI integration has gained most of its attention in the last decade. The result of the research was, among other things, a classification of AI methods used in combination with BIM, which was the starting point for the research carried out later in this article (Table 1). As demonstrated in Table 1, which is based on the research presented by Zhang et al. (2022), the following data has been collated: the number of publications in the field of the application of the technique in construction and construction management as a result of our own research.

The methodology of the study carried out is shown in Figure 1. Therefore, the author searched for combinations of the phrases: BIM and various artificial intelligence methods, using articles grouped in the Scopus database. An example search record looks like this: (TITLE-ABS-KEY (BIM) AND TITLE-ABS-KEY (genetic AND algorithm)). Only the names of the artificial intelligence methods are changed – 27 searches were finally performed. The test was performed on March 20, 2024. The search results were exported in the "ris" format for later use in the VoSviewer programme (WoS). The research used advanced text mining. The text mining feature in VOSviewer provides support for creating term maps from a corpus of documents. To highlight keywords, WoS also uses available natural language processing techniques to create a term co-occurrence network based on English text data. NLP is about giving computers the ability to understand text and spoken words in the same way as humans. It combines computer linguistics and grammar-based modelling with deep learning artificial intelligence, enabling computers to understand and process human language in the form of text or voice data, as well as the intentions and feelings of the speaker or writer (Mostafa et al., 2023).

Table 1. Artificial intelligence methods used with BIM in publications according to the Scopus database (*own research*)

No	AI techniques in BIM – main groups	Subdivision of method groups	AI methods used in combination with BIM	Total number of publications	Number of Construction Management (CM) publications
1	Knowledge based Reasoning	–	Rule based Reasoning	60	15
2		–	Case based Reasoning	79	32
3	Metaheuristics	Evolutionary Algorithm	Genetic Algorithm	221	58
4		Swarm Intelligence	Particle Swarm Optimization	45	11
5			Ant Colony Optimization	28	6
6			Firefly Algorithm	4	2
7			Simulated Annealing	24	2
8			Symbiotic Organisms Search	3	0
9	Machine Learning	Supervised Learning	Artificial Neural Network	135	33
10			Convolutional Neural Network	120	16
11			Recurrent Neural Network	16	2
12		Unsupervised Learning	K Nearest Neighbor	16	2
13			Support Vector Machine	46	10
14			Decision Tree	50	9
15			K Means Clustering	17	5
16			Hierarchical Clustering	14	1
17			Network Clustering	39	18
18			Frequent Pattern Mining	3	2
19			Sequential Pattern Mining	3	1
20	Hybrid AI	Computer Vision	Image Processing	301	45
21			Feature Extraction	129	17
22			Registration	227	43
23		Natural Language Processing	Lexical Analysis	0	0
24			Syntactic Analysis	7	1
25			Semantic Analysis	353	80
26		AI Robotics	Data Collection Robot	17	5
27			Manufacture Robot	10	1

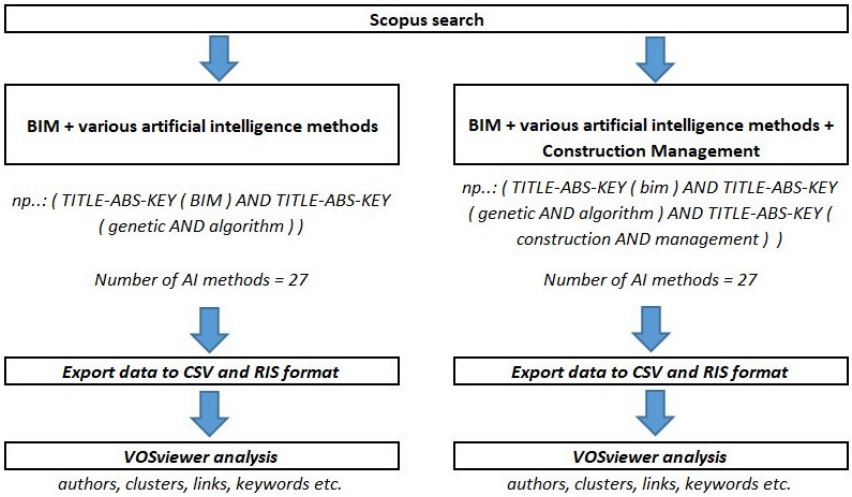

Fig. 1. Research methodology (*own research*)

2.2. Analysis of the use of AI methods with BIM in construction

Table 2 shows the most frequently used 10 artificial intelligence methods searched with the term BIM. In Table 2, the columns show:

- number of authors,
- number of clusters – indicating the collaboration of the authors,
- links – showing the connections between the authors,
- total link strength – indicating the overall strength of the co-authorship links of a given researcher with other researchers,
- keywords – number of keywords with min. 5 occurrences.

