Application of Artificial Intelligence Tools with BIM Technology in Construction Management: Literature Review

Ali Louai Mostafa[1,*], Mohamed Ali Mohamed[2], Sonia Ahmed[3], Waleed Mahfouz M. A. Youssef[4]

[1] Student of Master program in Building Information Modeling and Management at Syrian Virtual University, Damascus, Syria

[2] Lecturer Professor, Building Information Modelling and Management Master Program, Syrian Virtual University, Damascus, Syria

[3] Lecturer Professor at the Faculty of Engineering, Al-Rasheed University,and Building Information Modelling and Management Master Program, Syrian Virtual University, Damascus, Syria

[4] Structural Engineering, Faculty of Engineering, Cairo University, Giza, Egypt

Emails: ali_157357@svuonline.org; mhamadtop@gmail.com; Sonia_ahmed@ru.edu.sy; cvlmaster@yahoo.com

Abstract

Nowadays, the construction sector industry energizes all other industries to diversify their service areas, nonetheless this sector needs to keep leading with technological developments. Following the adoption of Building Information Modeling technology (BIM), the construction projects has become more controlled and coordinated, which has contributed to improve productivity rates and to rationalize resources usage. This research is studied the developments in construction, especially technologies that adopt artificial intelligence (AI) with BIM technology such as machine learning, Augmented Reality techniques (AR), digital assistants, robots, automatic planning, scheduling, and optimization. These techniques can be used during design and construction stages to improve collaborative processes that have become a cornerstone of BIM technologies, as well as financial control and scheduling. Through using BIM, the construction industry can adopt AI technologies like autonomous systems and rely on machine learning in project management to access AI-based project self-management.

Keywords: Artificial Intelligence (AI); AEC (Architecture; Engineering; and Construction); Building Information Modelling (BIM); Augmented Reality (AR); Autonomous

1. Introduction

The adoption of Building Information Modelling (BIM) has increased significantly over the past few years; however, the adoption of BIM is still lower than anticipated [1]. Due to the remarkable impact that BIM has on the AEC industry, as it led to substantial improvements in the performance and efficiency of projects delivery [1,2,3]. Despite the government and clients having an important role in the mandate of BIM, a mixed approach (top-down and bottom-up) is recommended to accelerate BIM implementation [4]. In their research, a six-step methodology to implement the BIM process that involves raising awareness, perceived benefits, AEC industry readiness, and organizations' capability

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[5,6]. Besides, barriers to BIM implementation are identified and removed, and key factors have been defined that influence the process [6]. It was concluded that, the most significant impediments to BIM adoption are lack of expertise, standardization, and protocols [7]. Whilst. the most significant drivers of adoption for both adopters and non-adopters are; the availability of trained professionals to utilize the tools; the cost savings associated with their use; the awareness of the technology in the industry; and the affordability of the software [7]. Companies could enhance their BIM performance by utilizing the BIM maturity matrix (BIM3) through stages 1) Identifying BIM and its performance, 2) Performance measurement and 3) Performance improvement [8,9].
In addition, BIM methodology can be applied to several topics for it saves the project cost and schedule [10]. Moreover, BIM is beneficial in conjunction with contractual agreements that promote the behaviour of stakeholders in large construction projects as illustrated by Figure (1). Increasing the value of stakeholder relationships through enhanced communication increases the likelihood of disputes avoided as shown in figure (1) as client satisfaction increased by 56%, 59% amongst architects and engineers respectively, conflicts of interest eliminated, and knowledge shared. Additionally, healthy interactions between project stakeholders are facilitated through improved problem-solving techniques [11,12]. Additionally, to effectively manage risk with BIM technology, the management system should review the conventional risk assessment procedures, and criteria must be developed and implemented as a daily practice for all construction projects [13,14,15]. Currently, the Syrian AEC industry is undergoing a transition from CAD to BIM, this should be promoted by the government and other related organizations to expedite spreading it as widely as possible to keep up with the ever-changing technology landscape [16,17,18]. In order to make building information modelling system (BIM) more accurate and practical, it is required to integrate artificial intelligence technology within it. Artificial intelligence is a state-of-the-art tool that takes advantage of the capabilities of modern processors and machines and advanced algorithms and protocols. It can be used to organize and benefit from the databases that are usually neglected in the construction sector. This will lead to better utilization of the BIM system features [19,20,21].

2. Research Methodology:

The research methodology employed for this study consisted of a thorough literature review to investigate the potential benefits of integrating building information modelling (BIM) and artificial intelligence (AI) in the construction sector. The primary objective was to analyse the impact of these modern technologies on construction processes and identify key areas where BIM and AI can be effectively implemented.

A. Literature Research

A comprehensive search was conducted across academic databases, research journals, conference proceedings, and relevant industry publications. The search terms included variations of "BIM," "artificial intelligence," "construction," and related keywords. The intention was to gather a broad range of literature encompassing advancements, best practices, case studies, challenges, and future prospects of integrating BIM and AI in construction.

