

2025

3RD EDITION

23 - 25 April 2025

Proceedings of the Construction Business & Project Management Conference

Advancing Multidisciplinary Approaches for Sustainable Construction and Project Management

University of Cape Town · iYunivesithi yaseKapa · Universiteit van Kaapstad
DUT DURBAN UNIVERSITY OF TECHNOLOGY INYUVESI YASETHEKWINI YEZOBUCHWEPHESHE
UNIVERSITY of GREENWICH
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SACPCMP The South African Council for the Project and Construction Management Professions CONSTRUCTING NEW PERSPECTIVES
cidb Construction Industry Development Board
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NRF National Research Foundation

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Proceedings of the Construction Business and Project Management Conference
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DECLARATION

Sixty-six submissions were received and 56 accepted for presentation at the Conference from authors based in 33 Universities, located in South Africa, Nigeria, Ghana, United Kingdom, Canada, Zimbabwe, India and Oman. All full papers in this publication went through a double-blind peer-review process which involves abstracts assessment by the scientific committee, feedback to authors on abstracts submitted, submission of full papers for the accepted abstracts, review of full papers by the scientific committee and panel of reviewers, feedback to authors on full papers submitted which included a decision on acceptance and evaluation of the revised papers by the scientific committee and reviewers to ensure the quality of content.

Instituitional Affiliation	Count of Affiliation	Affiliation%
Ahmadu Bello University, Nigeria	4	5%
Akenten Appiah Menka University of Skills Training and Entrepreneurial Development, Ghana	1	1%
Baze University, Nigeria	1	1%
Bell University of Technology, Nigeria	1	1%
Cape Peninsula University of Technology, South Africa	3	4%
Da Vinci Institute, South Africa	1	1%
Durban University of Technology, South Africa	13	15%
Federal University Lokoja, Nigeria	3	4%
Federal University of Technology Akure, Nigeria	2	2%
Federal University of Technology Owerri, Nigeria	1	1%
Federal University Oye-Ekiti, Nigeria	1	1%
Karkel Integrated Synergy Limited, Nigeria	1	1%
Kumasi technical University, Ghana	3	4%
Leeds Beckett University, United Kingdom	1	1%
Morgan State University, United States	1	1%
Nasarawa State University, Nigeria	1	1%
National University of Science and Technology, Zimbabwe	3	4%
Nelson Mandela University, South Africa	5	6%
Sathyabama University, India	1	1%
SD Dombo University for Business and Integrated Development Studies, Ghana	1	1%
SRM Institute of Science and Technology, India	1	1%
Tshwane University of Technology, South Africa	6	7%
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University College of Estate Management, United Kingdom	1	1%
University of Buraimi, Oman	1	1%
University of Cape Town, South Africa	3	4%
University of Georgia, United States	1	1%
University of Johannesburg, South Africa	7	8%
University of KwaZulu-Natal, South Africa	2	2%
University of Manitoba, Canada	1	1%
University of Plymouth, United Kingdom	1	1%
University of the Witwatersrand, South Africa	4	5%
University of Zululand, South Africa	1	1%
Total	**85**	**100%**

PREFACE

On behalf of the Construction Business and Project Management Research Group, University of Cape Town and the entire Organizing Committee, it is my honour and pleasure to welcome you to the Construction Business and Project Management Conference (CBPM) 2025, taking place from April 23rd to 25th, at the UCT Graduate School of Business Conference Centre in Cape Town, South Africa, as well as online. This year's conference theme: "Advancing Multidisciplinary Approaches for Sustainable Construction and Project Management," uniquely positions us to explore innovative, cross-sectoral strategies geared towards enhancing sustainability, efficiency, and resilience within the construction industry.

CBPM 2025 has been meticulously curated to provide a platform for knowledge exchange, collaboration, and capacity building among leading academics, industry professionals, policymakers, and emerging scholars across Africa and the broader global construction community. Over the course of three days, participants will engage with the keynote address presented by the Deputy Minister, Department of Public Works and Infrastructure, South Africa – Mr. Sihle Zikalala, guest speeches by the CEO of CIDB – Mr. Bongani Dladla, Prof. Ayyoob Sharifi, Prof. Celestine Iwendi and Ms. Suma Mwaitenda, cutting-edge research presentations, panel discussions, and a workshop that address critical contemporary challenges such as public procurement reform, technological innovation including BIM-IoT integration and Artificial Intelligence, sustainable design and materials, H&S and leadership in construction.

The programme reflects an interplay between theory and practice. Day 1 opens with a workshop on procurement reform, framing the discourse with multiple stakeholder perspectives on the evolving regulatory landscape in South Africa. Days 2 and 3 expand this focus, offering insightful sessions on the use of technology for sustainability, strategic management, inclusive leadership, infrastructure development, health and safety, and the latest advancements in AI and project risk management. The diversity of topics covered will no doubt stimulate dynamic conversations and bring about new research collaborations.

A highlight of our commitment to academic integrity and quality is our rigorous three-stage blind peer review process, ensuring that only original, impactful, and methodologically sound papers are included in the conference proceedings. The efforts of our dedicated Scientific Committee, reviewers, and editorial team have been invaluable in maintaining the highest standards, with selected papers representing the forefront of scholarship and industry relevance.

I encourage all delegates to take full advantage of the networking opportunities provided, whether in-person at the scenic V&A Waterfront vicinity or through our virtual platforms. Let this gathering not only broaden your knowledge and professional networks but also inspire practical solutions for driving transformational change in construction business and project management, especially within the African context.

Thank you for your participation and contribution towards making CBPM 2025 a milestone event. I look forward to engaging with you throughout the conference.
Warm regards,

April 23rd, 2025

Professor Abimbola Windapo
Chair, Construction Business and Project Management (CBPM) Conference 2025

SCIENTIFIC COMMITTEE 2025

The success of the 3rd edition of the CBPM Conference is a testament to the dedication and voluntary contributions of the Scientific Committee. We are deeply grateful to its members, whose collaboration with the CBPM Committee ensured a rigorous and constructive peer-review process.

Professor Yewande Adewunmi	University of the Witwatersrand, South Africa
Professor Adewumi Babafemi	Stellenbosch University, South Africa
Professor Francis K. Bondinuba	Kumasi Technical University, Ghana
Professor Fidelis Emuze	Nelson Mandela University, South Africa
Professor Chinyio, Ezekiel A.	University of Wolverhampton, England
Professor Nishani Harinarain	University of Kwazulu-Natal, South Africa
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Dr. Abdul Adediran	University of Johannesburg, South Africa
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CBPM 2025 ORGANISING COMMITTEE

Professor Abimbola Windapo	University of Cape Town
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Dr. Iruka Chijindu Anugwo	Durban University of Technology
Dr. Kehinde Alade	University of Cape Town
Dr. Amanda Filtane	University of Cape Town
Mr Darmarajan Chinasamy	University of Cape Town

THE PEER REVIEW PROCESS

All the full papers in this publication went through a rigorous two-stage blind peer review process by no less than two acknowledged experts in the subject area. Experts, including industry professionals and academics, were assigned to ensure that high-quality scientific papers were produced and included in the proceedings.

The first stage of review

Submitted abstracts were double-blind peer-reviewed. Each abstract was reviewed in terms of relevance to the conference theme and objectives, academic rigour, contribution to knowledge, originality of material and research methodology. Authors whose abstracts were accepted were provided with anonymous reviewers' comments and requested to address the review comments when developing their full papers.

The second stage of review

The submitted full papers were first of all checked originality and inappropriate copying using Turnitin/Ithenticate software. After that, the papers were assigned to experts in the field based on their areas of expertise for review. The full papers were reviewed in terms of relevance to the originality of the material; technical writing; academic rigour; contribution to knowledge; pertinent literature review; research methodology and robustness of analysis of data; empirical research findings; and overall quality and suitability of the paper for inclusion in the conference proceedings.

The third stage review

Authors whose papers were accepted after the second review were provided with additional anonymous reviewers' comments on evaluation forms, and requested to submit their revised full papers. Evidence was required relative to specific actions taken by the authors regarding the referees' suggestions. Final papers were only accepted and included in the proceedings after satisfactory evidence was provided. To be eligible for inclusion in the conference proceedings, these papers were required to receive a unanimous endorsement by the Scientific Committee and Review Panel that the paper had met all the conditions for publication. Out of 66 submissions, 56 papers were finally accepted and included in the CBPM 2025 conference proceedings.

At no stage was any member of the Scientific Review Panel or the Organising Committee, or the Editors of the proceedings involved in the review process related to their own authored or co-authored papers. The role of the editors and the scientific committee was to ensure that the final papers incorporated the reviewers' comments and to arrange the papers into the final sequence as captured on the USB memory stick and Table of Contents.

Professor Abimbola Olukemi Windapo
Chair, Conference CBPM 2025

COMMUNIQUÉ ISSUED AT THE 3RD EDITION OF 2025 CONSTRUCTION BUSINESS AND PROJECT MANAGEMENT CONFERENCE HELD IN UNIVERSITY OF CAPE TOWN GRADUATE SCHOOL OF BUSINESS, CONFERENCE CENTRE, CAPE TOWN, SOUTH AFRICA ON WEDNESDAY, 23RD APRIL TO FRIDAY, 25TH APRIL 2025

1. Preamble

Participants convened in Cape Town, South Africa from Wednesday 23rd April to Friday 25th April 2025, for the 3rd Edition of the 2025 Construction Business and Project Management Conference (CBPM). The event was held at the University of Cape Town Graduate School of Business Conference Centre, Cape Town, South Africa. The theme was "Advancing Multidisciplinary Approaches for Sustainable Construction and Project Management,"

CBPM 2025 bring together leading scholars, industry practitioners and policymakers in exchanging knowledge, showcase cutting-edge research, and develop actionable solutions to advance the construction industry. The event foster dialogues, highlight best practices, and create opportunities for meaningful collaboration that leave a lasting impact on the sector.

The Conference was officially declared open by the Chair of the Conference, Prof Abimobola Windapo (Mrs). Keynote Address was delivered by Deputy Minister, Sihle Zikalala Department of Public Works and Infrastructure, South Africa delivered the keynote address. Mr Bongani Diadia (CEO of CIDB South Africa) delivered a compelling lead paper titled. The paper emphasized the significance of the South African construction Company Law and Implementation in the context of national development, followed by presentations by panelists. Other guest speakers include Mr Lufuno Ratsiku, President of the South African Council for the Project and Construction Management Professions (SACPCMP), Mr Global Theunis van Zyl, Managing Director of VAN ZYL & ASSOCIATES, Mr Jaco de la Rey, Director of HKA's Claims, Consulting and Expert Services, Prof Ayyoob Sharifi of Hiroshima University, among others.

Over 85 participants attended the Conference, during which 55 insightful papers were presented in twelve parallel sessions.

2. Observations

The Conference observed the following:

1) The creation of favourable policies will reduce the rate of inflation as well as its subsequent effects on the prices of building materials for construction projects.
2) Encouragement/support for innovative research in the development of new local building materials for production.
3) Drastic measures to counter the problem of transportation cost, cost of power supply, and the increase in fuel prices in order to improve the ease of movement and distribution of raw materials to the factory (distribution of the finished products from the factory to the end-user) is key in physical development of countries.
4) A shift from over-dependency on imported materials to the use of local materials to boost productivity.

5) Data reinforces the critical role of proactive climate risk management in safeguarding project budgets. Insurance-based adaptations are underutilized in the contraction practice.
6) The need for broader construction sensitization, training, and investment in climate-resilient technologies across the sector of the country.
7) Domesticate the law with negative implications for sustainable human settlements.
8) Lack of political will to implement the Law by government and its agencies has led to uncontrolled construction development, loss of livelihood, poor zoning compliance, destruction of heritage among others.
9) Specific reforms that can speed up adjudication and improve fairness in public procurement Government agencies and stakeholders are essential.
10) Alternative innovative methods for public procurement should include pricing, functionality, and gender equality.
11) The tender adjudication process needs to recognize contractor functionality as a significant criterion to ensure successful project delivery.
12) Artificial Intelligence (AI) has come to stay in the construction industry and business.
13) Effective strategies for improving cybersecurity should include better integration of security measures into everyday operations and prioritising innovations like infrastructure security and defensive artificial intelligence (AI) while addressing resource challenges.
14) By aligning cybersecurity initiatives with overall business strategies, construction firms can build resilience against cyber threats and achieve sustainable growth.
15) The construction business sector promotes collaboration and harmonization among various levels of government, Ministries, Departments and Agencies (MDAs). However, this is a missed opportunity arising from poor implementation and enforcement of some laws.
16) Non-establishment of Commission/Boards/Planning Authorities for the preparation of National Physical Plans in most states.
17) Poor funding for physical planning projects of construction projects, particularly for preparation of physical development plans of various hierarchies, as well as setting up the required institutions.
18) Current tender adjudication method, seen tenders sometimes awarded to incorrect contractors because of the tender adjudication team's inefficient knowledge regarding the Preferential Procurement Policy Framework Act (PFA).
19) Challenges such as high costs of construction/building materials, limited technical knowledge, and resistance to adopting new systems hinder construction progress in Africa.
20) The current state of cybersecurity in the most African construction industry reveals a mixed level of preparedness, with companies recognising the risks but often struggling to implement effective measures.
21) Low awareness of critical security steps such as proper environmental assessments and elastic log monitoring for large data sets.
22) The protection, preservation, restoration, and conservation of heritage properties are missing because of noncompliance with the applicable section of the Law and lack of collaboration with the relevant institutions.

3. Recommendations

In view of the aforementioned observations, the Conference made the following recommendations:

1) There is an urgent need to fully implement and enforce the construction building Law in order to enhance national development.
2) As a matter of urgency, all states/countries are encouraged to achieve sustainable human settlements.
3) There should be collaboration among various levels of government and Ministries, Departments and Agencies to ensure effective development of our societies.
4) Appropriate institutions and agencies for the Construction Industry should be established as provided to enhance physical development of every sector of the society.
5) An integrated approach should be adopted in the development process in the built environment.
6) Adequate funding should be made available by governments for physical planning projects.
7) Various agencies responsible for construction/physical planning should endeavour to employ or award contracts to qualified contractors/personnel for effective project delivery.
8) There should be collation and implementation of international and national conventions, treaties, and laws relating to the conservation and protection of heritage resources, including cultural artefacts, historical and archeaological sites, and monuments.
9) The existing current trends in procurement practices should be reviewed to accommodate some realities. The role of the government in ensuring a fair and equitable procurement system is recommended in order.

Conclusion

In conclusion, the construction sector and the conferee appeal to the government and various stakeholders to take necessary actions, as articulated in the observations and recommendations to ensure that the countries Law is properly implemented all over states and concern countries to address the challenges of national development.

The Conference ended in an appreciative way where the stakeholders and participants were networking and collaborations.

WORKSHOP AND PANEL DISCUSSION

The CBPM 2025 Organising Committee would like to thank our Presenters, Panel Discussants and Moderators for accepting the invitation to come and share their presence and thoughts on advancing multidisciplinary approaches for sustainable construction and project management debacle with construction stakeholders, the academic and professional community

CBPM PROCUREMENT WORKSHOP REPORT

Introduction

The Construction Business and Project Management (CBPM) 2025 Conference hosted a workshop on procurement reforms, focusing on South Africa's new Public Procurement Act, 2024 on 23 April, 2025. This event attracted a diverse audience of industry professionals, academia, government stakeholders, and online participants, all committed to enhancing transparency, fairness, and efficiency within the construction sector across Africa.

Objectives and Themes

The workshop aimed to:

- Examine the implications of the new Procurement Act and its alignment with constitutional mandates.
- Explore stakeholder engagement strategies for effective policy development.
- Address challenges such as traditional contracting practices, corruption, and the integration of digital technologies.
- Promote best practices for sustainable, inclusive, and value-driven procurement.

Keynote and Opening Remarks

Professor Abimbola Windapo set the tone with a welcome address emphasizing the industry's need for collaborative efforts to foster sustainable development. She underscored the importance of leveraging multidisciplinary approaches to build resilient and inclusive construction ecosystems.

Presentation Highlights

Mr. Silas Makalichi, a civil engineer strategy expert and Technical Director, Navi Professional Consulting delivered a presentation on South Africa's procurement landscape and the new legislative framework. His key points included:

1. **The 2024 Procurement Act: A Transformative Framework**
    a. Replaces fragmented laws such as the Preferential Procurement Act of 2000, unifying standards under a single, modern legal structure.
    b. Establishes the Public Procurement Office (PPO) under the National Treasury, tasked with standardizing procedures, frameworks, and templates across departments.
    c. Implements ICT integration, including mandatory e-procurement platforms, real-time tracking, and automated compliance checks (e.g., conflict-of-interest flagging).
    d. Facilitates provincial autonomy through binding instructions, allowing local adaptations aligned with national norms.
    e. Promotes transparency via public registries of firms with unethical histories.
2. **Addressing Vulnerabilities in Procurement**
    a. Recognizes risks such as political interference, corruption, and the proliferation of fraudulent certificates.
    b. Emphasizes the need for industry-led capacity building, training, and mentorship, especially for small and medium enterprises (SMEs).
    c. Advocates for simplification of bidding processes to support SME inclusion and reduce administrative burdens.
    d. Highlights the benefits of international best practices, emphasizing adaptability to local contexts.

3. **Contract Management and Dispute Resolution**
    a. Clarifies the distinction between variations, extensions of time, and contract termination clauses.
    b. Discusses legal precedents relating to time of essence clauses, including compliance with clear contractual language and notice requirements.
    c. Promotes the use of dispute resolution mechanisms, such as arbitration and the newly established Public Procurement Tribunal, to reduce litigation timelines.
    d. Stresses the importance of well-drafted contracts that specify exact timelines, obligations, and penalties to mitigate risks.
4. **Innovative Approaches and Future Directions**
    a. Calls for the integration of green procurement, environmental impact assessments, and local content standards.
    b. Urges industry and government collaboration to develop tailored contracts suited to various project sizes and risks.
    c. Encourages digital transformation, including AI and predictive analytics, to enhance transparency, demand forecasting, and efficiency.
    d. Recognizes the importance of stakeholder engagement in shaping responsive and inclusive procurement policies.

