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AI, BIM AND ACHIEVING THE SDGS: EXPLORING THE GAPS FOR A SUSTAINABLE CONSTRUCTION INDUSTRY

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Abstract: The construction industry is at the forefront of adopting innovative technologies to meet the global challenges posed by sustainable development. This study explores the intersection of Artificial Intelligence (AI), Building Information Modeling (BIM), and the achievement of the United Nations Sustainable Development Goals (SDGs) within the construction sector. Through a comprehensive review of existing studies, the research investigates how AI and BIM can synergistically contribute to achieving key SDGs, such as sustainable cities and communities, responsible consumption and production, and climate action. The data was obtained from the Scopus database using keywords to extract it. The study findings highlight that AI enhances BIM capabilities by providing predictive analytics, optimizing resource management, improving decision-making processes, and promoting sustainability throughout the construction lifecycle. It also identifies the various research areas and future directions. The research concludes that while the nexus between AI, BIM, and SDGs presents significant opportunities for advancing sustainability in construction, a strategic and collaborative approach is necessary to fully realize their potential and overcome existing barriers. This study provides valuable insights for industry stakeholders, policymakers, and researchers aiming to leverage emerging technologies to drive sustainable development in construction.

Keywords: AI, BIM, SDGs, technology, industrial revolution

1 INTRODUCTION

The United Nations' sustainable developments goals (SDGs) (UN, 2015) as a holistic agenda to improve lives, environments and society. Over the years, it has become a yardstick adopted by various sectors and contexts to measure their activities against the deadline. The SDGs are made up of 17 goals covering multiple aspects. This does not exclude the construction industry, which has been severally observed to be a massive contributor to the environmental negative impact due to its activities; it is responsible for approximately 38% of global CO_2 emissions (World Green Building Council, 2019). Often characterized by inefficiencies, waste, and significant environmental impact, traditional construction methods fall short of addressing the need for sustainable practices. On the other hand, the industry is also essential in achieving the SDGs. For instance, plays a pivotal role in achieving several SDGs, including Goal 9 (Industry, Innovation, and Infrastructure) and Goal 11 (Sustainable Cities and Communities).

However, the industry has been trying to shift from the traditional ways of doing things and adopt more efficient approaches through the adoption of innovations and emerging technologies. It has therefore been observed to be undergoing a transformation triggered by emerging technologies, especially post covid (Adekunle et al., 2023, 2021a). Considering the race towards the target year and the digital transformation post-COVID, it is important to explore the nexus between the adoption of technology and achieving the SDGs in the construction industry. Specifically, this study looked at the nexus between AI, BIM adoption and achieving the SDGs. The other sections of the manuscript looked into the literature review, methodology, findings and conclusions.

2 AI, BIM AND SUSTAINABILITY

AI technologies, including machine learning, natural language processing, and computer vision, have revolutionized construction processes by enabling better project planning, design optimization, and real-time monitoring (Autodesk, 2023, Adekunle et al., 2024). AI can automate routine tasks, analyze vast datasets to inform decision-making and predict potential issues before they arise. For instance, predictive analytics in construction can foresee equipment breakdowns, material shortages, or schedule delays, allowing for proactive mitigation strategies. These advancements align with SDG targets, such as promoting sustainable industrialization and fostering innovation.

Furthermore, AI's capacity to enhance building energy efficiency through smart design and management systems is critical to achieving SDG 7 (Affordable and Clean Energy). AI-powered systems can optimize energy consumption patterns in buildings, reducing carbon footprints and promoting energy-efficient practices. AI algorithms are also used to design buildings with minimal environmental impact, incorporating renewable energy sources and sustainable materials. This is particularly necessary throughout a building's lifecycle to achieve sustainability (Adewale et al., 2024).

BIM, a digital representation of the physical and functional characteristics of a building, has long been recognized as a transformative tool in the construction industry. BIM facilitates collaboration among stakeholders, allowing architects, engineers, contractors, and clients to work from a single, coordinated model (Eastman et al., 2008). By providing a comprehensive overview of a project’s lifecycle, BIM supports optimising resource use, cost efficiency, and waste minimization, all critical components in achieving SDG 12 (Responsible Consumption and Production).

