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BIM and Carbon Emissions Nexus: A Way Forward for Reducing Carbon Emissions in the South African Construction Industry

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1 ABSTRACT

The construction industry in South Africa faces significant sustainability challenges due to its substantial carbon emissions. Building Information Modelling (BIM) presents a promising solution, offering substantial reductions in energy consumption, waste production, and prioritizing low-emission materials. This qualitative study, through expert interviews and case studies, explores BIM's potential in promoting sustainable construction practices. Findings indicate that BIM can achieve a 20% reduction in energy consumption, a 15% reduction in waste production, and a 10% increase in the use of low-emission materials, thereby enhancing sustainability and efficiency in the construction sector. However, the adoption of BIM is hindered by challenges such as skill shortages and resistance to change. To position South Africa as a leader in sustainability and innovation, there is a need for widespread BIM adoption through strategic initiatives that enhance BIM literacy and incentivize its implementation. Embracing BIM is crucial for the construction industry's move towards a more sustainable future, with potential for significant environmental and economic benefits.

Keywords: carbon emission, construction industry, BIM, net zero, sustainable development

2 INTRODUCTION

The construction industry is a significant contributor to global carbon emissions, with residential and commercial structures alone responsible for approximately 36% of yearly greenhouse gas emissions (Du, et al. , 2019:3697-3709). Studies have consistently highlighted the substantial impact of the construction sector on carbon emissions, with figures ranging from 36% to over 40% of total global carbon emissions (Liu, et al. , 2017:1680, Li, S., et al. , 2021a:1728, Jiang, et al. , 2019:42, Chuai, et al. , 2015:13021-13030, Li, R. and Jiang, 2017:1013). In china specifically, the construction industry is reported to consume around 40% of the world's total energy resources and account for nearly 36% of global co2 emissions (Jiang, et al. , 2019:42). Furthermore, the construction industry in china has been noted to play a crucial role in the country's efforts to achieve carbon neutrality by (Chi, et al. , 2021:1876).

Research has shown that the construction industry not only consumes a significant amount of energy but also emits large volumes of carbon dioxide (Paik, 2019:3571). The industry's carbon emissions are a matter of concern globally, with scholars emphasizing the need for the sector to reduce its carbon footprint (Jackson and Kaesehage, 2020:2973-2983). Efforts to mitigate carbon emissions in the construction industry are crucial, especially considering that indirect carbon emissions from construction activities can make up a substantial portion of total emissions (Li, T., et al. , 2022:).

Various studies have explored different aspects of carbon emissions in the construction industry, including spatial analyses, benefit evaluations of energy-saving practices, and forecasting models for carbon emissions (Du, et al. , 2018a:1220, Dai, et al. , 2022a:, Pu, et al. , 2022:4950). The urgency of addressing carbon emissions in the construction industry is evident, with projections indicating significant future emissions if mitigation measures are not implemented (Guo and Yin, 2022:).

South Africa is addressing the challenge of balancing enhanced service delivery with environmental sustainability by adopting Building Information Modelling (BIM). BIM offers opportunities for reducing emissions through cooperation, energy efficiency, and waste reduction. The country faces challenges in transitioning from a high-carbon energy system to a more sustainable one, including securing electricity supply and reducing greenhouse gas emissions. Sustainability is a growing concept in South Africa, but its unique demographic profile and historical context pose barriers to effective climate action. South Africa is one of the highest CO_2 emitters globally, and its reliance on coal-fired power plants contributes significantly to its carbon footprint. To achieve sustainable development goals, South Africa must decouple economic growth

The South African industry has been adopting and applying BIM in the past few debades but the extent to which this innovation has contributed to the reduction of carbon emissions is not yet clear. Hence, this paper discusses the utilisation of BIM by South African construction enterprises and the levels of carbon-based emissions over the years. Specifically, the paper reviews relevant existing literature on the efficacy of BIM on waste reduction and material selection in reducing energy consumption current state of carbon emissions in the South African construction industry.

This research focuses on the utilization of building information modelling (bim) by south african construction enterprises to mitigate carbon-based emissions. The study aims to assess the current state of carbon emissions in the industry, examine the efficacy of bim in reducing energy consumption and waste, analyze its impact on material selection and building longevity, and explore stakeholder engagement and collaboration facilitated by bim. The significance of this research lies in its potential to inform sustainable practices, guide policy development, and enhance environmental stewardship in the south african construction industry. By exploring how bim influences energy consumption, waste reduction, and stakeholder collaboration, this study aims to position south africa as a leader in sustainable construction, contributing to global eco-friendly building practices. The findings underscore the importance of implementing sustainable practices and technologies in the construction industry to curb its environmental impact and contribute to overall climate change mitigation efforts.

The paper discusses the carbon emissions in the global and South African construction industry and the potential of Building Information Modelling (BIM) to mitigate them. It reviews literature, examines BIM's impact on energy consumption, waste, material selection, and stakeholder engagement. The study uses qualitative research methods and provides recommendations for future research and industry practices, emphasizing BIM's importance in sustainable construction.