Panel Discussions and Interactive Sessions
The workshop included dynamic panel discussions:

Panel 1: Implications of the Act for Public Sector Procurement Practices
The panel addressed the critical impact of the new procurement legislation on public sector practices, emphasizing the need for improved transparency, skills development, and accreditation processes. This panel featured the following experts:

- Mr. Bongani Dladla, CEO of cidb, who highlighted the organization's efforts to promote fair competition and professionalize contractors, highlighting initiatives to align contractor accreditation standards with the new regulations.
- Dr. Amanda Filtane, an academic, discussed the importance of aligning university curricula with evolving legislative and professional standards to prepare future practitioners, ensuring that future practitioners are well-prepared to navigate the reform environment.
- Mr. Fabio Companie, Head of Construction Management at the City of Cape Town, contributed insights into how local government agencies are adjusting procurement processes, emphasizing the need for capacity building, digital integration, and stakeholder collaboration to effectively implement the reforms and sustain high standards in public projects.

The discussion reiterated that successful adoption of the legislation depends on proactive industry-government collaboration, strategic capacity development, and continuous curriculum updates. The panellists agreed that aligning educational programs with legislation, strengthening ethical standards, and leveraging digital tools are key to enabling fair competition and minimizing corruption. Furthermore, the panel highlighted that the act offers an opportunity to elevate procurement integrity, promote inclusive growth, and build a resilient construction industry responsive to both current demands and future challenges.

Panel 2: Case studies on dispute resolution
The dispute resolution segment of the workshop was convened as a core component of the broader forum on legislative processes and stakeholder engagement in the construction

industry. Chaired by Mr. Theunis van Zyl, a member of SAICE's adjudication committee, the panel brought together expert practitioners, academics, and legal professionals. Their collective objective was to explore mechanisms to improve dispute resolution frameworks, address contractual ambiguities, and ensure more effective, timely justice in construction disputes.

The Case Studies on Dispute Resolution panel featured the following individuals with diverse and deep experience in construction law, arbitration, and dispute management:

- Mr. Theunis Van Zyl's leadership and adjudication expertise provided a guiding framework.
- Mr. Jaco de LaRey, from HKA Consulting in Cape Town, specializes in dispute consultancy and arbitration, bringing practical insight into dispute management and conduct engineering analyses.
- Associate Professor Yog, based in Liverpool John Moore University, UK with construction law expertise, contributed international perspectives on adjudication and dispute procedures.
- Prof. Modupe Mewomo, from Durban University of Technology, a procurement specialist with extensive experience in dispute resolution, particularly in South African procurement law.
- Mr. Xhoba Mbiyo, a construction law practitioner at Bill Tolken Hendriske Law Firm in Cape Town, added practical legal experience on dispute resolution processes and dispute management contracts.

Discussion Highlights

The panel examined a broad array of dispute resolution issues, including contractual clauses on the termination process, the enforceability of variation and extension clauses, and the legal interpretation of contractual deadlines. They emphasized that disputes often arise from ambiguities in contract language, such as unclear termination rights or ambiguous clause formulations related to time of essence. The panel emphasised that for effective dispute resolution, contracts should specify clear procedures for notices, defaults, and the process for extension of time, including compliance with legal formalities like notice periods.

Specific case law reviews were presented, including UK and South African cases where courts had interpreted contractual clauses related to time and default. The importance of timely and clear notice of default, compliance with contractual and statutory stipulations, and the need for dispute clauses to survive contractual termination were highlighted. The panel discussed the advantages of dedicated tribunals, such as the South African Public Procurement Tribunal, which offer expedited dispute resolution processes to reduce delays and litigation costs. They highlighted that these tribunals are crucial for resolving disputes swiftly, especially for contractors or consultants lacking sufficient funding to engage in lengthy court proceedings.

Key Takeaways

The panel agreed that the current legislative frameworks, including the GCC and related dispute clauses, need to be precise, clear, and enforceable. They emphasized that contractual clarity including detailed notice procedures, penalty clauses, and dispute clause survivability, is vital for avoiding protracted litigations. The necessity of standardizing dispute resolution practices and encouraging early dispute resolution mechanisms, such as mediation, was emphasized. Furthermore, the panel recognized that education on dispute

procedures, timely reporting of contractor performance, and adherence to contractual remedies are important for construction industry health, transparency, and fair practice.

Conclusion

The dispute resolution discussion highlighted the importance of explicit contractual clauses, timely procedural compliance, and the establishment of specialized tribunals to facilitate swift justice. Panellists recommended continuous refinement of dispute clauses, greater stakeholder engagement, and increased use of alternative dispute resolution mechanisms such as mediation and arbitration to prevent disputes from escalating. The session highlighted that a proactive, clear, and well-structured dispute resolution framework is fundamental for building trust, ensuring fair outcomes, and supporting sustainable growth in South Africa's construction industry.

Acknowledged Participants

- Mr. Bongani Dladla, CEO of Construction Industry Development Board (cidb)
- Mr. Lufuno Ratsiku, President of the South African Council for Project and Construction Management (SACPCMP)
- Dr. Amanda Filtane, Lecturer, University of Cape Town
- Mr. Silas Makalichi, Technical Director, Navi Professional Consulting
- Mr. Fabio Companie, Head of Construction Management, City of Cape Town
- Mr. Theunis Van Zyl's Chair, Dispute Resolution Committee, SAICE.
- Mr. Jaco de LaRey, Director, HKA Consulting, Cape Town.
- Associate Professor Yog, Liverpool John Moore University, UK
- Prof. Modupe Mewomo, Durban University of Technology, South Africa.
- Mr. Xhoba Mbiyo, Director, Bill Tolken Hendriske Law Firm, Cape Town.
- Dr. Senator Okosun, Academic, Federal University, Lokoja.
- Delegates and online participants from over eight African countries

Conclusion and Next Steps

The workshop reiterated that effective procurement is central to sustainable development, economic growth, and industry integrity. The collective call is for rigorous implementation, ongoing capacity building, and embracing innovative digital solutions.

The organizers express sincere gratitude to all participants, and speakers, for their invaluable contributions.

CBPM Conference Secretariat
April 2025

ENDORSEMENTS

The Construction Business and Project Management Conference is accredited by the South African Council for the Project and Construction Management Professionals (SACPCMP) for **2.1 CPD Credits**. The conference is also supported by the Journal of Construction Business and Management.

SACPCMP

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KEYNOTE SPEAKER

The CBPM 2025 Organising Committee would like to thank our keynote speaker for accepting the invitation to come and share their presence and thoughts on advancing multidisciplinary approaches for sustainable construction and project management debacle with construction stakeholders, the academic and professional community.

Hon. Sihle Zikalala, Deputy Minister of Public Works and Infrastructure



Mr Sihle Zikalala (MP) is the Deputy Minister of Public Works and Infrastructure of the Republic of South Africa from 3 July 2024. He is a Member of Parliament of the Republic of South Africa.

Mr Sihle Zikalala is the former Minister of Public Works and Infrastructure of the Republic of South Africa (7 March 2023 – 30 June 2024). He was previously the MEC for Cooperative Governance and Traditional Affairs (COGTA) in KwaZulu-Natal (2022 – 2023). He has held the position of Provincial Chairperson of the African National Congress in KwaZulu-Natal (2015 – 2022) and also served as Premier of KwaZulu-Natal (2019 – 2022). In December 2022, he was elected into the National Executive Committee (NEC) of the African National Congress. On 30 June 2024, Mr Zikalala was appointed Deputy Minister of the Department of Public Works and Infrastructure (DPWI).

Zikalala joined the liberation movement at the tender age of fifteen years. It was the beginning of a journey that would see him entrusted with key responsibilities within the Liberation Movement in South Africa, including being appointed Secretary General of the ANC Youth League, ANC KZN Deputy Provincial Secretary and Provincial Secretary.

Prior to his deployment as Premier of KwaZulu-Natal, Mr Zikalala was the MEC for Economic Development, Tourism, and Environmental Affairs (EDTEA) and Leader of Government Business – positions which he held with great diligence and passion. It was under Mr Zikalala and the legislature collective that the province of KwaZulu-Natal pioneered ground-breaking transformation programmes under Operation Vula, which

included Radical Agrarian Socio-Economic Transformation (RASET) as well as a Bulk Buying and the Warehousing programme.

He has carved out a solid reputation for himself as an ardent proponent of the Black Industrialist Programme, a national government initiative which seeks to hasten the pace of the empowerment of black owned enterprises. Mr Zikalala contributed immensely to the attainment of peace in KwaZulu-Natal in the early 1990s. He remains seized with the task of deepening peace, advancing democracy and achieving social and economic prosperity for the people of South Africa.

At the heart of his efforts lies a passion to see the South African economy transformed, growing, and being competitive to reduce inequality, poverty, and unemployment.

Mr Zikalala is a champion for gender equality, youth empowerment, and an advocate for quality education. He strongly believes in education and regards it as an indispensable weapon in the arsenal to advance equality and improve people's quality of life.

Deputy Minister Zikalala holds a degree in Communication Science from the University of South Africa, an Honours degree in Public Administration from the University of KwaZulu-Natal (UKZN) and a master's degree in leadership studies from UKZN.



GUEST SPEAKERS

The CBPM 2025 Organising Committee would like to thank our guest speakers for accepting the invitation to come and share their presence and thoughts on advancing multidisciplinary approaches for sustainable construction and project management debacle with construction stakeholders, the academic and professional community.

Mr. Bongani Dladla



Mr. Bongani Dladla currently serves as the Chief Executive Officer of the Construction Industry Development Board (CIDB), following his tenure as Acting CEO since August 2024, after the passing of the late Mr. Cyril Gamede. In his leadership role, Mr. Dladla is entrusted with steering the CIDB's strategic vision to enhance delivery management, build industry capacity, and drive contractor development through impactful interventions and partnerships.

Mr. Dladla was appointed as Chief Operating Officer of the CIDB in early 2021 and has since played a pivotal dual role, assuming the acting CEO position from 1 August 2024. During this time, he has overseen the implementation of the CIDB's core developmental initiative, **B.U.I.L.D.**, aligning operational plans with national goals for infrastructure growth and industry transformation. A distinguished civil engineer by training, Mr. Dladla graduated *cum laude* from the University of KwaZulu-Natal with a Bachelor of Science in Civil Engineering. He furthered his studies at the University of Cambridge in the United Kingdom, earning a Master of Philosophy (MPhil) in Engineering for Sustainable Development.

Mr. Dladla's professional journey reflects a deep commitment to the construction sector, where he has accumulated significant experience in managing complex infrastructure programmes, leading public sector procurement reforms, and advancing digital innovation. His comprehensive understanding of the industry and strong leadership capabilities led the CIDB Board to confidently appoint him to the CEO position. At just 32 years old, Mr. Dladla brings a refreshing blend of youthful energy and visionary leadership to the CIDB. His tenure has been marked by a focus on accountability, transparency, and inclusive decision-making. Under his guidance, the CIDB continues to empower clients and contractors alike with the tools and systems required for sustainable success.

Mr. Silas Makalichi



Silas Makalichi is a seasoned Civil Engineer and business leader with a strong academic background. He holds a BSc Honours in Civil Engineering from the University of Zimbabwe (UZ), an MSc in Project Management from the University of Cape Town (UCT), and an MBA from Mancosa. He is a professionally registered PrTech Eng with the Engineering Council of South Africa (ECSA).

As Director at Navi Professional Consulting, Silas leverages his expertise in project management, strategic business development, and engineering to drive growth and innovation. He has a proven track record of delivering successful projects and mentoring young professionals in the industry.

Silas is also deeply passionate about community development. From a young age, he has been actively involved in various initiatives aimed at uplifting and empowering others. He believes in giving back and is committed to nurturing the next generation of leaders and engineers.

Mr. Lufuno Ratsiku



Mr. Lufuno Ratsiku is the current President of the South African Council for the Project and Construction Management Professions (SACPCMP), a key professional regulatory body within the Built Environment established in terms of the Legislation of Parliament, Act No 48 of 2000. His role ensures compliance and enhancement of the standards of project and construction management practices across South Africa with international agreements across the Built Environment Global Landscape. Mr. Ratsiku is a Built-Environment and Governance Professional, currently holding multiple influential positions in the industry. As the Founder and Managing Director of Genuine Tenacity Consulting, he leads a prominent company specializing in Quantity Surveying and Construction Project Management Services, where his leadership drives innovative solutions within the built environment.

Lufuno served as a Non- Executive Director of Johannesburg City Power and his term ended in August 2024 where he contributed towards the development of a smart utility strategy. He is a former Board Member of the Eskom Pension and Provident Funds (EPPF) where he was a Chairperson of the Human Resources and Remunerations Committee, safeguarding the interests of the fund and its members in terms of Regulations 28 of the pensions' funds Act. Lufuno is a Tribunal Member and Employer Assessor of the Compensation Fund, appointed by the Minister of Employment and Labour in terms of the COID Act No 130 of 1993. He currently serves as an Advisory Board Member of the Big 5 Global Leaders' summit based in the United Arab Emirates, Dubai. Additionally, he enriches the academic community as a researcher at the Centre for Applied Research and Innovation in the Built Environment (CARINBE) within the University of Johannesburg.

Professor Justus Ngala Agumba



Professor Justus Ngala Agumba is an Associate Professor at Tshwane University of Technology (TUT) in South Africa, specializing in construction project management. He holds a PhD in Engineering Management and is a registered Professional Construction Manager. His research focuses on health and safety, infrastructure delivery, and productivity in the construction industry. He has authored over 100 publications and collaborates with various institutions on projects involving AI in construction and gender equity in the industry. He is an active member of several professional bodies and engages closely with both academia and industry

Mr. Theunis Van Zyl



Theunis van Zyl is the Managing Director of VAN ZYL & ASSOCIATES and has 35 years of experience in the construction and consulting industry as Project Manager. Over the past 15 years, he has specialized in building, engineering, and construction claims as well as dispute resolution, serving as a consultant, Arbitrator, Mediator and Adjudicator. Theunis currently serves as the Chairman of the SAICE ADR Panel, an Exco Member of the MBAWC and an accredited Adjudicator, Arbitrator and Mediator on various panels to preside over contractual disputes under the GCC, FIDIC, NEC, GCC and MBA forms of construction agreements.

Professor Ayyoob Sharifi



Ayyoob Sharifi is Professor at the IDEC Institute, Hiroshima University. He also has cross-appointments at the Graduate School of Humanities and Social Sciences and the Graduate School of Advances Science and Engineering. His research is mainly at the interface of urbanism and climate change mitigation and adaptation. He actively contributes to global change research programs such as the Future Earth and has served as a lead author for the Sixth Assessment Report of the Intergovernmental Panel on Climate Change (IPCC). Before joining Hiroshima University, he was the Executive Director of the Global Carbon Project, leading the urban flagship activity of the project. Ayyoob is interested in pursuing research at the interface of climate change and urban planning. The ultimate goal of his research is to provide further insights into how to develop sustainable, peaceful, just, and resilient communities

Professor Celestine Iwendi



Professor Celestine Iwendi is a distinguished academic and internationally recognised expert in Artificial Intelligence (AI), with over 25 years of professional and academic experience. His groundbreaking contributions to AI, IoT, big data, and medical applications have positioned him as a leader in interdisciplinary research aimed at addressing global challenges.

As the Professor of Artificial Intelligence and Head of the Centre of Intelligence of Things (CIoTh) at the University, Professor Iwendi spearheads innovative research and educational programs that merge cutting-edge technology with practical solutions. Holding a PhD in Electronics Engineering, he possesses technical expertise in wireless sensor networks, machine learning (ML), and IoT. As a Senior Member of IEEE and Chartered Engineer, he has played a pivotal role in developing testing procedures, technical support systems, and safety compliance frameworks for electronic systems.

Professor Iwendi has been honoured by the Royal Academy of Engineering under the Exceptional Talent Scheme for his transformative contributions to AI and medical applications. He has also been featured in Elsevier's World's Top 2% Influential Scientists list for four consecutive years. His impactful research spans 13 of the 17 UN Sustainable Development Goals (SDGs), with 92.6% of his publications internationally co-authored and 60.7% ranked among the top 25% most-cited globally

Mr. Jaco De la Rey



Jaco de la Rey is a Director in HKA's Claims, Consulting and Expert Services, based in Cape Town, South Africa. With over 17 years of specialised experience in the construction and engineering sectors, Jaco is a recognised authority in contract law, dispute resolution, and claims advisory services across Africa.

He holds a Master of Laws (LLM) in Construction Law and Arbitration, is a Member of the Chartered Institute of Arbitrators (MCIARB) and is a qualified Arbitrator and Adjudicator. Jaco serves as Co-Chair of the RICS Diploma in Adjudication (South Africa) and is a sought-after speaker at regional industry conferences and professional events. He also contributes to academic development as a Senior Visiting Lecturer at the University of Pretoria's Department of Construction Economics, where he teaches postgraduate modules in Dispute Resolution, Contract Law, and Standard-Form Contracts.

In his leadership role at HKA, Jaco oversees multi-disciplinary teams of quantum, delay, and contract specialists on major infrastructure and energy projects governed by FIDIC, NEC, and other standard-form contracts. He provides strategic advice to clients on complex claims, counterclaims, contract management, and commercial dispute matters. Having participated in over 230 dispute adjudications, Jaco brings deep insight into the interconnected legal, technical, and commercial dimensions of construction disputes.

CONFERENCE PANELLISTS

The CBPM 2025 Organising Committee would like to thank our conference panellists for accepting the invitation to come and share their presence and thoughts on advancing multidisciplinary approaches for sustainable construction and project management debacle with construction stakeholders, the academic and professional community.

Mr. Fabio Companie



Fabio Companie is a passionate and dedicated construction project management professional, focused on urban infrastructure and project business. He emphasizes sustainability, efficiency, and community well-being in his work, aiming to enhance the quality of life through urban development. He identifies as a "Multi-Generational Affordability Preacher," underscoring his commitment to making urban infrastructure accessible and sustainable.