B. Literature Selection and Review

The gathered literature was screened based on relevance, quality, and recency. Key research articles, peer-reviewed papers, and scholarly publications were selected for an in-depth review. The literature was analysed and synthesized to identify recurring themes, theoretical frameworks, methodologies, and empirical evidence related to the integration of BIM and AI in the construction industry.

C. Data Extraction and Analysis

Key findings, insights, and arguments from the selected literature were extracted and organized systematically. The extracted data were then analysed using a thematic approach, identifying common patterns, divergences, and overarching trends in the literature. The analysis focused on elucidating the benefits, challenges, and potential implementation strategies of integrating BIM and AI in construction projects.

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D. Critical Evaluation

The literature review also involved critically evaluating the strengths and weaknesses of the existing research. This evaluation considered the methodological rigor, sample sizes, data sources, and limitations of the studies reviewed. It aimed to provide a balanced assessment of the current state of knowledge and identify gaps or areas that require further investigation.

E. Synthesis and Documentation

The final step involved synthesizing the reviewed literature to generate a comprehensive overview of the potential benefits and challenges associated with integrating BIM and AI in the construction sector. The findings were documented and presented in an organized manner, highlighting key insights and providing a foundation for future research or practical implementation.

3. Literature Review

By employing this research methodology, the literature review aimed to provide a comprehensive understanding of the current state of knowledge regarding the integration of BIM and AI in the construction industry. The findings from this review contribute to the existing body of literature and can serve as a valuable resource for researchers, practitioners, and decision-makers in the field of construction.

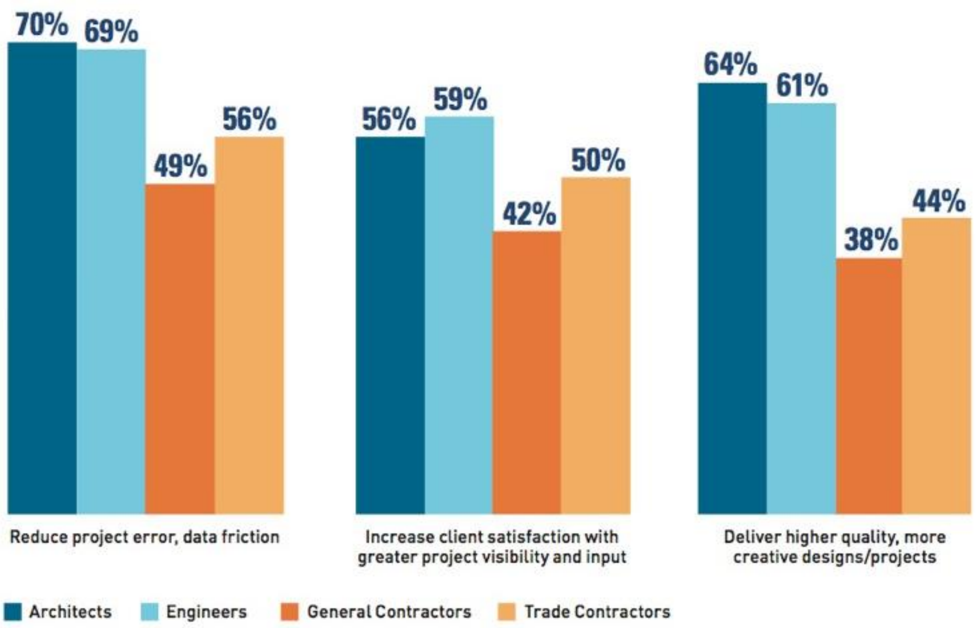

Figure 1: Project Outcome Improvements Using BIM (by Type of Company) (Cited in: Ref [20])

Figure 1 showcases the project outcome improvements achieved by different types of companies through the implementation of Building Information Modelling (BIM). The graph provides insights into the positive impacts of BIM adoption on project outcomes and highlights the variations across different company types.
From the graph, we can observe that companies across various sectors have experienced significant improvements in project outcomes by utilizing BIM. The types of companies mentioned in the graph may include architecture firms, engineering firms, construction companies, and other organizations involved in the built environment.
The graph demonstrates that the implementation of BIM has resulted in notable improvements in different aspects of project outcomes, such as cost savings, schedule adherence, quality enhancement, and risk reduction. These improvements are crucial for achieving successful project delivery and meeting client expectations.

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It is important to note that the extent of improvement may vary among different company types. For example, architecture firms may benefit more from enhanced visualization and design coordination, while construction companies may experience greater improvements in construction sequencing and clash detection.
The graph emphasizes the value of BIM as a transformative technology that contributes to more efficient and effective project management. BIM enables better collaboration and coordination among project stakeholders, facilitates data-driven decision-making, and improves overall project communication.
By leveraging BIM, companies can achieve improved project outcomes, leading to increased client satisfaction, reduced rework, and optimized resource allocation. The findings depicted in the graph reinforce the significance of BIM adoption as a strategic investment for companies operating in the construction industry.
Overall, Figure 1 highlights the positive impact of BIM on project outcomes and emphasizes the importance of integrating BIM into the workflows of different types of companies to realize its full potential in enhancing project performance.