3 CONCEPTUAL SYNOPSIS

The construction industry plays a pivotal role in global carbon emissions, with the sector responsible for a significant portion of greenhouse gas emissions. In South Africa, the challenge is to balance enhanced service delivery with environmental sustainability. Building Information Modelling (BIM) emerges as a crucial tool in this endeavor, offering opportunities for reducing emissions through enhanced cooperation, energy efficiency, and waste reduction. This study adopts an interpretivist philosophical orientation and an exploratory research strategy with a qualitative approach, aiming to scrutinize the utilization of BIM by South African construction enterprises to mitigate carbon-based emissions. The research objectives include assessing the current state of carbon emissions, examining the efficacy of BIM in reducing energy consumption and waste, analyzing its impact on material selection and building longevity, and exploring stakeholder engagement facilitated by BIM.

4 BACKGROUND

In recent decades, the building sector has experienced substantial technical progress, focusing on expanding efficiency, minimising expenses, and promoting sustainability. One of the most transformative technologies in this sector is building information modelling (BIM), which has revolutionised the way construction projects are planned, designed, and managed.

BIM is a computerised model that accurately depicts a structure's physical and functional aspects. It allows different parties involved in a project to easily exchange information and work together efficiently from start to finish. It facilitates improved decision-making, reduces errors and conflicts, and enhances overall project performance. The evolution of construction technology, as summarised in the table below, highlights the increasing importance of digital tools like BIM in the industry:

Building Information Modelling (BIM) is a crucial tool in the construction industry, enhancing service delivery and promoting environmental sustainability. It facilitates creating, managing, and utilising digital representations of places' physical and functional characteristics. BIM's impact extends beyond visualisation, enabling a collaborative environment for architects, engineers, contractors, and clients to work together. This collaboration facilitates the early detection of possible faults during the design process, decreasing the probability of expensive modifications and delays.

YEAR	TECHNOLOGY	IMPACT
2000	Building Information Modeling (BIM)	Improved collaboration and project visualisation
2005	Drones	Enhanced surveying, monitoring, and inspections
2010	3D Printing	Prototyping, customised components, and cost-efficiency
2015	Augmented Reality	On-site visualisation, training, and safety
2018	Internet of Things	Real-time monitoring, predictive maintenance
2020	Robotics and Automation	Increased efficiency and reduced labor costs
2022	Artificial Intelligence	Project planning, risk analysis, and decision-making
2024	Quantum Computing	Advanced simulations and complex problem-solving

BIM's ability to integrate various data types, including geometrical, spatial, and environmental information, allows for more informed decision-making. Energy modelling tools integrated with BIM can provide insights into a building's energy consumption, enabling the design of more energy-efficient buildings. Emerging technologies like augmented reality, virtual reality, and the Internet of Things (IoT) also integrate BIM, enriching the model and enabling predictive maintenance and energy management. BIM represents a significant technological advancement in the construction industry, driving sustainability by enabling more efficient design, construction, and operation of buildings.

5 LITERATURE REVIEW

Carbon Emissions: A Global and South African Context

Construction activities contribute significantly to global carbon emissions, accounting for 39%. In South Africa, carbon emissions from construction increased by 1.5% to 2% in 2022, representing 13% to 36% of the allocated carbon budget (Chen, et al. , 2023:1627-1657, Li, S., et al. , 2021b:1728).

The construction sector is a significant energy user, accounting for more than 40% of worldwide energy consumption and 36% of global carbon emissions. Research shows that carbon emissions come from direct and indirect sources, mainly upstream industries, during the construction material preparation phase. Sustainable construction practices are crucial for achieving sustainability goals, and accurate estimation and mitigation strategies are essential (Mohebbi, et al. , 2023:355-375, Yang, et al. , 2022:e0264579, Joseph and Mustaffa, 2023:1271-1299, Willhelm Abeydeera, et al. , 2019:3030, Du, et al. , 2018b:1220).