BIM's potential to reduce construction waste is particularly notable(Eze et al., 2024). The construction industry is notorious for material inefficiencies, with an estimated 30% of all construction waste being avoidable. BIM enables more accurate material estimations, reducing over-ordering and ensuring that resources are used more efficiently. Additionally, BIM models can simulate energy performance, allowing stakeholders to make more informed decisions regarding building design, which is crucial for promoting green building practices and reducing energy consumption (Azhar et al., 2011).

The synergy between AI and BIM offers unprecedented opportunities to accelerate the achievement of SDGs in the construction industry. AI enhances the capabilities of BIM by automating data analysis, optimizing design processes, and improving project management workflows. For example, AI-driven generative design allows architects to input constraints related to sustainability, such as energy efficiency or material usage and receive optimized building designs that meet these criteria. This integration ensures that sustainability is considered and actively embedded into the design and construction phases.

In addition to design and planning, the use of AI and BIM together can improve post-construction building management. AI can analyze data generated from BIM models to monitor a building’s performance, identify inefficiencies, and suggest modifications that align with SDG 13 (Climate Action). For example, AI can monitor a building’s energy consumption in real-time, comparing it to expected performance based on the BIM model, and provide insights to improve efficiency.

3 RESEARCH METHODOLOGY

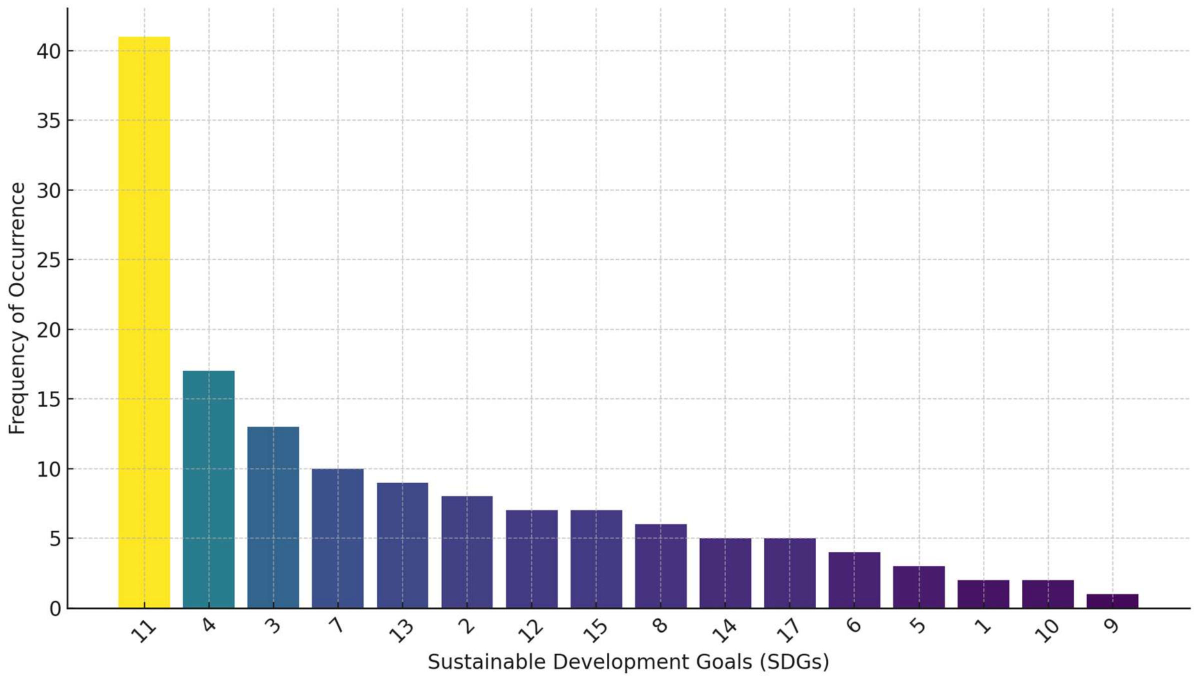
The study adopted a review of existing studies to identify the areas and nexus of AI and BIM in actualising the SDGs in the construction industry. To achieve this, a search of keywords was done in the Scopus database using the following keywords: "AI", "Artificial intelligence", "BIM", "Building information model*", and "SDG". This returned 456 publications. After applying exclusion and inclusion criteria. The following inclusion criteria were applied: document type (article, conference proceedings, book chapters and books), language (English) and field (Engineering), the output publications were reduced to 411, which was adopted for the study. The choice of articles, conference papers and books is to capture recency and works with rigour published in the area of focus. The adopted method, especially using the Scopus database and Vos viewer, has been adopted in similar research (Aghimien et al., 2019). The collected data was analysed to identify the SDGs where AI and BIM have been adopted and the various areas. The analysis using Vos Viewer involved the clustering of keywords based on co-occurrences and visualisation (van Eck and Waltman, 2019). The study cover all publications returned by the search between 1995 to 2024.