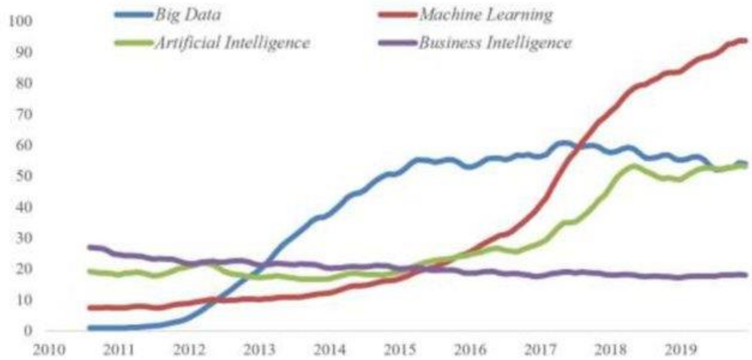

Figure 2: Popularity of Artificial Intelligence, Big Data, Business Intelligence and Machine Learning among Web Users between 2010 and 2019 [21]

Figure 2 illustrates the popularity trends of key terms such as Artificial Intelligence (AI), Big Data, Business Intelligence (BI), and Machine Learning (ML) among web users from 2010 to 2019. The graph provides insights into the changing interests and awareness levels of these technologies over the years. From the graph, we can observe that the popularity of AI, Big Data, BI, and ML has been steadily increasing over the decade. This trend indicates a growing recognition and interest in these fields among web users. The rising popularity can be attributed to several factors, including advancements in technology, increased accessibility of data, and the potential benefits that these technologies offer to various industries. In the early years (around 2010), the popularity of these terms was relatively low. However, as we move towards the later years, there is a noticeable upward trend in their popularity. This can be attributed to the increasing adoption of AI, Big Data, BI, and ML in various domains, such as healthcare, finance, marketing, and manufacturing. The graph highlights the increasing importance and relevance of these technologies in today's digital age. It is important to note that while AI, Big Data, BI, and ML are related, each term represents a distinct aspect of data analysis and decision-making. AI focuses on simulating human intelligence in machines, Big Data refers to the large volumes of data that require specialized processing techniques, BI involves analysing and interpreting data to drive business insights, and ML is a subset of AI that focuses on algorithms and models that learn from data. The popularity of these terms among web users indicates the growing curiosity and eagerness to explore and understand the potential applications and implications of AI, Big Data, BI, and ML. This trend underscores the significance of these technologies in shaping the future of industries and society as a whole

4. What is Artificial Intelligence?

In the field of artificial intelligence (AI), a significant milestone took place in the summer of 1956 when the Dartmouth Summer Research Artificial Intelligence Project was conducted at Dartmouth College. The project was led by John McCarthy from Dartmouth College, Marvin Minsky from MIT, Nathaniel Rochester from IBM, and Claude Shannon from Bell Laboratories [22,23,24]. This

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collaborative effort marked the first use of the term "artificial intelligence" and laid the foundation for the legitimacy of AI as a research discipline. During this period, the researchers sought to explore the idea that any aspect of human intelligence, including learning and other cognitive characteristics, could be precisely described to the extent that a machine could be constructed to simulate it. Their proposal emphasized the formalization and replication of intelligent human behaviour within machines. The Dartmouth Summer Research program played a pivotal role in shaping the field of AI, and its significance is commemorated by a plaque at Dartmouth College, presented in 2006 during a meeting that marked the 50th anniversary of the program [22,23, 24] The plaque at Dartmouth College provides a historical account of the emergence of artificial intelligence in 1955 when a group of individuals with military computing backgrounds applied to the Rockefeller Foundation for a summer fellowship grant seminar. This application ultimately led to the establishment of the Dartmouth Summer Research Artificial Intelligence Project. The central premise of their proposal was that intelligent human behaviour consists of processes that can be formalized and replicated in machines [22, 23]. Artificial intelligence, in essence, involves the simulation of human intelligence processes by machines, particularly computer systems. It encompasses various subfields and divisions, including Machine Learning (ML), Knowledge-Based Systems, Computer Vision, Robotics, Natural Language Processing, Planning and Self-Scheduling, Optimization, and Blockchain. These divisions represent different aspects and applications of AI, each contributing to the broader field's advancement and development [23,24,25].

4.1 Machine Learning (ML)

Machine learning is a branch of AI and computer science that focuses on using data and algorithms to simulate human-conscious processes and ways of solving issues and problems to improve accuracy.
Machine learning is the leading component of the growing field of data science. Machine learning uses statistical methods, algorithms train to make classifications or predictions and to uncover leading ideas in data mining projects. Additionally, Machine Learning is divided into the following sections: Supervised Learning, Unsupervised Learning, reinforced Learning, and Deep Learning [22,23,24,25,26,27].