Dr. Amanda Filtane



Dr. Filtane serves as a Lecturer in Construction Management at the University of Cape Town (UCT), where she teaches courses in construction management, integrated management, and project management for non-specialists. Her expertise encompasses productivity management, planning for production, and the integration of construction technologies, including virtual and digital construction methodologie

Dr. Yog Upadhyay



Dr. Yog Upadhyay is a distinguished legal academic and practitioner, currently serving as a Senior Lecturer in Construction Law and Dispute Resolution at Liverpool John Moores University (LJMU), within the School of Civil Engineering and Built Environment. He brings nearly two decades of experience in UK higher education, complemented by practical expertise in arbitration and legal consultancy

Professor Modupe Cecilia Mewomo



Prof. Modupe Cecilia Mewomo is a distinguished academic and professional in the field of construction management and quantity surveying, currently serving as a Senior Lecturer and Acting Head of the Department of Construction Management and Quantity Surveying at the Durban University of Technology (DUT) in South Africa

Mr. Xhoba Mbiyo



Mr. Xhoba Mbiyo is a distinguished South African attorney and conveyancer, currently serving as a Director at Bill Tolken Hendrikse Inc., a reputable law firm based in Bellville, Cape Town. Mr. Mbiyo earned his LLB degree from the University of the Western Cape. He is an admitted Attorney of the High Courts of South Africa and holds the qualification of an admitted Conveyancer.

KEYNOTE ADDRESS

Policy as a Catalyst: Government Strategies for Integrating Sustainability into Construction and Project Management in South Africa

Hon. Sihle Zikalala, Deputy Minister of Public Works and Infrastructure

Chairperson of the Session,
Honourable Guests,
Distinguished Delegates,
Members of the Construction and Infrastructure Sector,
Ladies and Gentlemen,

Good morning.

INTRODUCTION

It is both a privilege and a solemn responsibility to join you at this momentous gathering of the 2025 edition of the **Construction Business and Project Management Conference**, hosted here in Cape Town, one of the most vibrant and resilient cities on the African continent.

Gathered here, is a community of social actors who are advancing multidisciplinary approaches for sustainable construction project management.

In this room, are urban planning professionals who will remind us of the importance of water-sensitive urban design, urban forests, and green spaces as flood-resistant measures.

It is a platform that must remind us about the importance of revitalizing grassroot campaigns of planting trees and preserving wetlands which ultimately act as carbon sinks and natural buffers against flooding.
The conference must stimulate our imagination and push us to adopt innovation and technology to better develop and deliver sustainable infrastructure.

We hope to learn more on digital technologies like Green BIM and Digital Twin software products which have been demonstrated to have the capabilities to transform complex infrastructures into models of sustainability, efficiency, and improving safety.

In the aftermath of the tragic George Building collapse which left 34 people dead, we look to this conference to move beyond preaching about safety.

It must demonstrate how policy proposals like the establishment of the Office of the Engineer-General of South Africa spearheaded by DPWI could promote engineering excellence while providing the leadership required to bridge gaps in regulation, ensuring compliance with engineering standards, and overseeing large-scale engineering projects that are critical to South Africa's economic growth.

Government's trillion Rand investments in infrastructure over the next three years calls for meaningful coordination of the delivery of infrastructure in communities to be spearheaded by professional social facilitators which the Department of Public Works is committed to bring on board and professionalise in collaboration with the SACPCMP and the CIDB.

This will help to manage community expectations, build trust, and eliminate criminality and work stoppages at construction sites.

THE CONTEXT OF OUR CHALLENGE

Ladies and Gentlemen, this conference convenes at a critical juncture in our developmental journey. As a sector that underpins South Africa's economic infrastructure and human development, construction and project management are under growing scrutiny, not only for their ability to deliver, but also for how they deliver. We are no longer judged solely by cost-efficiency or speed. Today, the world demands that we also deliver climate responsibility, social equity, and long-term resilience.

The Republic's **Constitution** also calls for all procurement to be fair, transparent and equitable. The call for equity, because of the injustices of the past, The South African Constitution, one of the most progressive globally, and the principle of *Ubuntu*—which emphasizes interconnectedness, compassion, and mutual respect—together create a strong foundation for sustainability and the achievement of the Sustainable Development Goals (SDGs).

The Constitution enshrines rights to a healthy environment, access to water, education, and equality, directly aligning with several SDGs. Meanwhile, *Ubuntu* reinforces a communal ethic that values the well-being of both people and the planet, encouraging inclusive and responsible action for present and future generations. Together, they promote a holistic approach to development that is socially just, environmentally conscious, and rooted in the dignity and shared humanity of all people.

The title of this keynote, "Policy as a Catalyst", is therefore timely. It invites us to look beyond operational efficiency and into the transformative potential of policy frameworks. Policy, in our context, is no longer merely a mechanism for compliance; it is a strategic tool for sustainable change. It is the bridge between aspiration and implementation.

We know this all too well at the Department of Public Works and Infrastructure (DPWI). Our role is not only to manage South Africa's immovable asset base, but also to guide how infrastructure is conceptualised, funded, designed, built, and maintained. In this capacity, we have come to see that effective policy must go beyond legislation — it must ignite innovation, mobilise capital, empower communities, and above all, embed sustainability as a non-negotiable value.

THE GLOBAL URGENCY AND NATIONAL CONTEXT

Like many developing nations, South Africa is at a crossroads. On one hand, we are tasked with accelerating infrastructure delivery to meet social and economic demands. Conversely, we are bound by a global and moral imperative to reduce our environmental footprint and build resilience against climate change.

Infrastructure is the foundation upon which inclusive economic growth is built. But unless it is **sustainable**, we risk perpetuating inequality, depleting resources, and compounding the vulnerability of our communities. Therefore, sustainability is not a luxury—it is a necessity.

It must be woven into the fabric of every building, road, hospital, and school that we construct.

Across the globe, the construction sector finds itself at the centre of a critical triad of crises: climate change, resource scarcity, and structural inequality. The buildings and construction sector is responsible for an estimated 37% of global energy-related carbon dioxide (CO_2) emissions, according to the latest Global Status Report for Buildings and Construction by the United Nations Environment Programme (UNEP, 2022).

Furthermore, the sector consumes approximately 36% of global energy and over 30% of extracted raw materials, making it both a key driver of economic growth and a major contributor to environmental degradation.

In South Africa, the paradox is even more acute. On one hand, we are under pressure to roll out expansive infrastructure to close spatial inequalities, unlock economic growth, and deliver public services. On the other hand, we are a climate-vulnerable country, frequently affected by extreme weather, water stress, and energy insecurity.

The National Climate Change Adaptation Strategy (DEA, 2020) and the National Development Plan 2030 both highlight the urgent need to integrate sustainability and climate resilience into all phases of infrastructure delivery from planning to maintenance.

Our infrastructure gap is massive. According to the Development Bank of Southern Africa (DBSA), South Africa needs to invest R6.2 trillion by 2040 to meet infrastructure demand particularly in housing, energy, water, and transport (Sesele, 2022). However, the traditional construction model dominated by high-emission materials, inefficient design, and siloed procurement is incompatible with our environmental and fiscal realities.

Moreover, the industry still reflects legacy patterns of exclusion. Many rural and township communities remain underserved, and women and youth are underrepresented in both construction employment and decision-making. The sector must therefore evolve to be not just more productive, but also more equitable and ecologically sound.

It is within this dual reality for the urgency of infrastructure delivery and the imperative of environmental responsibility, that policy must serve as both guide and catalyst.

We must move beyond the outdated model of “build now, adapt later.” Instead, we must ask: Can our policies lead us to build right, the first time? Can they ensure every brick laid supports both development and sustainability?
At the DPWI, our answer is a resounding yes. But we cannot do this alone — and certainly not with outdated policy frameworks.

THE ROLE OF POLICY: FROM REGULATOR TO ENABLER
Colleagues, the world is rapidly changing, not only in how we construct buildings or deliver infrastructure, but in how we define progress itself. The old view of policy as a narrow set of regulations must be left behind. Today, the real strength of policy lies in its ability to influence markets, incentivise sustainability, and drive systemic transformation.

At the Department of Public Works and Infrastructure (DPWI), we have shifted our mindset: Policy is not a constraint. It is a catalyst. It is the lever through which we can build a resilient

infrastructure economy, an inclusive workforce, and a climate-conscious construction sector. To truly serve as a catalyst, sustainability policy in construction and infrastructure must perform four core functions:

1. **Set a Bold and Unambiguous Vision**

Policy must begin with vision, one that is **strategic, measurable, and inclusive**. The DPWI has aligned its infrastructure vision with three key pillars: **sustainability**, **inclusivity**, and **economic recovery**. This vision draws explicitly from:

- The National Development Plan 2030, which mandates sustainable human settlements and reduced emissions.
- The National Infrastructure Plan 2050, which calls for coordinated infrastructure development aligned with resilience and spatial justice (GTAC, 2023).
- South Africa's Just Transition Framework, which frames infrastructure as a climate and economic justice issue, especially for communities most impacted by climate change and inequality.
- cidb Amendment Bill that will create on construction industry, remove the barriers between the private sector and public sector.

In this light, infrastructure is no longer seen as a capital expenditure item alone. It is a **long-term national asset**, with social, economic, and environmental value and policy must reflect this complexity.

2. **Provide Practical Tools and Incentives**

Policy cannot just preach principles; it must offer the tools to act. This is why the DPWI has developed mechanisms such as:

- Cidb BUILD programme, which is making every construction site large enough to be a site for both skills and enterprise development.
- The Green Building Policy Framework, which provides minimum design and construction sustainability benchmarks for public buildings.
- Life-cycle costing tools, now integrated into project design templates and public procurement protocols.
- Sustainability screening models developed in collaboration with Infrastructure South Africa (ISA) to ensure early identification of environmental risks and opportunities during the planning phase of Strategic Integrated Projects (SIPs).

A 2024 review of South Africa's green infrastructure policy landscape highlights that without operational tools embedded at project level, even the most progressive policy tends to "remain rhetorical and aspirational" (Sesele, 2024). To avoid this, we have prioritised the mainstreaming of sustainability indicators across all stages of project management — from feasibility to procurement, construction to facility management.

3. **Convene the Right Actors Across the Ecosystem**

One of the most important roles of government policy today is not to control, but to coordinate.

Infrastructure projects involve numerous actors, such as engineers, contractors, architects, project managers, environmental planners, municipalities, communities, investors, and

regulators. Sustainability integration requires all these actors to speak a common language, follow shared standards, and work towards common outcomes.

The DPWI's annual Sustainable Infrastructure Development Symposium South Africa (SIDSSA) plays a major role in convening stakeholders. This platform has helped to:

- Mobilise over R100 billion in blended finance partnerships for sustainable projects,
- Bring banks and development finance institutions into alignment with green construction benchmarks,
- Promote collaboration between local government, industry, and academia on green skills development.

Sustainable Infrastructure Development Symposium South Africa 2023 symposium, themed ***"Green Recovery Through Infrastructure"***, featured panels on climate-resilient design, just transition job creation, and circular construction practices (SIDSSA, 2023).
In this regard, policy is not just a top-down tool, it is a platform for collaborative governance.

4. Embed Accountability and Transparency

Colleagues, no matter how progressive a policy may be, **implementation is what counts**. That is why we are working to ensure that policy instruments come with **clear accountability frameworks**.
For example:

- Public infrastructure projects above R50 million must now include an Environmental Impact and Resilience Assessment (EIRA).
- A Green Infrastructure Dashboard is being piloted to publicly track the sustainability indicators of major government projects, making data available to both citizens and oversight bodies.
- Municipal Infrastructure Support Agents (MISA) and the Office of the Chief Procurement Officer are working to integrate sustainability compliance into their audit and monitoring procedures.

We must add that transparency strengthens trust, and trust strengthens delivery. This is how policy credibility is built, and not just through publication, but through performance.

GOVERNMENT IN ACTION: THE DPWI's STRATEGIC VISION AND SUSTAINABILITY

While policies provide the framework, it is through institutional leadership and strategic interventions that real change is felt. At the Department of Public Works and Infrastructure (DPWI), we are not waiting for others to lead — we are acting.

We have identified three pillars in our sustainability approach: Policy coherence, project-level transformation, and people-focused outcomes. Let us examine three major strategies currently driving our agenda.

1. Green Building Policy Framework

The Green Building Policy Framework, launched by the DPWI, sets minimum sustainability performance standards for public buildings. It is grounded in:

- The use of energy-efficient materials and systems,
- A requirement for at least a 4-Star Green Star Rating (as per the Green Building Council of South Africa),

- Integration of climate-resilient design (like passive ventilation, rainwater harvesting, and greywater reuse), and
- Enforcement of life-cycle cost assessments over mere upfront cost evaluation.

This framework ensures that government leads by example in sustainable building. Already, buildings such as the Department of Home Affairs' new campus in Salvokop have achieved top-tier green design status (DPWI, 2023).

Moreover, this framework is aligned with the National Climate Change Response White Paper (2011) and the NDP 2030, anchoring it in national commitments.

2. Infrastructure Investment Plan (IIP): Sustainability as Core Criteria

The Infrastructure Investment Plan (IIP), launched in 2020 under the Presidential Infrastructure Coordinating Commission (PICC), is more than a funding pipeline — it is a filtering mechanism for sustainable infrastructure.

Every project entering the Strategic Integrated Projects (SIPs) intended to be assessed for:

- Carbon footprint and energy efficiency,
- Social value, such as job creation for youth and women,
- Climate vulnerability and resilience to future shocks.

To date, more than R340 billion worth of projects have been reviewed under the new sustainability screening criteria developed in partnership with Infrastructure South Africa (ISA) and the Council for Scientific and Industrial Research (CSIR) (ISA, 2023).

This approach ensures that climate-smart infrastructure becomes the default, not the exception.

3. Expanded Public Works Programme (EPWP) and Green Jobs

The EPWP, traditionally focused on basic employment, has undergone a strategic shift. It now includes green workstreams, including:

- Eco-furniture manufacturing from invasive alien vegetation,
- Solar panel installation at schools, clinics, and public buildings,
- Community-driven water harvesting systems, and
- Localised waste-to-building material innovations.

This shift not only promotes sustainability but is crucial for inclusion. Studies by Dladla (2023) and Emere et al. (2023) found that EPWP has significantly enhanced livelihood resilience in rural and peri-urban areas. As of 2024, over 5.6 million work opportunities have been created through EPWP, with a growing share of these linked to green infrastructure projects (DPWI Annual Review, 2024).

POLICY INSTRUMENTS AND PLATFORMS DRIVING CHANGE

Transformational policy must be anchored in institutions, supported by platforms, and reinforced by measurable systems. At the DPWI, we have developed or partnered with key entities to operationalise our sustainability agenda.

Let us examine three strategic instruments and platforms that are central to our success.

a. Infrastructure South Africa (ISA)

Established under the Presidential Infrastructure Coordinating Commission (PICC), ISA plays a pivotal role in pipeline curation, technical appraisal, and early-stage project preparation.

ISA now ensures that all Strategic Integrated Projects (SIPs) are:

- Screened for climate risks and carbon intensity,
- Evaluated using a resilience index,
- Rated on social return on investment (SROI), especially employment, gender inclusion, and long-term benefit.

According to ISA's 2023 Annual Overview, over 88 major infrastructure projects have now been assessed using this sustainability filter — covering sectors like energy, transport, sanitation, and housing (ISA, 2023).

This early-stage screening prevents environmental risks and encourages a shift from reactive adaptation to proactive design.

b. Public Procurement Reforms

South Africa's public procurement system is undergoing a shift from price-based decision-making to value-based and life cycle costing approaches. The DPWI, in partnership with National Treasury and the Office of the Chief Procurement Officer (OCPO), is:

- Incorporating environmental performance clauses into bid specifications,
- Prioritising bidders that use locally sourced, low-carbon or recycled materials, and
- Rewarding innovation in modular, circular, or digital construction technologies.

The Green Procurement Guidelines for the Built Environment, as piloted in 2024, must be expanded to national roll-out. They are aligned with ISO 20400 (Sustainable Procurement) and linked to the Municipal Infrastructure Grant (MIG) criteria (Treasury, 2024).

CASE STUDIES: SUSTAINABILITY IN PRACTICE

Ladies and Gentlemen, nothing illustrates impact like real-world implementation. Let me briefly present three key projects that reflect our policy vision in action.

i. Salvokop Precinct Development – Pretoria

A flagship project led by DPWI and Coega Development Corporation, the Salvokop Precinct consolidates multiple government departments in an eco-smart, transit-oriented development.

Key features:

- Targeting a 6-Star Green Star rating, the highest in South Africa,
- Passive design for natural lighting and ventilation,
- Full solar integration, rainwater harvesting, and greywater recycling,
- Mixed-use facilities to reduce commuting emissions.

This R18 billion precinct is a living case study in urban sustainability.

ii. Public Buildings Retrofit Programme

Over 1,000 government-owned buildings — schools, hospitals, office blocks — are currently undergoing retrofits to improve energy and water performance.

Retrofits include:

- Solar PV arrays on rooftops,

- Insulation, double-glazing, and LED installations,
- Smart meters for energy and water tracking.

Estimated savings from these initiatives exceed **R300 million annually** in utility costs, while cutting GHG emissions significantly (DPWI, 2024).

iii. Small Town Regeneration Programme

Across 80 municipalities, DPWI has partnered with local governments to rebuild community infrastructure, clinics, libraries, halls using:

- Stabilised earth blocks and biocomposite materials,
- Boreholes with solar pumping systems,
- Zero-waste construction zones managed by cooperatives.

This programme also ties into EPWP, creating local green jobs and stimulating community resilience and ownership.

COLLABORATION: THE MISSING LINK

Ladies and Gentlemen, too often, government departments works in silos. Engineers, architects, quantity surveyors, planners, and construction and project managers in the built environment operate within their domains.

We must ask: **Are we truly working together to build sustainably? Or are we simply working alongside each other?**

As DPWI, we recognise that the success of any policy hinges on how well it galvanises partnerships across sectors. The government cannot transform the construction industry alone. We need a united, coordinated effort that brings together all players in the value chain.

That is why we are focusing on the following **strategic interventions**:

(i) Policy Alignment and Institutional Coordination

We are working to **align infrastructure-related policies across departments** — from public works and energy to transport, environment and human settlements. This alignment is critical to avoid contradictions, streamline approvals, and ensure that sustainability is not an afterthought but a guiding principle from the outset.