4 FINDINGS

This section presents the findings of the study.

4.1 SDG FOCUS/SCORECARD

A critical analysis of the 411 publications collected was done. Figure 1 provides insight into the frequency of occurrence of the various SDGs in these studies. This shows the intensity of the focus of researchers on achieving these SDGs using the technology adopted.



Where: 1:No Poverty; 2:Zero Hunger; 3:Good Health and Well-Being; 4:Quality Education; 5:Gender Equality; 6:Clean Water and Sanitation; 7: Affordable and Clean Energy; 8:Decent Work and Economic Growth; 9:Industry, Innovation, and Infrastructure; 10: Reduced Inequalities; 11: Sustainable Cities and Communities; 12: Responsible Consumption and Production; 13: Climate Action; 14: Life Below Water; 15: Life on Land; 16: Peace, Justice, and Strong Institutions; 17: Partnerships for the Goals

Figure 1: SDG focus

The chart shows how often each SDG appears in the collected data, with SDG 11 (Sustainable Cities and Communities) being the most frequent. Furthermore, the study identified how the technologies have been adopted variously in this study. Generally,

- Artificial Intelligence (AI) was used for data-driven decision-making, optimizing resources, predicting outcomes, and enhancing sustainability efforts related to SDGs.
- Machine Learning helped analyze patterns in large datasets, enabling predictive maintenance, improving energy efficiency, and enhancing infrastructure related to SDGs.
- BIM was applied for detailed building models, promoting sustainable design, reducing waste, and ensuring efficient use of materials, aligning with SDGs.
- Internet of Things (IoT) sensors were used to monitor real-time data in infrastructure and environmental systems, improving efficiency and resource management under SDGs.
- Automation played a role in reducing manual tasks, improving construction processes, and enhancing the efficiency of infrastructure projects linked to SDGs.

4.2 RESEARCH FOCUS AREA

Using the Vos viewer software, the different research areas based on keyword clustering and visualisations were also identified. The visualisation is presented in Figure 2.