4.1.1 Supervised Learning

Supervised learning is a sub-category of machine learning and artificial intelligence. It utilizes structured datasets to train algorithms that can accurately classify data or predict results.
Supervised learning is used in the following areas:
1. Recognizing pictures and objects:
Machine learning serves on-site supervision by locating workers and equipment. It can be trained to detect hazards to a human worker. It could be used to measure and determine progress on job sites using software such as Synchro 4D Pro, and Navisworks manage.
2. Predictive analytics:
Predictive analytics serves pattern detection, contributes to site optimization, and detects conflicts between disciplines such as Navisworks manage & Synchro. It analyzes the risks introduced by other branches of AI and uses them to develop the most appropriate scenarios for the workplace and implementation methods like in Synchro.
3. Customer sentiment analysis:
It should leverage construction sites by predicting and analyzing psychosocial states for staff to avoid risk [22,23,26,28,29,30,31].

4.1.2 Unsupervised Machine Learning

Unsupervised learning uses machine learning algorithms to analyze and group unnamed data sets. Algorithms detect hidden patterns or data sets without human intervention. Their ability to recognize

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similarities and differences in information makes them the optimal solution for analyzing exploratory data, cross-selling strategies, customer segmentation, and image identification. Unsupervised learning is used to recognize objects, a computer vision, discover, classify, and split images and tools inside [32, 33, 34, 35]. Besides, unsupervised learning detects atypical data points within a data set by scanning and combing that data. In addition, knowing these anomalies and discovering patterns is useful in raising awareness about faulty equipment, human errors, or serious violations [36,37].

1. Customer Identification:

Unsupervised learning helps identify customers and aids companies in offering designs that suit the company's personality.

2. Recommendation engines:

Using past customer design data, unsupervised learning helps discover trends in data that could be used to develop more effective sales strategies [36,37,38,39].

4.1.3 Reinforcement Machine Learning

It is the process of training machine learning models to create a series of decisions, to achieve a goal in an uncertain and potentially complex environment. In reinforcement learning, artificial intelligence confronts a game-like situation, in which a computer uses trial and error to solve the problem. Reinforcement learning is used in cars and self-driving machines that perform specific tasks at construction sites such as heavy vehicles, and machinery from companies like Trimble. The self-driving mechanisms rely on what is called an agent, which is another name for reinforcement learning algorithms, and the system gets rewards when specific goals are reached [31,35,36,39,40,41].

4.1.4 Deep Learning DL

Deep learning is a powerful subset of machine learning that involves neural networks with three or more layers. Its primary objective is to mimic certain aspects of human brain behavior, although it falls short of replicating the full capabilities of a real brain. Deep learning algorithms excel at learning from large datasets, which enables them to make accurate predictions and improve overall quality [22,23,30,36,39,40,41]. While a single-layer neural network can provide approximate predictions, the inclusion of additional hidden layers in deep learning architectures enhances accuracy and enhances the quality of results. This makes deep learning well-suited for various applications, such as operating digital assistants like ChatGPT and Mid Journey Bot, self-driving cars and vehicles, and leveraging 5D BIM for cost estimation and management. One common type of deep learning architecture is Convolutional Neural Networks (CNNs). CNNs are widely used in computer vision tasks, including image classification, pattern detection within images, and object identification. Their ability to extract relevant features from visual data makes them highly effective in tasks related to image analysis and understanding. Another type of neural network used in deep learning is Recurrent Neural Networks (RNNs). RNNs are particularly useful for applications involving natural language processing and speech recognition. These networks have the ability to capture sequential dependencies and context, making them well-suited for tasks such as language translation, sentiment analysis, and speech-to-text conversion. Overall, deep learning algorithms leverage the concepts of forward and backward propagation to make predictions, perform analyses, and iteratively refine their predictions by correcting errors. This iterative learning process allows deep learning models to continually improve and achieve increasingly accurate results as they are exposed to more data and training iterations. [22,23,30,36,39,40,41].

4.2 Knowledge-Based Systems

Knowledge-based systems analyze knowledge, data, and other information from different sources to generate new knowledge and assist in decision-making by understanding the context of the data you review and process based on the knowledge they store. knowledge-based systems include three

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different types such as case-based systems, expert systems, and smart teaching systems [22,23,24,34,36,42,43,44,45].

4.2.1 Case-based systems

Involves reviewing prior knowledge of similar situations. The knowledge-based system provides effective solutions in specific situations. A state-based system can be used to address recurring issues on worksites such as latency [22,23,24,34,36,42,43].

4.2.2 Expert Systems

Expert systems mimic the decision-making processes of human experts. They are useful for complex analyses, calculations, and predictions. In addition, expert systems serve automatic 4D BIM scheduling, 5D BIM project procurement, and cash flows, and expert systems provide intelligent facilities management solutions throughout the project lifecycle, providing more sustainable design options for 7D & 6D BIM [41,42,43,44].