We are also strengthening institutions like the **Council for the Built Environment (CBE)** and **professional councils** to ensure sustainability is a cross-cutting priority in education, licensing, and practice.

(ii) Mainstreaming Sustainability in Project Lifecycle Management

We are embedding sustainability into **public sector project management methodologies**, ensuring that every stage — from feasibility studies and design to procurement and execution — factors in environmental and social performance.

Through our **Infrastructure Delivery Management System (IDMS)**, we are integrating green procurement practices and lifecycle costing into project planning. We want project managers to champion long-term value rather than short-term delivery.

(iii). Capacity Building Across the Sector

Another priority is to **equip professionals with the knowledge and tools** to implement sustainable practices effectively.

We partner with SETAs, universities, and industry bodies to incorporate **sustainable construction principles into training curricula**. Our goal is to build a generation of technically sound and environmentally conscious professionals.

We are also scaling up **skills development for SMMEs and emerging contractors** so that sustainability is not confined to big firms but democratised across the sector.

(iv). Incentivising Innovation and Sustainable Practice
We must also recognise and reward innovation. To encourage the private sector's adoption of sustainable methods and technologies, we are exploring **incentive mechanisms**, such as tax relief, preferential procurement scoring, and grants.

Additionally, the Department of Works and Infrastructure supports **pilot projects** demonstrating the viability of net-zero buildings, green materials, and water-wise infrastructure. These pilots will inform future policy and serve as benchmarks for replication.

(v) Monitoring, Accountability, and Adaptive Policy
Our commitment to sustainability means little without **measurement and accountability**. We are investing in improved **monitoring and evaluation frameworks** that track projects' environmental performance—emissions reductions, energy efficiency, water use, and waste management. These insights will inform a cycle of **adaptive policymaking**, ensuring we learn, improve, and evolve as we implement projects.

CHALLENGES WE FACE AND HOW WE ARE RESPONDING
Despite significant gains, we must acknowledge structural constraints:

- Skills Gaps: Many municipalities lack technical capacity in green infrastructure.
    - Response: Through the Construction Education and Training Authority (CETA), we are embedding green skills into TVETs and artisan training.

- Fragmented Standards: Disparate building codes and unclear enforcement mechanisms across provinces.
    - Response: The development of a Unified Infrastructure Code is underway, with SANS and CIDB integration.

- Funding Bottlenecks: Green innovations are often perceived as costlier.
    - Response: The Green Infrastructure Facility (GIF), under design, will enable blended finance partnerships — using public risk capital to unlock private investment.

CONCLUSION: FROM BLUEPRINT TO BREAKTHROUGH
Colleagues, we are no longer theorising about sustainability, we are building it. But to sustain this momentum, we must shift:

- From policy as paperwork to policy as performance,
- From construction as carbon cost to construction as carbon solution,
- From fragmentation to collaboration.

Let each bridge we build, each building we restore, each borehole we drill — reflect not just brick and mortar, but vision and values.

Let us build not only what is needed now — but what the future demands of us.

Let us move from fragmented efforts to focused collaboration.

And let us ensure that what we build today does not compromise tomorrow.

Policy can be the spark, but it is people—dedicated academics and professionals like you—who must carry the flame. Let us ignite transformation in how we build, manage, and lead.

Together, we can create a legacy of **inclusive, resilient, and sustainable** infrastructure—the pillars of a better South Africa.

I thank you!

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INVITED TALKS AT THE CONFERENCE WORKSHOP AND THE PLANERY SESSION

Current Trends in Procurement Practices: The role of the government in ensuring a fair and equitable procurement system.

Mr. Bongani Dladla

Mr. Bongani Dladla opened the conference by underscoring the pivotal role that procurement—particularly within the public sector—plays in delivering sustainable infrastructure and advancing socioeconomic development. Framing procurement as a strategic rather than merely administrative function, he argued that South Africa's constitutional imperatives of fairness, equity, transparency, competitiveness and cost-effectiveness can only be realised when procurement policies explicitly pursue long-term value, life-cycle costing and the correction of historical injustices. Drawing on two decades of regulatory experience at the Construction Industry Development Board (CIDB), he highlighted the emerging Public Procurement Act as an opportunity to create a unified yet differentiated framework that balances national oversight with context-specific guidelines for different project grades.

Turning to global trends, Mr. Dladla identified digital integration—especially e-procurement platforms, data analytics and artificial intelligence—as essential tools for enhancing transparency, reducing corruption and lowering the high transaction costs that currently exclude many small and medium enterprises. He cautioned, however, that built-environment professionals must remain actively involved in shaping these digital systems to avoid a reductive "tick-box" culture that overlooks the technical complexity of infrastructure delivery. He further advocated embedding environmental metrics in bid evaluation, proposing a consolidated scoring model that weighs price, preference and environmental impact to accelerate progress toward the Sustainable Development Goals.

Mr. Dladla devoted significant attention to inclusive procurement, asserting that labour-intensive construction methods, local sourcing and capacity-building requirements should be hard-wired into tender documents. While supporting set-aside programmes for targeted enterprises, he stressed that such measures must preserve genuine competition to prevent unintended market distortions or the emergence of so-called "construction mafias." Capacity building across government departments remains, in his view, a critical prerequisite: an uninformed client base hampers value creation and inhibits the adoption of innovative solutions or alternative offers from contractors.

In closing, he argued that procurement, when conceived as a holistic, knowledge-rich system, can act as a catalyst for economic growth, social equity and climate resilience. Investment in digital infrastructure, robust legislative frameworks and principled leadership will be required to ensure that no stakeholder is left behind. Mr. Dladla concluded with a call for collaborative engagement among government, industry and academia, asserting that only through shared expertise and transparent processes can South Africa build an inclusive and sustainable construction sector capable of meeting the nation's development challenges.

The New Procurement Act – Transforming Construction Sector Governance

Title: Building Transparency and Inclusion: The Role of the New Procurement Act in South Africa's Construction Sector

Mr. Silas Makalichi

Mr Silas Makalichi framed South Africa's 2023 New Procurement Act as a strategic instrument for fair, transparent, and cost-effective governance, fully aligning statutory practice with Section 217 of the Constitution and the developmental vision of the National Development Plan 2030. He explained that the Act consolidates a previously fragmented framework by creating a central Public Procurement Office within National Treasury to harmonise rules, enforce compliance, and standardise procedures across all spheres of government. It introduces a strengthened preferential-procurement regime that affords enforceable advantage to black-owned enterprises, women, youth, and persons with disabilities, thereby institutionalising inclusive economic participation. Mandatory e-procurement platforms digitise the tendering process to improve auditability, widen bidder access, and reduce administrative delays, while compulsory professional qualifications and continuous-learning requirements raise both competence and ethics among procurement officials. Robust transparency safeguards, including public reporting, whistle-blower protection, and systematic audits, are designed to rebuild confidence and deter corruption, aligning South Africa with OECD best practice and Sustainable Development Goal 16.

Turning to the construction sector, characterised by large capital projects, intricate supply chains, and protracted delivery timelines, Mr Makalichi argued that these reforms promise to curb cost overruns, shorten delays, and open public-sector opportunities to emerging contractors, while stimulating local production of construction inputs and promoting more sustainable value-for-money outcomes. Realising these benefits, however, depends on closing persistent digital-infrastructure gaps, bolstering municipal capacity, and overcoming institutional resistance from actors that have thrived under opaque procurement regimes. The presentation therefore advocates targeted digital-support programmes for rural and smaller contractors, ring-fenced training funds for local authorities, and the establishment of independent monitoring bodies to ensure compliance. It further calls for strong public–private collaboration, particularly with the Construction Industry Development Board and the South African Council for the Project and Construction Management Professions, and for context-specific implementation guidelines tailored to provincial and municipal circumstances.

Mr Makalichi concluded that, provided these challenges are proactively managed, the New Procurement Act can transform public procurement from a compliance-based routine into a catalyst for transparent governance, inclusive economic growth, and socially responsive infrastructure delivery within South Africa's construction industry.

Legislative Process and Stakeholder Engagement in Construction Governance

Title: Enhancing Governance through Legislative Process and Stakeholder Engagement in South Africa's Construction Sector

Mr. Silas Makalichi

Mr Silas Makalichi underscored that South Africa's construction industry, one of the country's primary engines of growth—must be governed by a legislative process that is robust, inclusive, and participatory. He described the law-making pathway as a cyclical journey comprising proposal, drafting, consultation, enactment, and implementation. Each stage, he stressed, is designed to keep policy relevant and forward-looking: needs are first identified through dialogue with affected parties, expert committees refine draft bills to ensure sectoral fit, and constitutionally mandated public-participation rounds allow contractors, professional bodies, and communities to test and adjust proposed rules before Parliament enacts them.

Mr Makalichi devoted particular attention to stakeholder engagement as the linchpin of construction-sector governance. Government departments, especially Public Works & Infrastructure and the CIDB, shape and implement legislation, while professional councils such as the SACPCMP, industry associations, trade unions, and construction firms supply technical insight and advocate for workable regulations. Civil-society organisations safeguard community interests, ensuring that infrastructure projects serve public needs. By convening these diverse voices, stakeholder engagement enhances transparency, curbs corruption risks, and generates laws that remain responsive to evolving project-delivery challenges.

Acknowledging persistent obstacles, power imbalances that mute smaller contractors and marginalised communities, limited capacity among public and private actors, and compressed legislative timelines, Mr Makalichi framed these hurdles as opportunities for innovation. He called for targeted capacity-building programmes to elevate the quality of dialogue, the deployment of digital engagement platforms to broaden participation (particularly in remote areas), and stronger government, industry partnerships to accelerate policy adaptation. He concluded that rigorous legislative processes and inclusive stakeholder engagement are twin pillars of effective governance; refining these mechanisms and embracing collaborative, technology-enabled tools will enable South Africa to craft laws that foster transparent, sustainable, and equitable infrastructure delivery while driving inclusive economic growth.

Real-life challenge of the constraints and stalemates imposed by Public Procurement in the context of our standard forms of contract

Mr. Theunis Van Zyl

Theunis van Zyl interrogated the legal moment at which a contract governed by the **General Conditions of Contract (GCC) 2015** truly terminates, arguing that the answer determines risk allocation, the applicability of delay penalties, and the conditions under which either party may invoke default or termination clauses.

He explained that GCC 2015 envisages only **five legitimate pathways to closure**: termination by the employer for external force-majeure events; termination by either party for specified internal events; completion through the sequential stages of practical completion, final completion, and expiry of the ten-year latent-defects period; employer default followed by a Clause 9.2 notice and termination; and contractor default followed by a Clause 9.3 notice and termination.

To illustrate the risks of misapplying these provisions, the presenter analysed a City of Cape Town project that was 90 percent complete when the employer failed to honour an interim payment certificate worth R 2.33 million. The contractor issued a Clause 9.3 default notice, yet the employer's legal team asserted that the contract had **"expired"** on a predetermined calendar date because no extension had been processed under section 116(3) of the Municipal Finance Management Act (MFMA). Litigation ensued and was ultimately settled out of court, leaving the underlying legal question unresolved.

Van Zyl observed that municipalities have begun issuing **"Memoranda of Agreement"** that impose automatic expiry dates irrespective of project progress. This practice conflicts with GCC 2015 and, according to the Construction Industry Development Board's Standard for Uniformity (August 2019), constitutes a substantial, and improper, alteration of the standard form. When the automatic date lapses, contractors are removed from site, works remain unfinished, and replacement contractors are procured at significant additional cost.

The resultant value-for-money erosion manifests in three ways: contractors are deprived of the opportunity to complete justified extensions of time; employers incur duplicate mobilisation costs, dispute resolution expenses, and reputational damage; and supply-chain policies override contractual mechanisms, thereby reducing legal certainty and discouraging market participation.

Van Zyl concluded that contract validity should be determined by the governing form, not by arbitrary calendar cut-offs, and that any modification to termination mechanics must follow due-process amendment procedures, including public participation when required by the MFMA. He emphasised that genuine value-for-money depends on whole-life cost assessment, avoidance of unnecessary delay, diligent monitoring of supply arrangements, and continuous process improvement, rather than on lowest price alone.

Measures and Strategies for Climate Change Adaptation and Mitigation in Urban Areas

Professor Ayyoob Sharifi

Professor Sharifi's keynote examined the pivotal role of cities in confronting the climate crisis and outlined a science-based, integrative pathway for urban mitigation and adaptation. He opened by situating the discussion within the Paris Agreement's ambition to keep global warming well below 2 °C, preferably 1.5 °C, noting that annual emissions of roughly forty gigatonnes of CO_2 leave the world with only about five years to preserve the 1.5 °C carbon budget and two decades to remain under 2 °C. Against that backdrop, he argued that cities—already responsible for more than sixty per cent of greenhouse-gas emissions—must become the fulcrum of global climate strategy because they are simultaneously the main loci of exposure to climate impacts and the most agile governance scale for rapid action.

Sharifi then synthesised findings from recent IPCC assessments to demonstrate how unabated emissions could propel global mean temperatures above five degrees by the end of the century, intensifying urban heat islands, flooding, drought and coastal-inundation risks. He traced the geography of urbanisation from 1950 to projections for 2030, showing that future population growth will be concentrated almost entirely in African and South-Asian cities, making these regions critical testbeds for climate-resilient development.
Moving from diagnosis to prescription, the speaker distinguished three archetypes—emerging, rapidly growing and established cities—and argued that each demands a tailored mitigation-adaptation mix. Emerging cities should electrify building services and embed circular-economy principles from the outset; rapidly growing cities must adopt compact, transit-oriented patterns to avoid lock-in of high-carbon sprawl; established cities need deep retrofits, land-readjustment and smart-infrastructure upgrades. Across all contexts, he detailed sectoral levers that collectively could shrink projected 2050 emissions from major cities by nearly ninety per cent: high-performance buildings, renewable and decentralised energy, efficient mobility, material substitution (e.g., engineered timber) and waste-system optimisation.

A core theme of the lecture was the necessity of designing policies that harvest co-benefits and synergies while averting trade-offs between adaptation and mitigation. Sharifi illustrated how higher urban density, if coordinated with mixed land use, green infrastructure and active-transport networks, lowers per-capita emissions and flood risk, yet warned that poorly managed densification can exacerbate heat stress. He showed that decentralised energy, water conservation, urban agriculture and nature-based solutions can simultaneously cut emissions, enhance resilience and advance multiple Sustainable Development Goals. Trade-offs such as redundancy versus efficiency in energy systems or park provision versus compactness can, in his view, be resolved through "smart, systemic design". The keynote concluded with a call for integrated urban climate action plans that replace fragmented adaptation or mitigation efforts. Professor Sharifi urged city leaders to align local strategies with national frameworks, mobilise finance for green and blue infrastructure, and cultivate knowledge partnerships with universities to mainstream life-cycle assessment and scenario planning. Effective urban initiatives, he argued, are pre-conditions for achieving the SDGs because they deliver cascading benefits for housing, health, equity and economic productivity. By embracing holistic, evidence-based planning, cities can transform from climate liabilities into engines of a low-carbon, resilient and equitable future.

Shaping the Future of Higher Education through Adaptive Learning and AI

Professor Celestine Iwendi

Professor Celestine Iwendi framed his keynote around the proposition that Africa possesses the intellectual and natural resources to lead in the global knowledge economy—provided its higher-education systems embrace adaptive learning and artificial-intelligence (AI) technologies. He opened by diagnosing structural deficiencies that stifle learning across the continent: overcrowded lecture halls, "one-size-fits-all" pedagogy, high dropout rates, digital fatigue in the wake of the pandemic, and prohibitive costs associated with professional associations and research infrastructure. Such conditions, he argued, have cultivated a subsistence mentality in which entrepreneurial quick fixes replace sustained scholarly inquiry. To reverse the trend, universities must re-engineer curricula and assessment around continuous, data-informed personalisation rather than rote repetition of legacy syllabi.

Defining adaptive learning as "technology that adjusts content and assessment in real time to student needs," Iwendi set out the core components of an AI-enabled educational ecosystem. Algorithms drawn from natural-language processing and machine learning automate grading, generate immediate feedback, predict at-risk learners, and power chatbots that answer routine queries—thereby liberating academics for research, curriculum redesign and high-value mentoring. In laboratory contexts, the same tools optimise experimental design, manage sensor data and speed the translation of ideas into patentable prototypes. He cited Arizona State University's AI-based learning system, Coursera's adaptive course pathways and Canada's AI-enhanced mathematics tutorials as models that African institutions can localise, provided access to reliable data centres, cloud computing and open-source software is secured.The speaker devoted considerable attention to ethical and infrastructural barriers. Large language models often hallucinate citations, embed cultural biases and demand datasets that many African universities have yet to curate. Over-reliance on automation risks eroding critical thinking unless educators require oral defence of AI-generated work and design assessments that privilege creativity over regurgitation. Iwendi therefore called for robust data-governance regimes, investment in EdTech innovation, and national policies that introduce AI literacy from secondary school onwards—mirroring China's mandate that every high-school curriculum include AI fundamentals.

Looking ahead, he envisaged AI as a "co-pilot, not a replacement" for human intellect. Hybrid block-learning formats—where a course is completed in four or five intensive weeks—can be enriched by adaptive quizzes, virtual laboratories and AI-augmented academic advising that guide students toward entrepreneurial career paths. Lifelong, adaptive platforms will allow graduates to reskill continuously, while universities that integrate AI across engineering, law, medicine and the arts will produce interdisciplinary problem-solvers capable of transforming African economies.Iwendi concluded with a pragmatic call to action: patent local innovations before publication; form international consortia to tap European research funds; build continent-wide data repositories for health, climate and engineering; and retrain faculty so they can model responsible AI use. If African higher-education leaders adopt these measures, AI will not steal jobs but will "take the jobs of those who refuse to learn it," turning the continent's latent potential into a globally recognised powerhouse of creativity and sustainable development.

Poorly Presented or Supported Construction Claims: Lack of Skill or Deliberate Strategy?