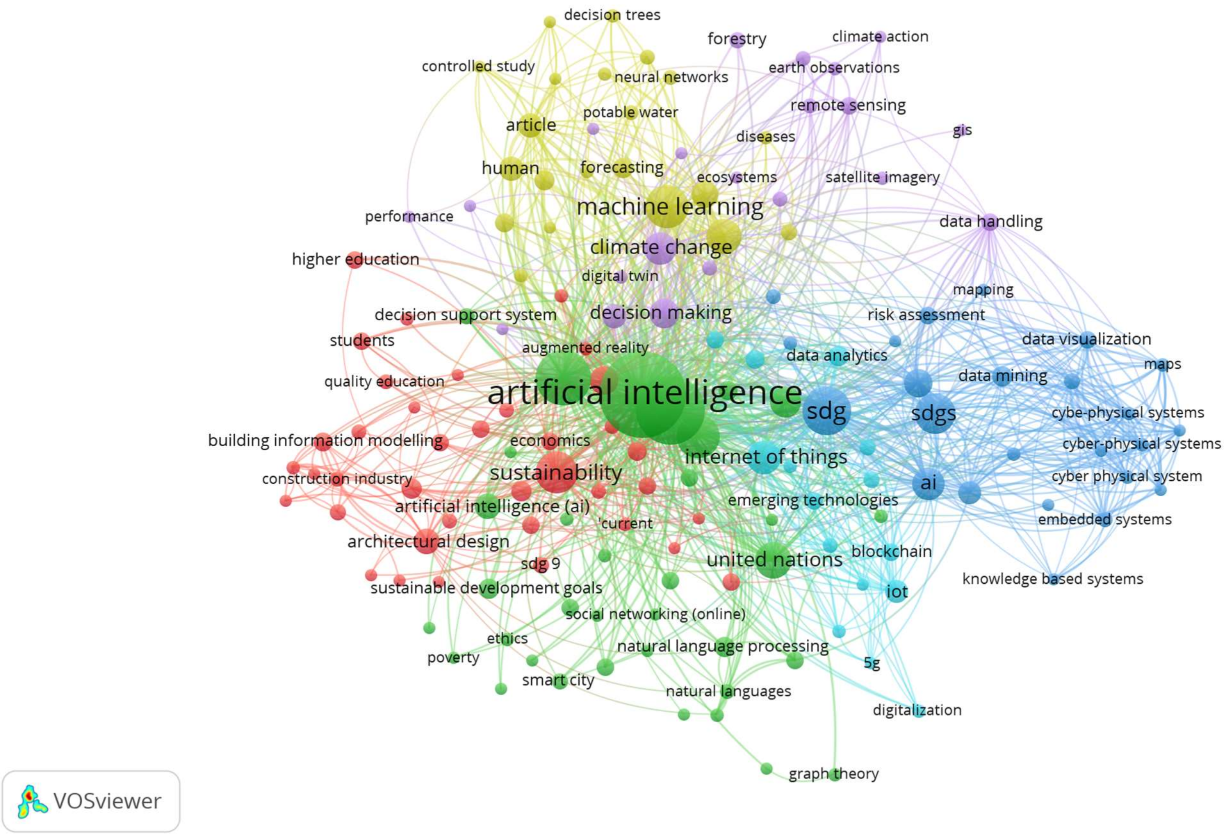


Figure 2: Research focus

AI, Sustainability, and Smart Cities(Green Cluster): The main keywords in this cluster include Artificial Intelligence, Sustainability, Smart Cities, SDG 9, Ethics, and Social Networking. Hence, the common name highlights the focus of the theme. The theme highlights the application of AI in fostering sustainable development, particularly in smart city initiatives. It also highlights ethical considerations in using AI for social networking and urban development.

BIM and Architectural Design in Construction(Red Cluster): This cluster includes keywords like Building Information Modeling (BIM), Construction Industry, Architectural Design, AI, AR and Quality Education. This cluster emphasizes the role of BIM in the construction industry and architectural design. It connects BIM's use to achieving SDG-related goals within the construction sector, such as improving resource efficiency and reducing waste. Aside from BIM, there are other emerging technologies, e.g. "artificial intelligence (AI)" and "augmented reality", suggesting a growing trend of using these technologies to revolutionize construction practices. Other keywords in this cluster Higher Education, Decision Support Systems, Human Factors, and Students. This cluster also touches on the role of AI in education and how it supports human decision-making. It emphasizes "higher education" and the use of AI for decision support, likely in academic and administrative contexts. The presence of "students" and "quality education" suggests that AI is being applied to improve learning outcomes, optimize curricula, and provide personalized educational experiences.

AI for Decision-Making and Climate Change(Yellow Cluster): The main keywords making up this cluster include Machine Learning, Decision Making, Climate Change, Digital Twin, and Neural Networks. This cluster focuses on the role of AI, particularly machine learning and decision-making processes, in addressing climate change and environmental challenges. Keywords like "digital twin" and "neural networks" point to using AI to create virtual models to simulate and predict outcomes in environmental management. The focus on climate action and forecasting indicates that AI technologies are being applied to enhance decision-making in mitigating and adapting to climate change.

AI, IoT, and Cyber-Physical Systems(Blue Cluster): In this research focus the major keywords identified are Internet of Things (IoT), Cyber-Physical Systems, AI, Data Visualization, Blockchain, and 5G. This cluster represents the intersection of AI with emerging technologies such as IoT, blockchain, and 5G. Data visualization and data mining indicate the use of AI to process large datasets and derive insights for sustainable development.