4.2.3 Smart teaching systems

Smart teaching Systems designed to support learning. Those systems are used to train construction industry cadres and provide users with customized feedback and guidance based on their performance and queries. Knowledge-based systems provide expertise to support decision-makers in the construction sector and can be used in the recruitment processes of individuals working in the construction sector [22,24,28,33,41,45].

4.3 Computer Vision

An AI field that enables computers and systems to extract meaningful information from digital images, videos, and other visual inputs, so it can take action or make recommendations based on that information [22,41]. If artificial intelligence enables computers to think, computer vision makes them see, observe, and understand. The use of computer vision requires software training to distinguish required features like the detection of defects in existing facilities.

Examples of an application using computer vision include:

1. Image Classification: Accurately predicts that the displayed image belongs to a field and category. For example, the detection of plant defects, identification of working machines, identification of human objects on the job site, or prediction of the necessary maintenance for every machine.

2. Object tracking: Application technologies in self-driving cars that mark and track objects' motion.

3. Content-based Image Retrieval: Used to browse, search and retrieve images from large data stores based on the content of images rather than the metadata tags associated with them. It increases search accuracy and data retrieval speed [24,41].

4.4 Robotics

Robotics is the science that includes all the engineering disciplines related to the design of robots and the tasks they can complete in all types of environments, especially those humans cannot endure. [25]

Robots all share three basic similarities when it comes to the way they are built:

1. Robots have mechanical construction that helps them endure the environmental conditions around them. Shapes follow function.

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2. They depend on electric power or on fuel. Robots need a certain level of electrical energy supplied to their engines and sensors to perform basic operations.

3. Robots have a certain level of code.

They are also classified as:

1. Remote-controlled robots, which rely on the human element.
2. Autonomous robots based on artificial intelligence.
3. Hybrid robots.

Potential applications of robots include:

1. Industrial robots for use in factories.
2. Building robots.
3. Agricultural robots.

4.5 Natural language processing (NLP)

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 modeling with deep learning artificial intelligence, enabling computers to understand and process human language in the form of text or voice data, and the intentions and feelings of the speaker or writer [23,24,25,2526 Besides, it is used for voice-operated, GPS systems and digital assistants. Examples include spam detection, machine translation, machine assistants, virtual chat bots, emotion analysis, and text summarization [26,38,39].

4.6 Planning and Self-Scheduling

Planning and self-scheduling systems are based on an understanding of work strategies, the division of work into organized tasks, and the sequence of tasks [26,37,42].

4.7 Optimization

Optimization plays a leading role in machine learning projects, adopting algorithms to learn and train from databases. It consists of a set of algorithms such as:

4.7.1 Evolution Algorithm

A general super native algorithm based on samples that use techniques inspired by biological evolution, such as reproduction, mutation, rearrangement, and selection [27,41].

4.7.2 Genetic Algorithm (GA)

Genetic Algorithm (GA) is a super native algorithm based on natural selection, commonly used to create high-quality solutions to search and optimization problems based on biologically inspired factors such as mutations, intersections, and selection [27,41].

4.7.3 Differential evolution

Differential evolution is a way that improves the problem by repeatedly trying to improve solutions based on specified criteria such as quality. It guarantees that you will find the best solutions, not at all the perfect solution [27,32,44,45].

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4.7.4 Particle swarm optimization

Particle swarm optimization improves a problem by repeatedly trying to improve a candidate solution for specific criteria like quality. Also, as in differential evolution, it guarantees that the best solution will be found. But not the perfect fit [28,38,44].

4.8 Block Chain:

Block chain is a reliable in areas requiring digital authentication, trade exchange, two-way authentication, and encrypted currency. Some of the latest applications require Block Chain to build logistics supply chains for building materials, integrate with the Internet of things, and Building Information Modeling (BIM) to manage data and information throughout the life cycle of the facilities [29,39,40,41].

5. AI with Building Information Modeling:

Artificial intelligence has many benefits in construction projects such as design improvement, collaboration, and in controlling budget and schedule.

5.1 Benefits of Artificial intelligence in design

Artificial intelligence using machine learning techniques, optimizations, and digital assistance, can create more complex or simple design solutions based on customer requirements. As AI will complete all tasks successfully and, in less time, thus improving workflow. Besides, Artificial intelligence can analyse the design, find clashes that the designers missed, detect errors on time and correct them before they cause real damage. Propose appropriate alternative solutions and save design time. Based on the database provided for artificial intelligence by building information modelling technology, artificial intelligence can generate new designs based on past design analyses, thus making the design process faster and more efficient [30,31,32,43].