Table 2. Relationships between authors and the most frequently occurring keywords for the analysed publications in the field of construction – top 10 methods (*own research*)

AI methods used in combination with BIM	Total number of authors	Clusters	Links	Total link strength	Keywords (min. 5 occurrences)
SEA – Semantic Analysis	1052	224	2059	2170	166
IP – Image Processing	898	223	1708	1807	135
R – Registration	784	147	2494	2615	99
GA – Genetic Algorithm	633	164	1113	1171	97
FE – Feature Extraction	396	105	741	785	57
CNN – Convolutional Neural Network	374	90	703	742	51
CBR – Case based Reasoning	227	64	355	379	30
RBR – Rule based Reasoning	183	52	271	288	28
DT – Decision Tree	149	37	276	281	17
PSO – Particle Swarm Optimization	144	35	262	278	17

The most commonly used artificial intelligence methods in scientific research related to BIM are semantic analysis, image processing, registration, genetic algorithms and artificial neural networks. As far as keywords are concerned, they do not contribute much to the research. The majority of the most frequently used keywords include the term AI method, the name BIM and the term architectural design. Only this allows us to draw a conclusion about the use of BIM and AI in architectural design, but it is certainly related to the fact that BIM is currently most often used in the design phase. Attention should be paid to the large number of clusters, which may be indicative of a large number of topics in the construction industry covered by the use of AI and BIM.

2.3. Analysis of the use of AI methods with BIM in construction

Firstly, the same research was carried out for the field of construction management. The search in the Scopus database was therefore narrowed by adding the term construction management for example (TITLE-ABS-KEY (bim) AND TITLE-ABS-KEY (genetic AND algorithm) AND TITLE-ABS-KEY (construction AND management)). The study covered the same number of methods as in the first case.

Looking at the main groups of AI methods, hybrid AI methods were most frequently used, followed by machine learning, metaheuristics and knowledge-based reasoning (Table 3).

Table 3. Relationships between authors and the most frequently occurring keywords for the analysed publications in the field of construction (*own research*)

Abbreviation	Total number of authors	Clusters	Links	Total link strength	Kewords (min. 5 occurrences)
RBR – Rule based Reasoning	47	13	69	75	4
CBR – Case based Reasoning	82	26	111	119	14
GA – Genetic Algorithm	126	42	163	169	22
PSO – Particle Swarm Optimization	37	11	59	–	3
ANN – Artificial Neural Network	36	7	83	–	0
CNN – Convolutional Neural Network	54	13	101	–	5
IP – Image Processing	119	33	187	194	23
FE – Feature Extraction	48	15	75	76	6
R – Registration	111	25	227	236	14
SEA – Semantic Analysis	259	66	493	509	30

The study covered the same number of methods as in the first case. Looking at the methods used in more detail, computer vision methods were most often used in combination with BIM models, but NLP, supervised learning, evolutionary algorithms and knowledge-based reasoning methods were also used quite frequently.

Table 3 shows data analogous to Table 2, but for the knowledge area of construction management. The most commonly used artificial intelligence methods in scientific research related to BIM are semantic analysis, image processing, registration, genetic algorithms, artificial neural networks and case based reasoning.

As far as keywords are concerned, they do not contribute much to the research. Most of the most frequently used keywords include the term AI method, the name BIM and the term architectural design and project management. Compared to construction in general, only one change was observed in the TOP 10 artificial neural networks ANNs replaced decision trees.

Conclusions

An undoubted advantage of AI systems equipped with text mining and NLP modules is the automation and support of literature searches. This allows for the rapid collation of publications selected from a database, e.g. Scopus, WoS, etc., based on keywords and selected constraints (e.g. publication date, affiliation, language etc.) and data mining. The use of WOSviewer (but also of many similar programmes) allows the display of links between authors and keywords, the examination of their strength, graphical representations, analyses of the occurrence of keywords, author affiliations and many other elements needed in a literature review. This saves time and avoids errors or omissions. This is particularly important given the large amount of data that often needs to be reviewed, filtered and presented in a graphically appealing way.

The advent of artificial intelligence presents a promising avenue for the advancement of Building Information Modelling (BIM) technology. The utilisation of artificial intelligence (AI) methodologies and techniques presents novel avenues for the processing of data amassed within BIM models. In particular, hybrid methods, such as computer vision, natural language processing and artificial neural networks, are increasingly being employed in the construction industry in conjunction with BIM models.

Artificial intelligence (AI) tools facilitate the search and presentation of bibliographic data. The author's attempt to perform a tabulation of the most important information on scientific articles is a promising one. It is important to exercise caution when dealing with the hallucination phenomenon, although it should be noted that some software is designed to avoid making unsubstantiated claims and instead indicate its limitations in understanding a particular topic.

The latest research suggests that artificial intelligence is playing a pivotal role in the development of BIM, leading to the emergence of innovative solutions that are poised to become widely adopted in the construction industry. These include the recognition of building components and materials, as well as the utilisation of data mining and natural language processing (NLP) for document creation.

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