Climate Action and Environmental Monitoring (Purple Cluster): The keywords in this cluster include Climate Action, Earth Observations, Ecosystems, GIS, Remote Sensing, and Risk Assessment. This cluster focuses on the application of AI in environmental monitoring and risk management. "Earth observations," "GIS," and "remote sensing" suggest the use of satellite data and geospatial technologies to monitor ecosystems, assess risks, and support decision-making for climate action.

5 DISCUSSION

A critical look at the focus from the existing studies in the focus area shows that the potential of adopting BIM and AI to advance the SDGs has not been fully explored in the construction industry. The benefits of these technologies provide strong support for achieving the SDGs. This might be due to several challenges affecting technology adoption, which have been identified severally in existing studies (Adekunle et al., 2021b; Ahmed, 2018; Otasowie et al., 2023; Pradhananga et al., 2021). These barriers include but are not limited to costs of implementation, lack of skills, and resistance to change, among others. It is, therefore, imperative that a strategic plan be implemented to overcome these barriers. This is important because of the impact of construction activities on the environment and the need to overcome them by achieving the SDGs. To fully harness the potential of AI and BIM in achieving SDGs, there is a need for more targeted policies and investments in upskilling the workforce and fostering a culture of innovation in construction. As the global community continues to prioritize sustainability, the construction industry must adapt by integrating AI and BIM into everyday practices, driving the industry toward more sustainable, efficient, and innovative outcomes.

A critical look at the results also shows the use of other emerging technologies aside AI. However, more focus has been on SDG 11, meaning the intersection of AI, BIM, and sustainability has been primarily focused on urban development, smart cities, and sustainable infrastructure. While urban sustainability is critical, this overemphasis suggests that rural development, ecosystems, and poverty reduction may receive less attention regarding technological applications, particularly those involving AI and BIM.

Other SDGs with some level of attention in connection with AI and BIM are SDG 4(Quality education) and SDG 3 (Good health). This highlights the importance of technological innovation in promoting educational accessibility and improving healthcare infrastructure, likely through smart technologies in educational facilities and healthcare systems. However, there is a need to research whether the innovation in education is reaching underserved populations and regions. In addition, while AI is increasingly used in healthcare, addressing disparities in global healthcare systems, especially in low-income countries, requires good attention.

Generally, there has been less attention on the other SDGs. Indicating that there has been less attention on the use of AI and BIM in tackling broader environmental issues like biodiversity conservation, marine ecosystems, and terrestrial ecosystems, conservation efforts, ecosystem restoration, climate adaptation, social inequalities, gender gaps, and poverty alleviation, sustainable economic growth and decent work opportunities in the construction industry. This is considered not encouraging as AI and BIM provide leverage in tackling the diverse challenges in these areas and achieving these SDGs. There is, therefore, a need to further explore the use of AI and BIM in these areas.

6 CONCLUSION

The study provides insight into the adoption of AI and BIM in achieving the SDGs through data collected from the Scopus database. The analysis reveals that while some SDGs, such as SDG 11 (Sustainable Cities) and SDG 4 (Quality Education), are well-represented, others—particularly those addressing social inequality, environmental conservation, and economic growth—are underserved in current AI and BIM applications. This highlights the need for a more holistic approach that leverages technology for infrastructure development and for fostering equality, sustainability, and collaborative efforts. It also needs researchers in the built environment to research into other areas beyond these two that are currently being given attention. Firstly, other aspects of AI can be explored, e.g. AI-powered monitoring systems, environmental sensors, and predictive analytics could play a crucial role in advancing these goals. AI can also be used to design inclusive infrastructure, while BIM can be applied to affordable housing initiatives that directly benefit low-income populations. Thirdly, AI and BIM to build climate-resilient infrastructure, optimize resource use, and integrate renewable energy systems into construction practices. Other areas for further research include but are not limited to Upskilling workers, fostering decent working conditions, and ensuring that automation complements rather than replaces jobs.

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