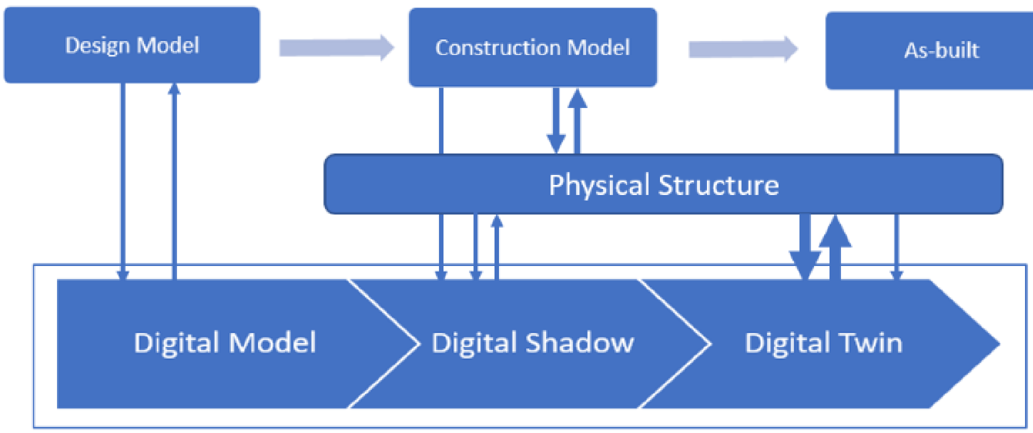

Figure (3) Using Digital Twin **[45]**

The figure presented here, adapted from the study by Tchana et al. titled "Designing a unique Digital Twin for linear infrastructures lifecycle management," showcases the application of a Digital Twin in the management of linear infrastructures. The figure illustrates how a Digital Twin is employed to enhance the lifecycle management of linear infrastructures, such as roads, railways, or pipelines. It visualizes the various stages of the infrastructure's lifecycle, including design, construction, operation, and maintenance, where the Digital Twin serves as a virtual representation of the physical asset. Through the use of real-time data collection, monitoring, and simulation, the Digital Twin enables proactive maintenance, optimization of operations, and effective decision-making. It empowers

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stakeholders to analyse performance, predict potential issues, and simulate scenarios to improve the overall lifecycle management of linear infrastructures.

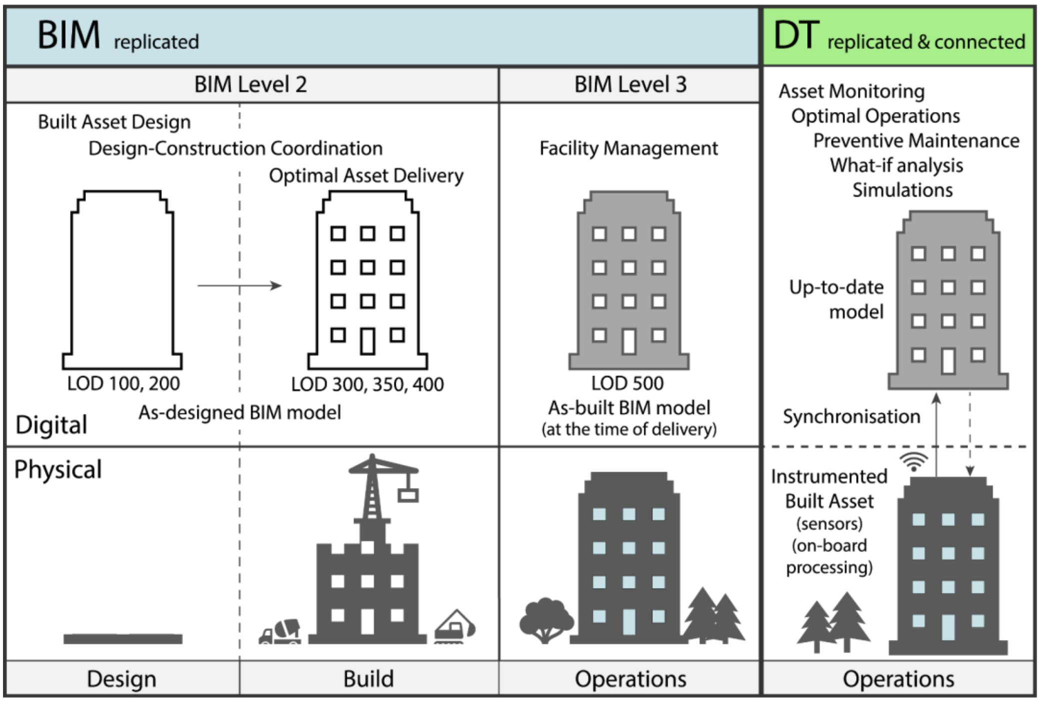

Figure 4: Overall differences between BIM and DT; Source **[46]**

In the article by Davila Delgado and Oyedele, "Digital Twins for the Built Environment: Learning from Conceptual and Process Models in Manufacturing," the authors present a figure that depicts the overall differences between Building Information Modeling (BIM) and Digital Twins (DT). The figure visually showcases the distinctions between BIM and DT, highlighting their unique characteristics and functionalities in the built environment. It provides a comparative analysis of the two technologies, emphasizing key areas such as data integration, real-time monitoring, and predictive analytics.