Mr. Jaco De la Rey

Mr Jaco de La Rey, director of Claims and Disputes at HKA Global, warned that many construction contractors still submit poorly particularised claims, creating fertile ground for disagreement and, ultimately, costly disputes. He opened by defining a construction claim as any request for extra time and/or money resulting from design changes, access delays, suspensions or other disruptions, then drew on judicial commentary (Paice v Harding, Galliford Try v Estura) to show how tribunals routinely view such submissions as overstated. Four doctrinal pillars frame a sound claim, he argued: contemporaneous **particularisation**, causal linkage between act and loss, the contractor's **burden of proof**, and an evidentiary **standard of proof** that eschews conjecture and demands factual substantiation. Where contracts (FIDIC, NEC, JBCC, GCC) require contemporary records and detailed supporting particulars, non-compliance, or "death-by-paper" tactics that swamp the other party in unstructured data, renders objective assessment almost impossible.

Mr de La Rey traced the typical path from claim to arbitration, showing how vague narratives, lack of causation analysis, global-sum approaches, and failure to recognise concurrent delay undermine contractors' own positions at both project and adjudication stages. Analysis of more than 600 South-African claims revealed that over 40 % escalate to formal disputes, a statistic he linked to inadequate record-keeping, limited scheduling expertise, and a reluctance to invest in proper cost build-ups. To reverse this landscape, he recommended early engagement of experienced claims consultants, strict adherence to contractual notice and evidence clauses, adoption of international best-practice protocols such as the SCL Delay & Disruption Protocol (Rev 2), and stronger employer insistence on fully substantiated submissions. Enhanced delay-analysis capability, clearer particular conditions in contracts spelling out evidentiary standards, and timely, contemporaneous resolution of emerging issues can, he concluded, lift claims practice from adversarial manoeuvring to rational, evidence-based settlement, ultimately improving project performance and reducing the burden on South Africa's dispute-resolution forums.

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ACADEMIC PAPERS: THEME 1 - INNOVATIVE USE OF TECHNOLGY

Exploring the Advantages of BIM-IOT Integration in Enhancing Construction Health and Safety

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Abstract

The construction industry faces significant workplace safety-related challenges, with a high rate of accidents and injuries. The use of advanced technologies such as Building Information Modelling (BIM) and Internet of Things (IoT) has reduced the number of such challenges. The objective of this research is to explore the integration of BIM and IoT technologies to improve Occupational Safety and Health (OSH) management in the construction industry. Given the limited research on the practical advantages of BIM-IoT integration for safety purposes, this study aims to address this gap by identifying and analysing these advantages. A Systematic Literature Review (SLR) is conducted, analysing articles published between 2010 and 2025 to identify the advantages of BIM-IoT integration in construction safety management. The findings highlight several key advantages of BIM-IoT integration, including enhanced safety monitoring, real-time decision-making, and improved hazard identification and risk assessment. Furthermore, the integration supports proactive safety measures, such as eliminating hazards during the design phase and improving workers' safety awareness. However, the study highlights the need for further research on regulatory compliance and cost-effectiveness, as well as design-phase hazard prevention, AI-driven safety monitoring, and standardised compliance frameworks to enhance BIM-IoT's impact on construction safety.

Keywords: Advantages, BIM, Construction Safety, IOT, Integration

1. Introduction

Workplace safety has become a critical priority for industries due to its profound impact on employee health and overall productivity, with the construction industry experiencing a disproportionately high rate of workplace accidents (Kim and Chi, 2019). Occupational hazards are a persistent challenge in construction (Heidary Dahooie et al., 2020), where the frequent occurrence of accidents not only diminishes workforce efficiency but also leads to increased absenteeism. Given the significantly higher accident frequency in construction compared to other industries, this sector faces heightened safety risks (Nadhim et al., 2016).

Integration of Digital technologies capable of analysing and effectively communicating safety issues is crucial for improving overall safety performance (Han et al., 2009). In the past decade, research has focused on using digital technologies to reduce health and safety risks on construction sites. Key advancements include computer vision, IoT sensors, wearable devices, BIM, and immersive technologies like augmented and virtual reality, all aimed at improving hazard detection and safety management (Zhang et al., 2017). Despite advancements, single-technology solutions fall short of optimal safety standards, with research showing that a multi-technology approach, integrating various tools, yields more reliable safety outcomes (Wang et al., 2021). Integrating BIM with real-time data from IoT devices enhances construction safety by linking IoT sensor networks to high-fidelity BIM models, enabling various applications (Tang et al., 2019).

In recent years, various studies have explored the application of BIM-IoT integration in safety management; however, there is a lack of research identifying and analysing the advantages of adopting BIM and IoT technologies for improving safety within the construction sector. The key question that needs to be addressed is "What are the advantages of BIM-IoT integration in construction health and safety? "This study seeks to address this gap by conducting a comprehensive review and analysis of studies on the application of BIM-IoT integration in safety management, to identify and extract the advantages this integration offers to safety management.

2. Literature Review

Adoption of digital technologies in construction projects has grown due to the numerous benefits they offer in enhancing safety on construction sites. According to Luo et al (2022), there is a growing trend in research focused on utilising digital technologies to improve construction safety, with Virtual Reality, Augmented Reality, Digital Twins, BIM and the IoT identified as the most effective technologies. While BIM and IoT have been applied in areas like health and safety management, research on their integration is still in the early stages (Dave et al., 2018).

2.1. BIM and Construction Safety

Recent studies have shown that implementing the BIM methodology can improve the working conditions at

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construction sites (Cortés-Pérez et al., 2020). Azhar (2017) found that BIM can be utilised for better construction safety performance. BIM, a growing digital technology, is gaining attention for its role in enhancing safety design and improving construction safety management practices due to its object-oriented nature and effectiveness (Jin et al., 2019; Ding et al., 2014). Based on the literature reviewed, the main application of BIM in the safety management of the construction industry can be summarised in three aspects: interactive training of workers, site layout optimisation, and automatic checks for safety issues (Chatzimichailidou and Ma, 2022).

Several studies have investigated the use of BIM in managing construction safety issues. A classification of BIM-based tools highlighted the application of Virtual Reality for enhancing construction safety, particularly in training activities (Getulli et al., 2018). Another review compared BIM-based approaches with traditional risk management tools, emphasising BIM's potential in risk management, although it lacked a systematic selection of research published after 2015 (Zou et al., 2017). Research on using BIM and related technologies in the design phase focused on improving safety management and minimising design errors, with particular attention to Design for Safety (DfS) and its barriers (Xiaer et al., 2017). An investigation into BIM's shortcomings and its impact on safety involved a survey of field engineers in the construction industry (Alomari et al., 2017). Lastly, the relationship between BIM and worker safety performance was studied by identifying key factors and barriers through a literature review and a survey of practitioners (Ganah and Godfaurd, 2015).

2.2. IOT and Construction Safety

IoT has demonstrated significant potential in high-risk Environment, Health, and Safety (EHS) industries, where human lives are at stake, offering safe, reliable, and efficient solutions through fine-grained operation and rich data collection (Wang et al., 2021). In construction, IoT automates safety monitoring and hazard detection, enabling connected devices to transfer and analyse data effectively, making it a suitable technology for facilitating seamless data transmission across systems (Tabatabaee et al., 2022).
Several studies have investigated the use of IoT in managing construction safety issues. Yang et al. (2020) developed a tool based on IoT for detecting Personal Protective Equipment (PPE) to ensure that workers are provided with the appropriate PPE before beginning construction activities. Additionally, a protective IoT-based system was created by Kanan et al. (2018) to automatically monitor, localise, and warn construction workers in hazardous areas.

A detailed evaluation of the LoRa protocol demonstrated its suitability for IoT-based safety monitoring, provided battery-related constraints are addressed (Augustin et al., 2016). A Wi-Fi-based IoT safety surveillance system was proposed to connect field devices like cameras and smoke detectors, offering an innovative safety solution despite challenges such as power supply and mobility (Jiang et al., 2013). Computer vision-based wireless sensing technology monitored workers' compliance with personal protective equipment (Park and Brilakis, 2012), while motion tracking systems detected unsafe postures to reduce musculoskeletal risks (Ray and Teizer, 2012; Seo et al., 2013).

2.3. BIM-IoT Integration

Over the past decade, the integration of BIM and IoT has attracted growing interest, with a steady increase in related scholarly publications. These technologies offer complementary strengths: BIM provides detailed, component-level visualisations of construction projects, while IoT enhances safety management by supplying real-time data on-site conditions (Mohd-Nor et al., 2019). By combining these capabilities, BIM-IoT integration supports data-driven decision-making and more proactive safety interventions (Mohammed et al., 2020).

2.3.1. BIM-IoT integration and construction safety

According to Tang et al. (2019), prevalent applications integrating BIM and IoT data for health and safety management include safety training and on-site monitoring. Numerous studies have explored BIM-IoT integration for managing construction safety, highlighting its potential to enhance hazard identification, real-time monitoring, and overall safety performance.

Li et al. (2015) developed the Proactive Construction Management System (PCMS) for real-time safety monitoring and feedback, improving safety awareness and efficiency on a Hong Kong site, with global applicability for workforce training. Riaz et al. (2014) developed a BIM and sensor-based safety monitoring solution for confined spaces. Cheng and Teizer (2013) created a framework to stream real-time data to a VR platform for improved safety awareness. Kanan et al. (2018) introduced an IoT-based wearable system to provide real-time hazard alerts on construction sites. Ding et al. (2022) implemented an IoT-BIM system for managing hazardous energy in construction sites. Qian (2021) developed a tunnel monitoring system combining BIM, IoT, and GNSS to enhance safety and construction management. Kim et al. (2016) developed a BIM-based automated safety system to address scaffolding hazards by simulating worker movements and identifying potential risks. The system, integrated into commercial BIM software, successfully detected hazards and improved early safety communication in a real-world project. Scianna et al. (2022) integrated IoT sensors with BIM for real-time bridge deflection

monitoring, linking the physical structure to its digital twin for continuous risk assessment.

3. Research Methodology

A Systematic Literature Review (SLR) synthesises past research through a structured process to identify key themes, gaps, and future research areas while minimising bias and ensuring consistency (Zhou et al., 2015). This study employs an SLR to examine BIM-IoT integration for construction safety management, following a seven-step approach (Figure 1).



Figure 1: The SLR steps (Wright et al., 2007)

In Step 1, the research question is defined to establish scope and relevance, ensuring a balanced focus (Glasziou et al., 2001). In Step 2, an SLR protocol is developed to provide a structured selection process, covering background, research question, and strategy (Henderson et al., 2010). In Step 3, a comprehensive literature search is conducted, using defined search terms and strict inclusion/exclusion criteria to ensure consistency (Wright et al., 2007). In Step 4, selected studies are evaluated using the CASP checklist to assess quality and relevance. In Step 5, data extraction is carried out using tailored forms to avoid duplicates, with a two-stage screening of titles, abstracts, and key sections. In Step 6, data analysis is performed by grouping key findings based on BIM-IoT integration similarities in construction safety, including design and construction. Finally, in Step 7, the results are presented through descriptive analysis, categorising text data to reveal patterns, and pattern coding, identifying themes to refine insights and develop a theoretical framework (Saldaña, 2021; Miles & Whitehouse, 2013).

4. Findings and Discussion

To identify the advantages of BIM-IoT integration in construction health and safety, the systematic review steps are applied as follows.

Step 1: Determining research questions

- "What are the advantages of BIM-IoT integration in construction health and safety?"

Step 2: research contract

The protocol developed to guide the selection of studies used in this research includes the following steps:

- Background

Since the research explores BIM-IoT integration in construction safety and its advantages, this foundation informs the inclusion and exclusion criteria in the review protocol.

- Research question

The overarching objective of conducting an SLR is to address the following question:
"What are the advantages of BIM-IoT integration in construction health and safety?"

- Research strategy and data sources

To identify the most relevant answers to the research question, the strategy outlined in Figure 2 is applied throughout the SLR process.

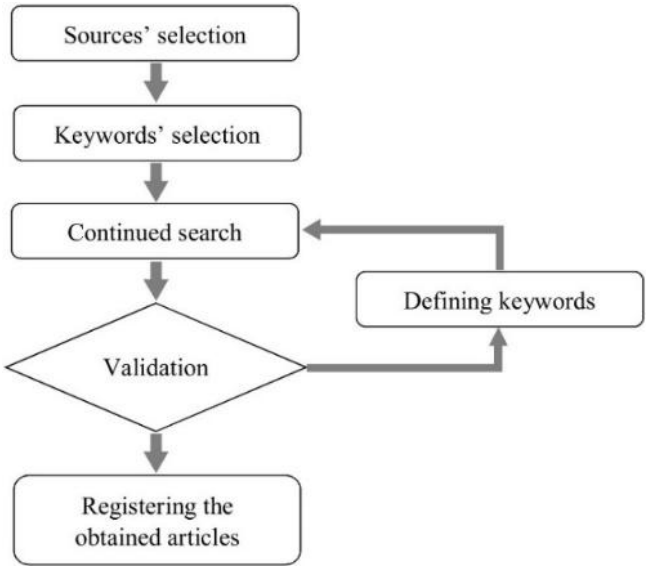


Figure 2: Research strategy

The keywords for the SLR are derived from the research question, focusing on terms like "BIM," "IoT," "Safety," and "Advantages/Benefits". Three major indexed databases —Science Direct, Scopus, and Web of Science (WoS) —are targeted due to their reliable citation indexing and peer-reviewed content.

Step 3: Text search

The authors utilised the following input and output criteria in the selection of articles for the SLR, as illustrated in Table 1.

The search, conducted from August 2024 to January 2025 using keywords, yielded 542 articles (315 from ScienceDirect, 124 from Scopus, and 103 from WoS). After removing duplicates and irrelevant studies, 198 articles remained (Table 2).

At this stage, 198 papers were reviewed based on keywords, abstracts, and full texts, resulting in the selection of 94 articles (Table 3).

Table 1: Background Information of Informants from IGOPLAS

Criteria	Inclusions	Exclusions
Publication timeline	• Between 2010 and 2025	• Before 2010
Document type	• Journal (research articles)	• chapters in a book, books, reports, review papers, conference papers
Type of domain	• BIM-IOT integration in safety management only	• Exclude BIM-IOT integration in other domains (Facility management and …)
Language	• English	• Non-English

Table 2: BIM-IOT initial search results

Databases	Science direct		Scopus		Web of Science	
Search BIM-IOT	Total articles	Selected articles	Total articles	Selected articles	Total articles	Selected articles
Numbers	315	142	124	32	103	24

Table 3: Keywords and reviewing abstracts

Databases	Science direct	Scopus	Web of Science
Search keywords	51	20	23
Final selected articles	94		

Step 4: Quality evaluation
In this section, the codes are classified as outlined in the results presentation step (Figure 3).

The results of the data extraction process and data analysis are presented in Table 4 (see Appendix 1).

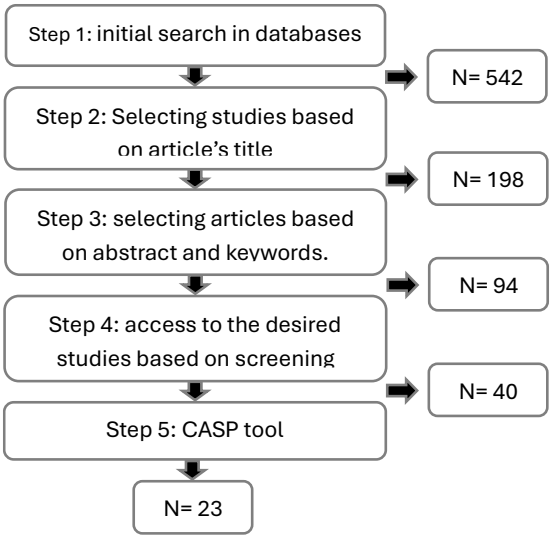


Figure 3: Steps for selection of the articles

The final evaluation used the CASP instrument, assessing 10 criteria like research design and methodology. Articles were rated on a 5-point scale and categorised into quality groups. The qualitative scores were then categorised into very good (41-50), good (31-40), medium (21-30), poor (11-20), and very poor (0-10). Those scoring below 20 were excluded, leaving 23 articles for analysis.

Steps 5 and 6: Data extraction and Data analysis
To extract relevant data, the following questions guide the data extraction process:

- Does the article address BIM-IoT integration in construction safety?
- Are the research objectives clearly stated?
- Does the article provide insights relevant to the research questions?

Step 7: Results presentation and interpretation
The integration of BIM and IoT offers significant advantages for the OSH management (Figure 4). The bar chart visualises the number of references for each advantage of BIM-IoT integration in the OSH management. The findings highlight improved safety monitoring as the most cited advantage (17 references), reinforcing the role of real-time data collection and hazard detection in construction safety. Enhanced real-time decision-making and emergency response, referenced by 12 sources, further highlight the dynamic nature of BIM-IoT integration in preventing accidents and managing emergencies more efficiently. Additionally, enhanced hazard identification and risk assessment are strongly supported by 11 references, underscoring the proactive role of BIM-IoT in identifying and mitigating risks before incidents occur.

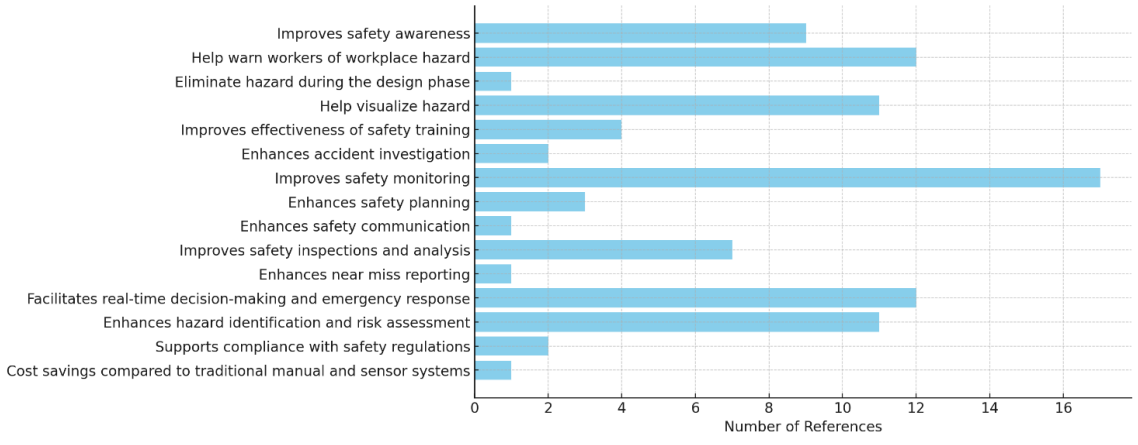


Figure 4: Advantages of BIM-IOT integration for OSH management

Among design-phase benefits, hazard elimination during design received comparatively fewer references, indicating the need for broader adoption despite its recognised potential. Similarly, hazard visualisation (11 references) is frequently cited, underscoring its role in enhancing situational awareness and proactive safety planning. Additionally, improving workers' safety awareness and warning workers of workplace hazards were frequently noted, demonstrating the technology's role in fostering a safety-conscious culture. However, advantages such as enhanced near-miss reporting and compliance with safety regulations were less frequently referenced, suggesting areas for further exploration and improved implementation.