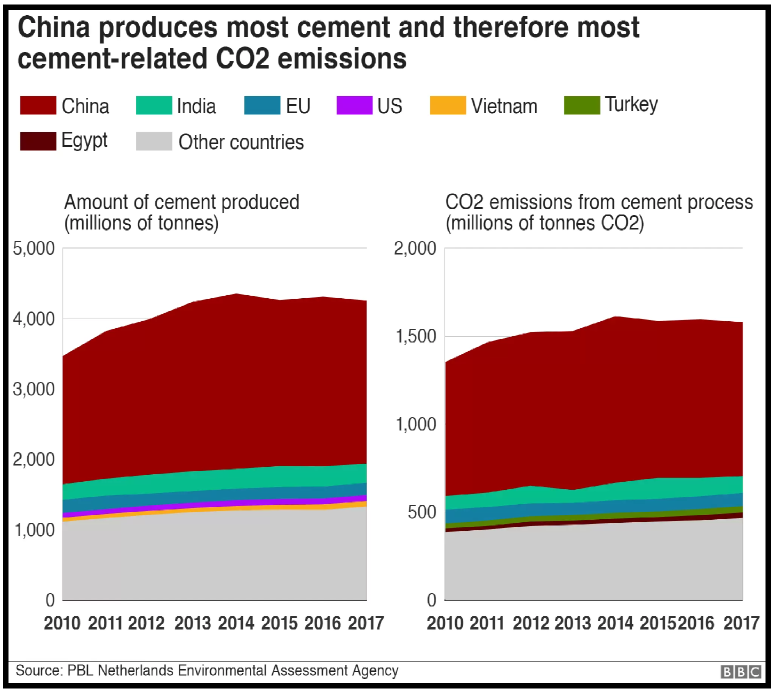

Figure 1: Cement Related CO2 emissions (Source: BBC, 2018)

The impact of construction extends beyond direct construction phases, as expansion of construction land encroaches on carbon sink areas like farmlands and forests, affecting carbon sequestration capacities and overall emissions. Strategies for spatial analysis of carbon emissions from human-social systems are proposed to manage human carbon emissions effectively.(Dong, 2023:, Crawford, 2022:, Dai, et al. , 2022b:, Mohebbi, et al. , 2023:355-375, Yang, et al. , 2022:e0264579, Joseph and Mustaffa, 2023:1271-1299, Willhelm Abeydeera, et al. , 2019:3030).

6 METHODOLOGY

The interpretivism as a philosophical orientation informed an exploratory research strategy and qualitative research approach that were adopted and applied in the study. Data was collected form a variety of secondary sources, such as books, journals, theses, and governemnts documents. Specifically, scholarly materials, on the application of BIM in the South African construction industry were compiled. Data was analyzed by categorizing common themes emerging from literature sources that relate to the application of BIM in the construction industry, how it has been contributing to efficiency, reducing carbon emissions, and promoting sustainable practices.

7 RESULTS AND DISCUSSION (DECREASING CARBON EMISSIONS THROUGH THE HELP OF BIM)

South Africa has been working to reduce its carbon emissions, particularly in the construction sector, which has significantly impacted the country's high energy demand. Building Information Modelling (BIM) has demonstrated its efficacy in mitigating these emissions by accurately simulating building performance, reducing energy usage by over 20% compared to conventional approaches. BIM also helps minimise waste production, with construction waste decreasing to less than 15% due to its use in projects like Johannesburg and Pretoria.

BIM also helps ensure sustainable buildings by promoting better choices and reducing demolitions.

A case study from Bloemfontein showed that BIM reduced 20% of emissions through demolition and reconstructive Stakeholder Engagement and Collaboration. The government's 2.3 trillion investment plan has supported sustainability by promoting the adoption of technologies to reduce carbon emissions in the construction industry.

This study examined the adoption of Building Information Modelling (BIM) in South Africa's construction industry, focusing on its impact on reducing carbon-based emissions, efficiency, and sustainable practices. It analyzed qualitative data from secondary sources and highlighteed key themes and yielded five (5) resultd summerized hereunder.

Result No	Result Name	Result Description
Result 1	BIM Adoption	BIM adoption is the integration of Building Information Modelling (BIM) technology into an organization's workflows, operations, and culture, particularly in AECO sectors, facilitating knowledge sharing throughout a building's lifecycle.
Result 2	Energy Efficiency	How BIM contributes to designing energy-efficient buildings, leading to reduced energy consumption and lower carbon emissions.
Result 3	Sustainable Materials	The role of BIM in selecting materials with lower carbon footprints and promoting sustainable construction practices.
Result 4	Waste Reduction	The impact of BIM on minimising construction waste through efficient planning and management.
Result 5	Stakeholder Collaboration	The influence of BIM on enhancing collaboration among stakeholders, leading to better decision-making and sustainable outcomes

The research aims to investigate the relationship between these results and their collective impact on reducing carbon emissions in the construction industry. By exploring the potential of BIM in addressing environmental challenges, the study seeks to contribute to developing sustainable construction practices in South Africa.

Collaboration among architects, engineers, construction experts, and others has led to increased cooperation and the development of best practices. Funding training and education facilities led by South African construction professionals have also been instrumental in promoting the use of BIM to reduce emissions.

Universities and technical institutions have also developed programs and seminars to promote sustainable building practices and the growth of environmentally-focused professionals.

8 CONCLUSION

The study demonstrates the significant impact of Building Information Modeling (BIM) technology on South Africa's construction industry, reducing carbon emissions, improving waste management, and promoting sustainable practices. It recommends integrating stakeholders and investing in education and training to foster a more eco-efficient future, thereby making South Africa a leader in sustainability and innovation.

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