5.2 Benefits of Artificial intelligence in collaboration

There are already great collaborative tools like Autodesk BIM 360 & BIM Collaborate Pro, which allow teams to collaborate more simply than ever before. AI has allowed dozens of professionals to work together simultaneously. BIM technologies allow everyone working on the same project to access forms and documents to make the necessary modifications. Team members look at and respond to the adjustment according to their designs. With AI, even reliance on manual modifications and changes will be unnecessary. Once a member updates something in the shared model, AI can respond by modifying all other affected areas and sending alerts to other team members to notify them about the changes. In the final designs, all the information will be synchronized and modified perfectly so that the viewer believes that one person is working on everything without a single mistake [31,32,33,45,46].

5.3 Benefits of Artificial intelligence in budget and schedule

Cost and time management is the main problem with construction projects that AI can contribute to its resolution through budget monitoring, scheduling, and task coordination. Given enough information from previous similar projects - which has become more realistic and simpler today due to the building information modelling technology - made the predictions more accurate. Some adjustments from the human element will need to be made initially, but with artificial intelligence and machine learning, processes will improve until they finally reach the point where no human intervention will be needed [23,24,33,43,44,45,46].

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6. Impact of AI on Building Information Modelling Technology (BIM)

The large amounts of data from construction sites make it difficult for companies to use this data efficiently. AI organizes the data in databases, thus improving the application of building information modelling in new projects and improving the operations of the AEC construction industry [26,34,45,46,47].

6.1 AI contribution to construction sector

AI has remarkable contributions to construction projects such as:

1. Preventing construction projects from exceeding the budget and improving labour.

2. Propose different building designs to choose the optimum design.

3. Reducing risk and ensuring safety at construction sites.

4. Project planning and productivity improvement.

5. Analysing construction sites and using prefabricated elements.

6. Relying on artificial intelligence in the administration of utilities and installations after implementation [33.34,45,46,47,48].

6.2 Autonomous project management systems

Self-controlled systems are able to deal with different situations more realistically by relying on artificial intelligence. These systems are able to handle potential problems by digital assistants.

Self-controlled systems organize tasks and schedules that help BIM managers in different business, day-to-day tasks, organize meetings, control budgets, and reports. Automated scheduling will play a significant role in improving and making project management smoother and more accurate, with robots, computer vision, drones, sensors, and digital cameras to keep track of real-time workflow and real-time of the work site, and notifications about any change in schedule or budget against the expected project scenario [34,35,45,46].

6.3 Machine Learning (ML) in project management

Machine learning helps to achieve productive and efficient analysis of the project's work and advises the project manager about the risks of the later phases by analysing the risks of previous projects, risks that occurred in the past phases of the project, and the best way to deal with them or avoid them altogether. Soon, AI may be able to transform conceptual designs more precisely into actual designs that meet the requirements of the customer and the owner automatically by proposing timetables, costs, components (staff and executing agents), and relationships between them. The accurate record of project events, risks, and problems occurring during implementation can be collected, archived, and used to improve subsequent operations. They can also offer suggestions for improved scheduling, multiple scenarios for avoiding risks, reducing cost and saving time as required by the owner, and relying on real (more realistic) time for different tasks. It can also give alerts by relying on the process of analysing project data when it will occur. It is worth noting that, machine learning will predict the future of the project, give higher quality decision-making, link the data with the capabilities available and use it in a way that will maximize project management, and predict risks and potential opportunities before they occur and act accordingly. They may be able to make decisions on their own [35,36,37,38,45,46,47,48].

6.4 AI-based project self-management

Self-management will require limited data, little intervention, and a little bit of human supervision. In addition, they will need a complete understanding of the project and control of the project environment. This application can use the "emotional intelligence" perception and analysis algorithm that interacts with the project parties, understand their requirements and achieve their satisfaction and commitment throughout the project. There is no real example of fully applying artificial intelligence independently in project control.

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Artificial intelligence will create the ability to automate processes using gadgets. One obstacle to implementing these technologies is the lack of a system that allows data to be collected and supplied to applications. However, with BIM technology, there will be a great database, elements, and objects that can be provided to AI algorithms and use them more efficiently in real life applications [38,39,40,47,48,49,50].

6.5 AI in prefabricated factories

Prefabricated factories use various techniques for producing off-site elements, "building depending on prefabricated elements" with autonomous robots. The main objective is to improve the quality and time of tasks and activities. Increase productivity by relying on robots that have a qualitative role in construction.

In the last decade, pre-built construction elements were used, with a higher level of "full layering" detail and depending on 3D printers. The challenge of using these printers remains to select the appropriate and high-quality materials for implementation and to understand the resistance and effectiveness of the materials used at construction sites [39,40,41,49,50].