Overall, the results confirm that BIM-IoT integration enhances real-time monitoring, decision-making, and risk mitigation in construction safety. However, further research is needed to optimise its application in hazard prevention during the design phase and regulatory compliance.

5. Discussion

The findings reinforce the significant role of BIM-IoT integration in improving OSH management, particularly through enhanced safety monitoring, real-time decision-making, and hazard identification. These benefits align with previous studies (e.g., Riaz et al., 2014; Ding et al., 2022), which emphasise the ability of BIM-IoT systems to provide real-time insights for proactive safety interventions. The high citation frequency of these advantages suggests strong industry recognition of their value in accident prevention and emergency response.

Despite these advantages, hazard elimination during the design phase received fewer references. This indicates that while BIM-IoT has the potential to enhance safety at the design stage (Hu et al., 2024), its practical implementation remains limited. This gap may be due to insufficient integration of safety data into BIM models or the lack of standardised protocols for incorporating hazard identification into early design workflows. Future research should explore ways to optimise BIM-IoT frameworks for hazard prevention at the pre-construction stage.

Similarly, the low emphasis on regulatory compliance and near-miss reporting suggests a disconnect between BIM-IoT applications and compliance-driven safety management. While some studies highlight the potential of digital tools to improve safety documentation and compliance tracking (Liang & Liu, 2022), practical adoption appears to lag. Addressing this issue may require policy alignment, stakeholder engagement, and enhanced automation in compliance tracking.

Overall, while BIM-IoT integration has demonstrated strong capabilities in real-time hazard monitoring and emergency response, further advancements are needed to leverage its potential in design-phase safety and regulatory compliance fully. Future studies should focus on bridging these gaps through enhanced data integration, standardisation, and industry adoption strategies.

6. Conclusion and Further Research

This study highlights the significant advantages of BIM-IoT integration in Occupational Safety and Health (OSH) management, with strengths in real-time safety monitoring, emergency response, and hazard identification. The findings confirm that BIM-IoT systems enable proactive safety interventions by leveraging real-time data and visualisation tools. However, despite these advantages, certain areas, such as hazard elimination during the design phase and regulatory compliance support, remain underexplored. The limited emphasis on these aspects suggests that while BIM-IoT holds promise for improving safety from the early design stage, practical adoption and implementation challenges persist. Addressing these gaps requires further research and industry-driven innovations to optimise BIM-IoT frameworks for holistic safety management.

Future research should focus on enhancing BIM-IoT integration for design-phase hazard prevention, optimising predictive safety analytics, and standardising safety compliance frameworks. Further studies are needed to develop automated hazard detection tools, explore AI-driven safety monitoring, and address barriers to industry adoption. Investigating these areas will help unlock the full potential of BIM-IoT for proactive and data-driven safety management in construction.

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Appendix 1

Table 4: Advantages of using BIM-IOT integration for OSH Management

N	Advantages	References
1	Improve safety awareness	Fan et al (2021), Ding et al (2013), Cheng and Teizer (2013), Kiani et al (2014), Li et al (2015), Ding et al (2022), Parn et al (2019), Chen et al (2021), Riaz et al (2014)
2	Help warn workers of workplace hazard	Fan et al (2021), Ding et al (2013), Kiani et al (2014), Li et al (2015), Parn et al (2019), Liang and Liu (2021), Chen et al (2021), Qian (2021), Hossain et al (2023), Yuan et al (2016), Cheung et al (2018), Riaz et al (2014)
3	Eliminate hazard during the design phase	Hu et al (2024),
4	Help visualize hazard	Sakr and Sadhu (2023), Scianna et al (2022), Fan et al (2021), Ding et al (2013), Cheng and Teizer (2013), Kiani et al (2014), Zhang and Bai (2015), Li et al (2015), Parn et al (2019), Hossain et al (2023), Hu et al (2024),
5	Improves effectiveness of safety training	Fan et al (2021), Cheng and Teizer (2013), Li et al (2015), Teizer et al (2013),
6	Enhancing accident investigation	Scianna et al (2022), Li et al (2015)
7	Improve safety monitoring	Sakr and Sadhu (2023), Scianna et al (2022), Cheng and Teizer (2013), Fan et al (2021), Kiani et al (2014), Zhang and Bai (2015), Li et al (2015), Ding et al (2022), Liang and Liu (2021), Chen et al (2021), Qian (2021), Hossain et al (2023), Riaz et al (2017), Yuan et al (2016), Hu et al (2024), Jiang and Jiang (2024), Cheung et al (2018)
8	Enhancing safety planning	Scianna et al (2022), Fan et al (2021), Pang et al (2024),
9	Enhancing safety communication	Yuan et al (2016),
10	Improve safety inspections and analysis	Sakr and Sadhu (2023), Scianna et al (2022), Fan et al (2021), Li et al (2015), Ying et al (2020), Yuan et al (2016), Riaz et al (2014)
11	Enhancing near miss reporting	Li et al (2015)
12	Facilitating real-time decision-making and emergency response	Sakr and Sadhu (2023), Ding et al (2013), Cheng and Teizer (2013), Zhang and Bai (2015), Li et al (2015), Parn et al (2019), Chen et al (2021), Qian (2021), Yuan et al (2016), Pang et al (2024), Cheung et al (2018), Riaz et al (2014)
13	Enhancing hazard identification and risk assessment	Scianna et al (2022), Kiani et al (2014), Zhang and Bai (2015), Li et al (2015), Qian (2021), Riaz et al (2017), Yuan et al (2016), Hu et al (2024), Jiang and Jiang (2024), Pang et al (2024), Cheung et al (2018),
14	Supports compliance with safety regulations	Ding et al (2022), Liang and Liu (2021)
15	Cost savings compared to traditional manual and sensor system	Hossain et al (2023)

Key Drivers of Wearable Technology Usage for Worker Safety on Construction Sites in Nigeria

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Abstract

Despite significant advancements in wearable technology, the construction industry faces high rates of accidents, injuries, and fatalities. Hence, this study aims to evaluate the key drivers of wearable technology in Nigeria's construction sites to foster the health and safety of workers and other stakeholders in building projects. A post-positivist philosophical approach guided a quantitative research methodology employing a questionnaire survey for this study. The population comprises professionals with health and safety certifications who interact with safety protocols and wearable technology on construction sites within Lagos state. Using snowball sampling, 360 questionnaires were distributed online and physically; 164 copies were retrieved, screened, and analysed using descriptive analysis. The ranking of drivers reveals that enhanced safety outcomes, regulatory compliance, and potential cost savings are the primary motivations for adopting wearable technology. The standard deviation results showed that the responses from the survey were consistent and uniform since all their values were less than one (1). Based on the findings of this research, it is recommended that government bodies introduce policies that incentivise the adoption of wearable technology through subsidies or tax benefits. Regulatory frameworks should also be established to standardise the use of these technologies across the industry. The outcome of this study points to the need for further exploration into the long-term sustainability and cost-effectiveness of wearable technology in the construction industry. Additionally, it opens the door for research into how these technologies could be integrated into safety protocols in other regions or sectors within Nigeria.

Keywords: Wearable Technologies, Health and Safety, Construction Sites, Drivers, Nigeria

1. Introduction

The construction industry is a key sector of the economy as it is engaged in building structures that form the framework of societies and economies. Though it is a crucial industry, it is one of the riskiest industries in terms of accidents, injuries, and fatalities (Griffiths et al., 2017). Making improvements to safety in this industry is paramount, and as we have seen with the developments in wearable technologies, they could be the fix we need. It gives real-time monitoring information, reducing many of the risks typical of construction sites (Chen *et al.*, 2023). Wearable technology refers to a group of gadgets that are worn on the body or integrated into garments. These devices are smart helmets, wearable sensors, bright vests, and augmented reality. Glasses or goggles aim to improve the worker's safety by tracking the worker's environment and health status. For instance, smart helmets can identify the driver's fatigue and attentiveness levels; wearable biosensors can track physiological conditions and toxic substances in the surroundings; and smart vests can help locate a worker to prevent accidents such as collisions and falls (Chen et al., 2023). Implementing these technologies in the construction sector is expected to bring several benefits, such as fewer accidents, increased production, and improved workplace safety (Okoye *et al.*, 2017). However, there are reasons wearable technology has not been fully embraced in the construction industry. The existing literature highlighted several sources of the issue, such as high costs, non-standardisation, change management resistance, and training insufficiency, as key challenges (Umeokafor & Teizer, 2023). Moreover, identifying the factors influencing people to incorporate wearable tech devices is crucial for driving their acceptance (Okpala et al., 2022). Some factors, including safer practices, compliance with the law, the possibility of reduced costs, and higher productivity, are always considered when construction firms decide which measures to adopt (Davis, 1989). Understanding these drivers will help stakeholders formulate specific measures that suit the popularisation of wearable technology.

Despite significant advancements in wearable technology, the construction industry faces high rates of accidents, injuries, and fatalities. This remains the case when wearable devices that can monitor and analyse protective data in real-time are available to boost the protection of workers (Griffiths et al., 2017). The author also found a high frequency of different types of accidents, indicating that the opportunity for wearable technology and smart garments to enhance safety performance on construction sites remains unexplored. There is a significant research gap in identifying how well these technologies are being adopted and for what purposes in practice (Chen *et al.*,

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2023). This work employs a survey research method and collects primary data from a large pool of participants, including construction employees, site supervisors, and safety personnel.

This study aims to evaluate the key drivers of wearable technology in Nigeria's construction sites to foster the health and safety of workers and other stakeholders in building projects. The outcome of this research will be a valuable addition to the literature on wearable technology in construction, possessing practical implications for various stakeholders in the construction sector. Thus, this study seeks to address the barriers by promoting the use of wearable technology and leveraging key drivers to enhance its implementation in construction safety, thereby improving the safety of construction workers and reducing the high incidence of accidents and injuries in the construction industry.

2. Wearable Technology in Construction

Wearable technology encompasses various devices worn on the body to monitor, collect, and analyse data in real-time. In the construction industry, these devices include smart helmets, wearable sensors, smart vests, and augmented reality glasses (Tetteh et al., 2024). These technologies aim to enhance safety by providing real-time information about the worker's physical condition and environmental hazards, thereby enabling prompt intervention and the prevention of accidents (Nnaji et al., 2020). Smart helmets, for instance, are equipped with sensors that can detect fatigue, alertness levels, and even environmental conditions such as temperature and humidity (Khosravi et al., 2021). These helmets can alert workers and supervisors if there are signs of heat stress, dehydration, or other health issues, allowing for timely interventions to prevent accidents and enhance worker safety.

Additionally, smart helmets can be integrated with augmented reality features, providing workers with visual overlays of construction plans and real-time data about their surroundings, which can improve accuracy and reduce errors (Oke & Arowoiya, 2022). Smart helmets represent a significant advancement in personal protective equipment for construction workers. These innovative helmets are embedded with various sensors to monitor crucial physiological parameters, including heart rate, body temperature, and fatigue (Campero-Jurado et al., 2020). By continuously tracking these vital signs, smart helmets can detect anomalies that may indicate health issues or the onset of fatigue, thereby preventing accidents before they occur. These advanced features make smart helmets an invaluable tool for enhancing worker safety on construction sites. By providing continuous health monitoring, precise location tracking, seamless communication, and timely alerts, smart helmets protect workers from immediate dangers and contribute to the overall safety culture of the construction industry (Ibrahim et al., 2023).

Wearable sensors are another critical component of wearable technology in construction (Ibrahim et al., 2025). These sensors can be embedded in clothing or worn as standalone devices such as wristbands or armbands (Okpala et al., 2021). They monitor various physiological parameters, including heart rate, body temperature, and movement patterns. By analysing this data, the sensors can detect signs of physical strain, overexertion, or dangerous fatigue levels, prompting immediate action to prevent injuries. Wearable sensors have emerged as invaluable tools within construction site environments, strategically deployed to monitor and enhance various aspects of safety and productivity (Ahn et al., 2019). These devices can be affixed to workers' clothing or equipment, providing continuous real-time data on critical parameters such as movement, posture, and exposure to hazardous substances like chemicals or particulate matter. For instance, wearable sensors are adept at detecting sudden falls or accidents, promptly alerting supervisors and emergency response teams to minimise response times and mitigate injuries (Umeokafor & Teizer, 2023). This capability is crucial in high-risk construction environments where immediate intervention can differentiate between minor incidents and serious harm. Moreover, the integration of wearable sensors on construction sites goes beyond safety. They also play a pivotal role in optimising workflow efficiencies by monitoring workers' activity levels and fatigue, helping to schedule breaks and tasks more effectively. This proactive approach enhances productivity and reduces the likelihood of accidents caused by worker fatigue or overexertion (Ibrahim et al., 2023). In addition to enhancing safety and productivity, wearable sensors improve overall site management by providing comprehensive data insights (Turner et al., 2020). This data can inform decision-making processes related to resource allocation, task prioritisation, and equipment maintenance, fostering a more streamlined and efficient construction operation (Jones et al., 2018). Overall, wearable sensors represent a transformative technology in the construction industry, offering multifaceted benefits that range from enhancing safety protocols and productivity to optimising management strategies. As these devices evolve, their integration into construction practices promises to elevate further safety standards, efficiency, and overall project outcomes.

Smart vests combine multiple wearable technologies, including sensors and GPS, to provide comprehensive safety monitoring. These vests can track workers' locations, detect hazardous conditions, and communicate alerts to the workers and the site management team (Edirisinghe, 2019). Integrating various sensors allows smart vests to monitor various physiological and environmental parameters. Moreover, the data collected by smart vests can be used

to analyse patterns and identify recurring safety issues, allowing for proactive measures to prevent future incidents (Edirisinghe, 2019). Smart vests also contribute to improving overall site efficiency. By tracking the location and movement of workers, site managers can optimise workflows, reduce idle times, and ensure that personnel are deployed effectively. This capability enhances productivity and helps coordinate emergency responses more efficiently. In addition, smart vests can support compliance with safety regulations by providing detailed records of safety conditions and responses on-site (Jones et al., 2018; Cai et al., 2023).

In conclusion, smart vests represent a significant advancement in wearable technology for construction safety. By combining real-time monitoring, alerting systems, and data analytics, these vests offer a multifaceted approach to managing safety risks. As the construction industry evolves, adopting smart vests and other wearable technologies will likely play a crucial role in creating safer and more productive work environments. These wearable technologies enhance safety by providing real-time information about the worker's physical condition and environmental hazards. This immediate feedback allows for prompt intervention and the prevention of accidents, ultimately creating a safer and more efficient work environment. By leveraging the capabilities of wearable technology, the construction industry can significantly reduce the incidence of accidents, improve worker health and safety, and increase overall productivity.

3. Research Methodology

This study adopted a post-positivist philosophical approach to establish the key drivers of wearable technology usage on construction sites in Nigeria. This philosophical viewpoint guided a quantitative research methodology employing a questionnaire survey. Creswell (2014) states that the quantitative research approach collects numerical data that may be categorised, ranked, or assessed using units of measurement. Using data from the reviewed literature, a closed-ended questionnaire was created for this study to collect data from the target population. The target population for this study included construction workers, site managers, safety officers, and other stakeholders involved in construction projects in Lagos State. These individuals were selected based on their interaction with safety protocols, health and safety certification, and wearable technology on construction sites. The study's design required a snowballing sampling technique—a method of gathering data in which research participants help recruit new study participants. Research using hardly identifiable respondents has employed this method (Mould-Millman et al., 2017; Akinradewo et al., 2022; Ebiloma et al., 2024). Two building professionals from academia and industry were chosen to achieve this, and additional professionals and stakeholders who met the study's requirements and were eligible to participate were also found.

There were two distinct sections of the questionnaire. Section A collected background information from the respondents, while Section B concentrated on the key drivers of wearable technologies. Participants used the survey's 5-point Likert scale to indicate their level of agreement or disagreement with the factors. A 5-point Likert-type scale increased answer quality and rate while reducing respondents' frustration (Joshi et al., 2015). Tables and charts were used to derive statistical conclusions based on their responses. Microsoft Excel and the Statistical Package for Social Science (SPSS) software were used to analyse the data. The mean item scores, percentiles, and frequencies were computed from the collected data. Percentiles and frequencies were used to examine the respondents' demographic data, and the mean item score was used to sort the variables according to the respondents' answers. 164 copies of the 360 survey questionnaires that were distributed were recovered. Every recovered questionnaire was examined and determined to be appropriate for analysis. The filled questionnaires represented a response rate of 45.5%; this is considered robust for a study of this nature, significantly exceeding the 30% threshold commonly accepted as a satisfactory response rate in construction-related studies (Ryal-Net & Kaduma, 2015). This high response rate strengthens the validity of the study's findings. It contributes to the depth of insights regarding the use of wearable technologies on construction sites in Lagos State, Nigeria. Cronbach's alpha was used to assess the study instrument's reliability; the results showed an alpha value of 0.926, confirming the validity of the data obtained from the questionnaire survey.

4. Findings and Discussion

4.1. Socioeconomic Background of Respondents

The analysis of the socioeconomic background of the respondents, who are professionals in the Nigerian construction industry, particularly in Lagos State, aims to verify the suitability of the respondents to provide adequate information to achieve the study's objective. To verify the respondents' suitability and reliability of the information provided, the following background information was requested: profession, years of experience, educational qualification, and professional registration status.

As presented in Table 1 in terms of profession, builders make up the most significant proportion (51.2%) of respondents, followed by Quantity Surveyors (20.7%), Safety Officers (9.8%), Electrical Engineers (7.9%), Civil Engineers (6.7%), and Mechanical Engineers (3.7%). This distribution suggests that the study has adequately represented the various professions within

Table 1: Socioeconomic Background of the Respondents

Characteristics	Frequency (n=164)	Percentage
Profession		
Builder	84	51.2%
Civil Engineer	11	6.7%
Electrical Engineer	13	7.9%
Mechanical Engineer	6	3.7%
Quantity Surveyor	34	20.7%
Safety Officer	16	9.8%
Years of Experience		
1 - 5 years	102	62.2%
6 - 10 years	55	33.5%
11 - 15 years	5	3.0%
16 – 20 years	2	1.2%
Educational Qualification		
B.SC	115	70.1%
HND	12	7.3%
M.SC	33	20.1%
PHD	3	1.8%
OND	1	0.6%
Professional Registration Status		
Corporate	6	3.7%
Graduate	143	87.2%
Licentiate	5	3.0%
Technician	10	6.1%

(Source: Author's Survey)

the construction industry. The analysis of professional experience reveals that most respondents have 1-5 years of experience (62.2%), while 33.5% have 6-10 years, 3% have 11-15 years, and 1.2% have 16-20 years. This indicates a relatively young and experienced workforce. Regarding educational qualification, most respondents hold a Bachelor's degree (70.1%), followed by a Master's degree (20.1%), a Higher National Diploma (HND) (7.3%), Doctor of Philosophy (PhD) (1.8%), and an Ordinary National Diploma (OND) (0.6%).

This high level of educational attainment suggests that the respondents are knowledgeable and competent in their respective fields. The professional registration status of the respondents indicates that the majority (87.2%) are Graduate members of their respective professional bodies, followed by Corporate members (3.7%), Licentiate members (3%), and Technician members (6.1%). This suggests that the respondents are professionally qualified and registered. The socioeconomic background analysis indicates that the respondents are suitable and reliable sources of information for achieving the study's objectives.

4.2. Key Drivers of Wearable Technology Usage on Construction Sites

The key drivers behind the adoption of wearable technology in the construction industry are presented in Table 2. This table provides an overview of the mean scores and standard deviations for 25 potential drivers. Improved worker safety and risk reduction emerged as the top driver, with a mean score of 4.30, indicating that respondents strongly associate wearable technology with enhanced safety and reduced risk. Enhanced productivity and efficiency followed closely with a mean score of 4.01. Real-time data analysis and insights, compliance with regulatory requirements, and competitive advantage and market differentiation also ranked highly, with mean scores ranging from 3.99 to 3.97. These scores suggest that respondents value wearable technology for its potential to improve operational performance, decision-making, and competitiveness. Other significant drivers include cost savings and return on investment (3.97), improved worker health and well-being (3.96), enhanced collaboration and communication (3.96), and increased transparency and accountability (3.95). These findings highlight the importance of wearable technology in promoting a safe, healthy, and productive work environment. The ranking of drivers reveals that safety, productivity, and efficiency are the primary motivations for adopting wearable technology. The lowest-ranked drivers include alignment with organisational goals and objectives (3.77), access to new technologies and innovations (3.82), and improved data-driven decision-making (3.80). The standard deviation results showed that the responses from the survey were consistent and uniform since all their values were less than one (1).

Table 2: Descriptive Statistics for Key Drivers of Wearable Technology Usage

Drivers	Mean	Std. Deviation	Rank
Improved worker safety and risk reduction	4.30	.929	1
Enhanced productivity and efficiency	4.01	.739	2
Real-time data analysis and insights	3.99	.779	3
Compliance with regulatory requirements	3.99	.783	4
Competitive advantage and market differentiation	3.97	.713	5
Cost savings and return on investment	3.97	.787	6
Improved worker health and well-being	3.96	.759	7
Enhanced collaboration and communication	3.96	.712	8
Increased transparency and accountability	3.95	.785	9
Better decision-making and planning	3.94	.781	10
Improved incident response and emergency management	3.94	.757	11
Enhanced supply chain management	3.93	.788	12
Improved asset tracking and management	3.92	.700	13
Environmental sustainability and reduced waste	3.92	.759	14
Improved worker training and development	3.91	.832	15
Improved customer satisfaction and experience	3.91	.813	16
Enhanced project management and control	3.90	.769	17
Improved quality control and assurance	3.90	.884	18
Reduced workers' compensation claims	3.90	.788	19
Improved business continuity and resilience	3.87	.837	20
Enhanced reputation and brand image	3.84	.791	21
Improved stakeholder engagement and trust	3.84	.821	22
Access to new technologies and innovations	3.82	.793	23
Improved data-driven decision-making	3.80	.745	24
Alignment with organisational goals and objectives	3.77	.778	25

(Source: Author's Survey)

5. Discussion of Findings

This study identifies enhanced safety outcomes, regulatory compliance, and potential cost savings as primary drivers for wearable technology adoption, aligning with existing literature (Chen et al., 2023; Tetteh et al., 2024). Enhanced safety outcomes emerged as the primary driver, consistent with previous findings (Chen et al., 2023; Tetteh et al., 2024). Wearable devices provide real-time monitoring and alerts, reducing the likelihood of accidents and improving response times. Regulatory compliance, encouraged by bodies like the Occupational Safety and Health Administration (OSHA), is another significant driver (Mollo, 2024). Firms recognise the importance of adhering to safety regulations. Potential cost savings through reduced accidents, lower insurance premiums, and increased productivity drive adoption (Chen et al., 2023). The study's findings corroborate existing literature, highlighting the importance of safety, compliance, and cost savings.

The construction industry's adoption of wearable technology is driven by a desire to improve worker safety, productivity, and efficiency. Wearable technology supports regulatory compliance and cost savings and enhances collaboration, transparency, and accountability. The findings suggest that organisations value wearable technology for its potential to transform the construction industry. By understanding these key drivers, stakeholders can develop targeted strategies to promote the adoption of wearable technology. Adopting wearable technology can benefit the construction industry, including improved worker safety, increased productivity, and enhanced competitiveness. As the industry continues to evolve, wearable technology will likely play a critical role in shaping its future.

6. Conclusion and Further Research

The study's results conclusively demonstrate that wearable technology has the potential to transform the construction industry by enhancing productivity, safety, and efficiency. The findings highlight the significance of wearable technology in improving construction processes, reducing errors, and enhancing worker well-being. However, successful implementation requires careful consideration of cost management, standardisation, change management, and comprehensive training. The study identified key drivers of wearable technology adoption, including improved productivity, enhanced safety, and increased

efficiency. Based on the findings of this research, it is recommended that government bodies introduce policies that incentivise the adoption of wearable technology through subsidies or tax benefits. Regulatory frameworks should also be established to standardise the use of these technologies across the industry. The outcome of this study points to the need for further exploration into the long-term sustainability and cost-effectiveness of wearable technology in the construction industry.

Additionally, it opens the door for research into how these technologies could be integrated into safety protocols in other regions or sectors within Nigeria. Future studies could evaluate the return on investment (ROI) over an extended period and examine how wearable technology impacts project costs, profitability, and operational efficiency in the long run. This study focused on wearable technology as an independent safety tool. However, future research could examine how these devices can be seamlessly integrated into broader occupational health and safety systems already in use on construction sites. Understanding how wearable technology interacts with current safety practices will provide deeper insights into how best to implement these technologies for maximum effectiveness.

Additionally, future studies could explore the regional and sectoral differences in the adoption of wearable technology. This research focused on Lagos State, Nigeria, but technology adoption may vary significantly across different regions and sectors within the construction industry. Comparative studies across other states or countries and exploring adoption in specialised construction sectors (e.g., infrastructure projects, residential buildings) would offer a more comprehensive understanding of the factors influencing the uptake of wearable technology.

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Strategies for Blockchain Technology Adoption in Facility Management Practices in Nigeria

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Abstract

The digitalisation in Nigeria's facility management sector is inadequate, leading to inefficient and complex procurement processes. As a result of the COVID-19 pandemic, blockchain technology could handle the challenges within the sector. Hence, this study aims to determine blockchain technology adoption strategies in Nigeria's facility management practices. A post-positivist philosophical approach guided a quantitative research methodology employing a questionnaire survey for this study. The population comprised builders, civil engineers, estate managers, and facility managers selected from professional institutes and associations within Lagos state. Using the random sampling technique, 389 questionnaires were distributed online and physically; 195 copies were retrieved, screened, and analysed using descriptive analysis, while Cronbach's Alpha tested the reliability. Results revealed that organisational culture, leadership, and stakeholder engagement were particularly important. While technological advancements, data security, and cost-effective solutions are also valued, the role of government policy, partnerships, and the development of skilled professionals are viewed as moderately significant, with a need for broader awareness and training to drive adoption further. The wide range of standard deviations across responses indicates that while general agreement exists on these strategies, the degree to which they are prioritised varies significantly among different respondents. The findings of this study provide invaluable insights that will enhance the effectiveness and efficiency of facility management practices through blockchain technology. The transition towards blockchain adoption requires concerted efforts from all stakeholders, including government agencies, educational institutions, and industry professionals, to create an enabling environment that fosters innovation, collaboration, and continuous learning in facility management.

Keywords: Blockchain, Contractual Arrangements, Facilities Management, Innovation, Nigeria, Stakeholders

1. Introduction

Blockchain technology has emerged as a potential solution to the challenges of facility management (FM) practices, offering unique features such as security, immutability, transparency, and accountability (Guo & Yu, 2022). As a decentralised, secure, and transparent system, blockchain can transform facility management processes, revolutionising maintenance procedures and contract payments. By implementing a blockchain system, maintenance needs and repair contracts can be securely stored, with the ledger automatically updating through data from sensors that monitor appliance conditions and schedule routine check-ups. Furthermore, FM urgently needs to track and manage energy consumption in real time, reduce costs, and improve efficiency (Sweetlyn, 2023). The digitalisation of FM is fundamentally transforming the field, shifting from traditional document-based methods to advanced digital practices. As technology progresses towards smart buildings, FM must adapt and utilise tools to transition from digital dormancy to a digital revolution (Collins & Lindkvist, 2022). The advantages of implementing blockchain technology in the business procedure of the built environment are accelerated as scalability alternatives are also included with the proper growth of technology. The idea is to conduct transactions off-chain and store and access data on the blockchain (Akinradewo et al., 2022). There is much that blockchain technology can offer to the facility management sector.

Blockchain could be the solution. Facilities can now manage data using a blockchain instead of a database. The Harvard Business Review states, "Blockchain Technology is among the most disruptive forces of the past decade with its power to record, enable, and secure huge numbers and varieties of transactions" (Vargas & Tapscott, 2019). While the technology is still in the early stages, understanding how Blockchain can enable construction companies to be more productive is important. Blockchain enables near-real-time settlement of all recorded transactions, allows for the debugging of potential conflicts and fraud prevention, and helps to reduce risks. Blockchain will profoundly impact how facilities managers operate and maintain buildings (Shi & Tay, 2019). Smart Contracts and Blockchain are the heart of innovative building management. Blockchain streamlines operations, reducing paperwork and administrative costs while optimising energy usage (Guo & Yu, 2022). One of the potential applications of blockchain technology in facility management is the management of building maintenance. According to Perera *et al*. (2020),

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blockchain technology can facilitate the sharing and updating of building maintenance data among stakeholders, including building managers, tenants, and contractors.

Nigeria's facility management (FM) field is still evolving and faces several challenges. Despite its growth and establishing the Nigerian chapter of the International Facilities Management Association (IFMA) in 1997, FM in Nigeria has not fully benefited from digital innovations that could enhance its effectiveness. One of the primary challenges is the public perception of FM as an "all-comers affair," which undermines practitioners' competence and the profession's overall image (Oyedele, 2019). The FM industry globally has seen significant technological disruptions, particularly in integrating smart technologies. However, the adaptation of digitalisation in Nigeria's FM sector remains poor, leading to inefficient and complex procurement processes. As a result, the potential of FM to add value to the built environment and achieve strategic organisational objectives is not fully realised (Nwokedi, 2020). Blockchain technology, a peer-to-peer distributed digital ledger, offers potential solutions to these challenges. It provides transparency in data handling, traceability of transactions, and ease of collaboration between parties. In the context of FM, blockchain can streamline operations, secure data, and enhance decision-making processes. However, its implementation in Nigeria's FM sector is fraught with challenges, including technological adoption barriers and the need for a framework that enables its practical use (Omotayo *et al.*, 2021). Therefore, this research aims to identify strategies for adopting blockchain technology in facility management practices in Nigeria. It seeks to determine recommendable and workable strategies for the effective use of blockchain in FM processes, demonstrating its potential impact and addressing its implementation challenges. By doing so, the research hopes to contribute to the advancement of FM in Nigeria, ensuring it can leverage digital innovations to improve efficiency, security, and sustainability in managing facilities.

2. Research Methodology

Using empirical data, this study adopted a post-positivist philosophical approach to establish the strategies for adopting blockchain technology in facility management practices in Nigeria. This philosophical viewpoint guided a quantitative research methodology employing a questionnaire survey. Creswell (2014) states that the quantitative research approach collects numerical data that may be categorised, ranked, or assessed using units of measurement. Using data from the reviewed literature, a closed-ended questionnaire was created for this study to collect data from the target population. The professionals and stakeholders involved in facility management in Lagos state were chosen as the study's population. These professionals are Builders, Civil Engineers, Estate Surveyors, and Facility Managers. A population frame of 14278 was established for the study based on the register of professionals in Lagos state obtained from the directories of professional bodies in Nigeria. The professional bodies are the Nigerian Institute of Building (NIOB), the Nigerian Society of Engineers (NSE), the Nigerian Institute of Estate Surveyors and Valuers (NIESV), and the International Facility Management Association (IFMA) within Lagos state, Nigeria. Taro Yamane's formula was used to calculate the sample size, resulting in 389 (Table 1). The number of respondents to be allotted to each of the groups of professionals in the construction industry was determined using the proportional stratified random sampling method. The random sampling method was used to select respondents to whom copies of the questionnaire would be administered. Years of professional registration were used to select respondents for each group.

Table 1: Determination of Sample Size for the Study

S/N	Professionals	Population	Sample size
1	Builders	1288	35
2	Estate Managers	2180	58
3	Civil Engineers	8500	231
4	Facility Managers	2370	65
Total		14278	389

(Source: Author's Findings)

There were two distinct sections of the questionnaire. Section A collected background information from the respondents, while Section B concentrated on the adoption strategies. Participants used the survey's 5-point Likert scale to indicate their level of agreement or disagreement with the factors. A 5-point Likert-type scale increased answer quality and rate while reducing respondents' frustration (Joshi et al., 2015; Akinradewo et al., 2022; Ebiloma et al., 2024). Tables and charts were used to derive statistical conclusions based on their responses. Microsoft Excel and the Statistical Package for Social Science (SPSS) software were used to analyse the responses. The mean item scores, percentiles, and frequencies were computed from the collected data.

Percentiles and frequencies were used to examine the respondents' demographic data, and the mean item score was used to sort the variables according to the respondents' answers. Out of the three hundred and eighty-nine (389) questionnaires administered to professionals and stakeholders across Lagos State, one hundred and ninety-five (195) were filled correctly and returned, representing a response rate of 50.13%. This response rate is considered robust for a study of this nature, significantly exceeding the 30% threshold commonly accepted as a satisfactory response rate in facility management and construction-related studies (Ryal-Net & Kaduma, 2015). The high response rate can be attributed to the comprehensive follow-up with respondents and the relevance of the research topic to current industry challenges. The responses obtained provide a broad and diverse representation of the opinions and experiences of professionals in facility management within Lagos State, making the findings of this research reliable for analysis. Each response was carefully reviewed to ensure completeness, and only fully completed questionnaires were included in the final analysis. This high response rate strengthens the validity of the study's findings. It contributes to the depth of insights regarding adopting blockchain technology in facility management practices in Lagos State. Cronbach's alpha was used to assess the study instrument's reliability; the results showed an alpha value of 0.930, confirming the validity of the data obtained from the questionnaire survey.

3. Findings and Discussion

3.1. Respondents' Socio-economic Characteristics

Table 2 presents the socio-economic characteristics of the respondents based on the one hundred and ninety-five (195) questionnaires used for the analysis. These characteristics provide valuable insights into the demographic and professional background of the participants, which are essential for understanding their perspectives on the application of blockchain technology in facility management. The key characteristics analysed include profession, years of experience, educational qualifications, professional affiliation, and registration status with relevant industry bodies. This information helps to contextualise the findings and highlights the diversity of the respondent pool in terms of expertise and professional standing within the facility management industry in Lagos State.

Table 2: Socio-economic Characteristics of the Respondents

Characteristics	Frequency	Percentage
Profession		
Civil Engineer	88	45.1%
Estate Manager	30	15.4%
Facility Manager	37	19.0%
Builder	40	20.5%
Years of Experience		
1-5	35	17.9%
11-15	28	14.4%
16-20	28	14.4%
21-25	39	20.0%
6-10	31	15.9%
Above 25	34	17.4%
Education		
B.Sc	44	22.6%
HND	35	17.9%
M.Sc	35	17.9%
OND	42	21.5%
PhD	39	20.0%
Professional Affiliation		
AFMPN	37	19.0%
NIESV	30	15.4%
NIOB	40	20.5%
NSE	88	45.1%

(Source: Author's Survey)

Regarding professional background, the data reveals that 45.1% of respondents are Civil Engineers, 15.4% are Estate Managers, 19.0% are Facility Managers, and 20.5% identify as Builders. This diverse representation emphasises the multidisciplinary nature of facility management, highlighting the relevance of various professional perspectives in assessing blockchain technology. The high representation of civil engineers and builders is significant, as these roles directly

involve operational aspects where blockchain could enhance efficiency, transparency, and data integrity. The distribution of years of experience among respondents indicates that 17.9% have 1-5 years of experience, 36.9% have 6-10 years, 20.0% have 21-25 years, and varying percentages have experience in other brackets. This mix of experience levels is beneficial for gaining a well-rounded understanding of the industry. Notably, the significant percentage of respondents with 6-10 years of experience suggests they have been exposed to recent technological advancements, including blockchain. Insights from this cohort are valuable as they can offer perspectives on the practicality and relevance of blockchain applications in their day-to-day operations.