6.6 Use artificial intelligence at construction sites "autonomous robotic impressions"

This classification includes autonomous robotic systems used directly at construction sites like single-function robots STCRS. These robots can do individual tasks assigned to them, such as robotic arms in factories. They are transported on carts (mobile platforms) and used for simple tasks (painting surfaces and walls, building Cement blocks, Cement slurry). This technology is important because they help to accomplish structural tasks more productively and efficiently. A leading advantage is to not overeat safety and protection measures, especially in places that are difficult for people to perform. It is difficult for robots to conduct their work in parallel with the human element. The purpose of using robots is to create a controlled environment within the factory, which helps to perform work with robots more accurately and efficiently [32,40,49,50].

7. Risks and constraints to use the applications of artificial intelligence

7.1 Cultural obstacles

The construction industry is one of the last industries to adopt modern technology because of its high cost and high risk of errors, even small ones. The unique and different nature of each construction site requires AI to learn and adapt to different environments very quickly. AI technologies adopt the black box principle of decision-making, which means it does not explain how or why the decisions were made. To build confidence in the construction sector, decision-makers must understand how each decision is made, which requires using interpretable AI, which can offer explanations for its decisions [49,50].

7.2 Security constraints

While AI can enhance security and detect breaches, it is also a target of exploitation by hackers and cybercriminals. It is a constraint with high economic and financial implications. Even small mistakes often result in risk in costs, time, and quality. The safety of human staff may be at risk, and reducing security barriers requires using machine learning techniques, deep learning, and training algorithms to resist high-risk attacks [49,50].

7.3 Lack of skilled labour

There is a global shortage of artificial intelligence engineers, and it is rare to have artificial intelligence engineers with experience in the construction industry who are capable of finding the right solutions to the problems they face [47,49].

7.4 Initial cost

The high initial costs of AI-based solutions are a leading constraint. This includes the cost of robots and maintenance [46,47].

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7.5 Powerful processors and Internet accessibility

Most construction sites are relatively remote, lacking power, telecommunications, and Internet access. Sometimes even construction activities lead to power or communication interruptions, which is a huge problem with using artificial intelligence tools on worksites [47,48].

8. Conclusion

In conclusion, the construction sector can greatly benefit from embracing modern technologies such as building information modelling (BIM) and artificial intelligence (AI). By incorporating these technologies into various aspects of construction, we can unlock numerous opportunities for improvement. Here are some key areas where BIM and AI can make a significant impact:

1. Enhanced Site Monitoring: Leveraging drones and sensing devices at construction sites allows for real-time monitoring of workflows and improved site control. This technology provides valuable insights into project progress, identifies potential bottlenecks, and enables timely interventions to ensure efficient construction processes.

2. Advanced Automation: Introducing self-driving vehicles and robots in construction tasks enhances both quality and accuracy. These automated systems can perform repetitive or hazardous tasks, reducing human error and increasing overall productivity on the job site.

3. Intelligent Design Processes: By integrating AI algorithms into design processes, construction professionals can optimize designs and identify potential conflicts or inefficiencies at an early stage. This proactive approach helps minimize rework, improve structural integrity, and streamline the overall construction process.

4. Collaborative Tools: Digital assistants like Fireflies.ai and Chat GPI facilitate seamless collaboration among project stakeholders. These AI-powered tools can collect and analyze data from meetings, record notes, and provide notifications, fostering effective communication and enhancing cooperation between team members.

By embracing these modern technologies, the construction sector can achieve higher productivity, improved quality control, reduced costs, and enhanced collaboration. It is crucial to raise awareness and promote the adoption of BIM and AI to drive innovation and revolutionize the construction industry.

9. Recommendations

Here are some recommendations for utilizing artificial intelligence (AI) and building information modelling (BIM) in the construction sector:

1. Integration of AI with BIM: Explore the integration of AI technologies, such as deep learning and machine learning, with BIM software. This integration can help improve the quality and efficiency of engineering work by leveraging AI algorithms to analyse and process data collected from various construction operations.

2. Genetic Algorithm for Design: Consider adopting evolutionary algorithms, such as the genetic algorithm, in the design processes of structures, particularly for steel structures. These algorithms can optimize design solutions by simulating natural selection and evolving solutions that meet specified criteria.

3. Utilize AI-Enabled Collaboration Tools: Take advantage of AI-powered collaboration tools, such as Fireflies.ai and Chat GPI, to enhance cooperation and communication between project stakeholders. These tools can collect and analyse data from meetings, record notes, and provide notifications to BIM managers, improving overall project coordination and efficiency.

4. Training Experienced Personnel: Invest in training experienced personnel who can effectively leverage the integration of AI and BIM technologies. These individuals should have a strong understanding of construction operations and possess the necessary skills to implement and optimize AI solutions within BIM workflows.

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5. BIM Training for Construction Engineers: Provide training programs for construction engineers to enhance their proficiency in BIM technology. This training should include practical knowledge and hands-on experience in using AI-enabled tools and techniques within the construction sector, empowering engineers to leverage the full potential of AI in their projects.

By implementing these recommendations, construction companies can harness the power of AI and BIM to improve productivity, enhance collaboration, and optimize design and construction processes.

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