The educational qualifications of respondents reveal that 22.6% hold a Bachelor of Science (B.Sc), 17.9% possess a Higher National Diploma (HND), 20.0% have a Doctor of Philosophy (PhD), and varying percentages have attained other qualifications. This diverse educational background indicates that the respondents are well-equipped with the knowledge and expertise necessary to provide informed insights into the application of blockchain technology in facility management. The data on professional affiliations shows that 19.0% are members of the AFMPN, 15.4% belong to NIESV, 20.5% are affiliated with NIOB, and 45.1% are part of NSE. The significant representation of professional affiliations indicates that respondents are engaged with recognised professional bodies, ensuring that their insights come from qualified professionals who are likely to be familiar with best practices and the latest facility management and technology developments. This professional engagement reinforces the validity of the study's findings, as these affiliations often require adherence to industry standards and continuous professional development.

3.2. Strategies for Adopting Blockchain Technology in Facility Management in Lagos State

Table 3 presents the analysis of strategies for adopting blockchain technology in facility management in Lagos State based on the perceptions of 195 respondents. The responses were evaluated using mean scores and standard deviations, which provide insight into the most effective strategies according to the participants and the level of consensus around these strategies.

Table 3: Strategies for Adopting Blockchain Technology in Facility Management Practices

Strategies	Mean	Std. Deviation	Rank
Positive Organisational Culture	3.29	1.436	1
Incentives for Early Adopters	3.22	1.412	2
Strong Leadership and Vision	3.17	1.414	3
Stakeholder Engagement	3.13	1.359	4
Technological Advancements	3.07	1.381	5
Enhanced Data Security	3.04	1.425	6
Cost-Effective Solutions	3.03	1.418	7
Government Policy and Legislation	3.00	1.503	8
Public-Private Partnerships	2.99	1.518	9
Industry Collaboration and Partnerships	2.98	1.407	10
Availability of Skilled Professionals	2.92	1.432	11
Increased Awareness and Training	2.90	1.492	12
Development of Standardised Protocols	2.88	1.401	13

(Source: Author's Survey)

The outcome revealed that all the strategies are critical to adopting blockchain technology in facility management practices in the study area. Starting positive organisational culture, which received the highest mean score of 3.29, suggests that respondents believe a supportive and adaptable organisational environment is crucial for successfully adopting blockchain technology in facility management. The relatively high standard deviation (1.436) indicates that while many respondents agree on the importance of organisational culture, there are varying levels of emphasis on this strategy, possibly depending on the current culture within their organisations. Incentives for early adopters also scored highly (mean 3.22, SD 1.412), reflecting a strong belief that offering rewards or incentives can encourage the uptake of blockchain technology. However, responses varied, indicating different views on how significant such incentives should be. Strong leadership and vision were another key strategy identified, with a mean score of 3.17 (SD 1.414). This shows that respondents value the role of leadership in setting a clear direction for blockchain adoption. However, the moderate standard deviation suggests that the impact of leadership varies across different organisations. Stakeholder engagement scored a mean of 3.13 (SD 1.359), highlighting that involving all relevant parties—such as government, businesses, and end-users—is a moderately important strategy. The relatively lower standard deviation indicates consistency in the belief that engaging stakeholders is

essential for blockchain's integration into facility management.

Regarding technological support, technological advancements received a mean score of 3.07 (SD 1.381), indicating that respondents believe ongoing technological improvements are necessary to facilitate blockchain adoption. However, the high standard deviation suggests that opinions vary on how well current technological developments support blockchain implementation. Enhanced data security also scored moderately (mean 3.04, SD 1.425), emphasising the importance of secure data handling as a driver for blockchain adoption. However, some respondents may see this as more critical than others. Similarly, cost-effective solutions (mean 3.03, SD 1.418) were identified as a necessary strategy, indicating that the financial feasibility of blockchain must be demonstrated to ensure widespread adoption. The relatively high response variability suggests that cost concerns differ across organisations depending on their budgets and scale.

Regarding the role of governance, government policy and legislation received a mean score of 3.00 (SD 1.503), showing that while respondents believe that supportive legal frameworks are necessary, there is significant variation in opinions, with some respondents placing more emphasis on policy than others. Public-private partnerships scored similarly (mean 2.99, SD 1.518), suggesting that collaborations between the government and private sector are seen as moderately effective in driving blockchain adoption, though again, opinions differ widely. Industry collaboration and partnerships (mean 2.98, SD 1.407) received a slightly lower score, indicating that while collaboration within the industry is viewed as important, it is not seen as a top priority compared to other strategies. Other strategies, such as the availability of skilled professionals (mean 2.92, SD 1.432), increased awareness and training (mean 2.90, SD 1.492), and the development of standardised protocols (mean 2.88, SD 1.401), all scored below 3.00, suggesting that these are seen as less critical, although still relevant. The relatively high standard deviations across these responses indicate various opinions on the importance of skill development, awareness, and standardisation for blockchain adoption. This could reflect different levels of organisational readiness or varying degrees of familiarity with blockchain technology among respondents.

In summary, the analysis highlights several key strategies for promoting blockchain adoption in facility management in Lagos State, with organisational culture, leadership, and stakeholder engagement seen as particularly important. While technological advancements, data security, and cost-effective solutions are also valued, the role of government policy, partnerships, and the development of skilled professionals are viewed as moderately significant, with a need for broader awareness and training to drive adoption further. The wide range of standard deviations across responses indicates that while general agreement exists on these strategies, the degree to which they are prioritised varies significantly among different respondents.

4. Discussion of Findings

This study identified several key strategies to enhance blockchain technology adoption in Nigeria's facility management sector. Respondents highlighted the most effective strategies as fostering a positive organisational culture, offering incentives for early adopters, and establishing strong leadership with a clear vision for technological advancement. These findings are consistent with global best practices for technology adoption, which indicate that organisational support and effective leadership are crucial in overcoming resistance and promoting innovation in emerging technologies (Venkatesh et al., 2003). A positive organisational culture encourages collaboration, innovation, and acceptance of new technologies, while strong leadership can provide the necessary guidance and resources for implementation. The results underscore the importance of engaging stakeholders and developing supportive government policies for blockchain integration into facility management. Engaging stakeholders, including facility managers, service providers, and tenants, is essential for identifying specific needs and ensuring that blockchain solutions are tailored to address these needs effectively. Research indicates that stakeholder engagement is critical for successfully implementing new technologies, as it fosters collaboration and aligns interests across various parties (Zhu et al., 2012). Furthermore, supportive government policies can enable blockchain adoption, offering frameworks for standardisation, regulation, and funding that facilitate implementation.

The findings indicate that the skills gap remains a significant barrier to effective blockchain adoption. Therefore, comprehensive education and training initiatives should be developed to ensure that all facility management professionals are well-equipped to utilise blockchain technology effectively. Training programs should not only focus on technical skills but also encompass understanding the strategic benefits of blockchain, case studies, and best practices to build confidence among professionals. Additionally, enhancing industry-specific education can help bridge the gap between theoretical knowledge and practical application. Partnerships with educational institutions can facilitate the development of specialised training programs tailored to the unique needs of facility management professionals. Such initiatives could also include certification programs that validate professionals' expertise in blockchain technology, thus

fostering greater confidence in its adoption. The study also highlighted the importance of continuous feedback and improvement in the adoption process. Establishing channels for ongoing communication between stakeholders can facilitate the identification of challenges and allow for iterative adjustments to blockchain implementation strategies. This aligns with agile methodologies, emphasising flexibility and responsiveness to change, making them well-suited for dynamic environments like facility management.

In summary, implementing these strategies can pave the way for more effective blockchain integration in facility management, ultimately leading to enhanced operational efficiency, improved data security, and better service delivery. Future research should explore additional strategies for effectively implementing blockchain technology, considering both local challenges and international best practices in technology adoption (Hosseini et al., 2016; Newton & Chileshe, 2012). By fostering a culture of innovation, incentivising early adopters, ensuring stakeholder engagement, and prioritising training and education, the facility management sector can unlock the transformative potential of blockchain technology and significantly improve its operations and service delivery.

5. Conclusion and Further Research

The study identified several critical strategies essential for enhancing the adoption of blockchain technology in facility management. The most significant strategies included fostering a positive organisational culture that embraces innovation, providing incentives for early adopters to encourage experimentation and implementation, and ensuring access to comprehensive training programs that equip professionals with the necessary skills. The findings of this study provide invaluable insights that will enhance the effectiveness and efficiency of facility management practices through blockchain technology. This will improve project outcomes and pave the way for more sustainable and innovative practices in the industry. The transition towards blockchain adoption requires concerted efforts from all stakeholders, including government agencies, educational institutions, and industry professionals, to create an enabling environment that fosters innovation, collaboration, and continuous learning in facility management.

The following areas are recommended for future studies: researching to develop a comprehensive framework for implementing blockchain technology in facility management within Nigeria, addressing local challenges and opportunities, investigating the impact of blockchain technology on operational efficiency, service delivery, and client satisfaction within facility management practices in Nigeria; this can provide quantitative and qualitative data to support the adoption of blockchain solutions, conducting comparative analyses of successful blockchain implementations in facility management across different countries, identifying best practices and lessons learned that can be adapted for the Nigerian context. Others are undertaking longitudinal studies to assess the long-term effects of blockchain adoption on facility management outcomes, including cost savings, operational improvements, and overall project success; also, to explore the intersection of blockchain technology with other emerging technologies (such as IoT and AI) in the context of facility management, examining how these technologies can work synergistically to enhance operations.

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A Scoping Review on The Role of 3d Printing in Construction: Revolutionising Design and Reducing Waste

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Abstract

This scoping review explores the role of 3D printing technology in the construction industry, focusing on its impact on design innovation and waste reduction. Covering research published between 2010 and 2024, this study systematically maps existing literature to identify key trends and assess the practical implications of 3D printing in addressing material waste and design limitations. The review synthesises findings from peer-reviewed articles, industry reports, and case studies retrieved from databases such as Scopus. Expected findings include significant advancements in design flexibility and sustainability, as well as identifying research gaps and future directions. The insights provided will be valuable for construction professionals, researchers, and policymakers seeking to leverage 3D printing for improved construction practices.

Keywords: Construction innovation, Design flexibility, Waste reduction, 3D Printing

1. Introduction

The construction industry faces significant challenges related to material waste, inefficiencies, and limitations in design flexibility (Adaloudis & Roca, 2021). As demands for sustainable building practices increase, professionals are turning to emerging technologies to address these issues. Among these, 3D printing has emerged as a transformative tool with the potential to revolutionise the industry (Berman, 2017). This scoping review explores how 3D printing influences design innovation and waste reduction within the construction sector. Through a comprehensive synthesis of existing research, industry reports, and case studies, this paper maps the current body of knowledge. It identifies key trends and gaps in the use of 3D printing in construction.

3D printing technology allows for the automation of building construction, reducing reliance on traditional labour-intensive methods (Chen et al., 2023). This shift towards digital fabrication enhances efficiency, accuracy, and customisation, making it possible to create complex architectural structures that would otherwise be cost-prohibitive. The ability to print structures layer by layer minimises waste and optimises the use of materials, significantly contributing to sustainable construction practices.

Additionally, 3D printing plays a critical role in addressing the global housing crisis by enabling rapid and cost-effective construction of homes. Several pilot projects worldwide have demonstrated the feasibility of 3D-printed buildings as a solution for low-cost housing and disaster relief shelters (Garg et al., 2023) By reducing construction time and costs, 3D printing offers an innovative approach to solving housing shortages in urban and rural areas.

The integration of 3D printing with other emerging technologies, such as artificial intelligence (AI) and robotics, further expands its potential applications. AI-driven optimisation of print paths and automated quality control mechanisms enhance precision and consistency in construction (Gebler, 2014). Moreover, advancements in material science are paving the way for the use of eco-friendly and high-performance construction materials, strengthening the durability and sustainability of 3D-printed structures (Hager et al., 2016). Despite its numerous advantages, challenges remain in fully integrating 3D printing into mainstream construction. Regulatory barriers, high initial investment costs, and the need for skilled labour in operating and maintaining 3D printing equipment present obstacles to widespread adoption (Hamid et al., 2013). Nevertheless, ongoing research and industry collaborations continue to drive progress in overcoming these challenges, making 3D printing an increasingly viable and promising solution for the future of construction.

Purpose of the Review

The primary purpose of this review is to systematically map and assess the role of 3D printing in the construction industry, focusing on two key aspects:

1. **Design Innovation**: How 3D printing is enabling greater flexibility in architectural design, enhancing aesthetic and functional capabilities (Hossain et al., 2020).

2. **Waste Reduction**: How 3D printing contributes to sustainable practices by

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minimising material waste during construction processes (Hamid et al., 2013).

The objective is to provide a comprehensive overview that can guide construction professionals, policymakers, and researchers in understanding the potential of 3D printing technology.

2. Literature Review

2.1. Evolution of 3D Printing in Construction

The concept of 3D printing, also known as additive manufacturing, has its roots in the 1980s when it was primarily used for rapid prototyping in manufacturing industries (Berman, 2017). Over time, advancements in digital fabrication technologies have allowed for the expansion of 3D printing into large-scale applications, including the construction industry (Adaloudis & Roca, 2021). Unlike traditional subtractive manufacturing methods, which involve cutting and shaping materials, additive manufacturing builds structures layer by layer, significantly reducing material waste and allowing for greater design flexibility (Hossain et al., 2020).

Research indicates that 3D printing in construction gained momentum in the early 2000s when various academic and industrial projects began experimenting with automated construction processes (Shuaib et al., 2023). Initial breakthroughs included Contour Crafting, a robotic construction system developed to print building structures using concrete-based materials. Since then, 3D printing has evolved to incorporate advanced robotics, computational design, and artificial intelligence, making it a viable alternative to conventional construction methods (Chen et al., 2023).

2.1.1. Design Innovation through 3D Printing

One of the most significant advantages of 3D printing in construction is its ability to enable innovative architectural designs that were previously difficult or impossible to achieve using conventional techniques (Hossain et al., 2020). By utilising parametric design and computational modelling, architects and engineers can create highly complex and customised structures with enhanced aesthetic and functional properties (Olawumi et al., 2023).

2.1.2. Customisation and Complex Geometries

Traditional construction methods often rely on standardisation and prefabrication to ensure efficiency and cost-effectiveness. However, this standardisation limits design flexibility, as intricate and organic geometries are difficult to produce using conventional materials and construction processes (Hossain et al., 2020). 3D printing allows for the creation of highly customised building components, optimising both structural performance and design uniqueness.

For instance, research by Gebler, (2014) highlights how 3D printing can be used to create free-form architectural elements, including curved walls, lattice structures, and biomimetic facades. These forms are not only visually striking but also functionally superior, as they can enhance natural ventilation, daylight penetration, and thermal insulation.

2.1.3. Integration with Computational Design and AI

The integration of 3D printing with artificial intelligence (AI) and machine learning has further expanded its capabilities in construction (Olawumi et al., 2023). AI-driven generative design allows architects and engineers to explore a vast range of design options and optimise structures for weight reduction, load distribution, and material efficiency (Panda et al., 2023).

Machine learning algorithms can also improve the accuracy and reliability of 3D printing by analysing real-time data from sensors embedded in construction robots. This ensures precise layer deposition, reduces errors, and enhances overall build quality. Additionally, AI-based predictive modeling helps optimise material usage, reducing waste and improving sustainability outcomes (Robayo-Salazar, 2023).

2.1.4. Waste Reduction and Sustainable Practices

The construction industry is one of the most significant contributors to global waste, with an estimated 35% of all materials used in building projects ending up as waste (Shuaib et al., 2023). 3D printing has been identified as a promising solution to this issue due to its ability to minimise waste generation through controlled material deposition.

2.1.5. Material Efficiency and Sustainable Construction

Unlike conventional construction methods, which involve cutting, moulding, and assembling prefabricated materials, 3D printing builds structures directly from digital models, reducing the need for excessive material handling and processing (Olawumi et al., 2023). The process of additive manufacturing ensures that only the required amount of material is used, minimising waste and optimising resource utilisation.

Research by Tay et al., (2017) indicates that 3D printing can also enhance sustainability by incorporating alternative construction materials such as recycled concrete, geopolymer cement, and bio-based composites. These materials not only reduce environmental impact but also improve the durability and thermal performance of 3D-printed structures.

2.1.6. Circular Economy in Construction

3D printing aligns with the principles of the circular economy by promoting material reuse and reducing reliance on virgin raw materials. Studies have explored the potential of repurposing construction and

demolition waste (CDW) as a feedstock for 3D printing (Gebler, 2014). By converting waste materials into printable building elements, 3D printing helps close material loops and reduce landfill waste.

2.1.7. Challenges and Barriers to Adoption

Despite its numerous advantages, 3D printing in construction still faces several challenges that hinder widespread adoption.

2.1.8. Regulatory and Standardisation Issues

One of the primary barriers to the adoption of 3D printing in construction is the lack of standardised regulations and building codes for 3D-printed structures (Gebler, 2014). Since 3D printing is a relatively new technology, many construction authorities have yet to establish comprehensive guidelines for ensuring the safety, durability, and compliance of printed buildings.

Studies indicate that regulatory uncertainty creates hesitancy among construction firms and investors, limiting the large-scale implementation of 3D printing (Berman, 2017). Addressing these challenges requires collaboration between researchers, policymakers, and industry stakeholders to develop standardised testing protocols and certification systems for 3D-printed buildings.

2.1.9. Cost and Scalability Concerns

While 3D printing has the potential to reduce labour and material costs in the long run, the initial investment required for purchasing and maintaining 3D printing equipment remains high (Berman, 2017). The cost of large-scale 3D printers, high-performance printing materials, and specialised software can be prohibitive for small and medium-sized construction firms.
Moreover, scalability remains a challenge, as current 3D printing technologies are primarily suited for small to medium-sized projects. Large-scale infrastructure projects, such as high-rise buildings and bridges, require further technological advancements to make 3D printing a viable construction method (Chen et al., 2023).

2.1.10. Skilled Workforce and Training Needs

The successful implementation of 3D printing in construction requires a workforce with expertise in robotics, computational design, and material science (Nadal et al., 2017). However, there is currently a shortage of skilled professionals who possess the necessary knowledge to operate and maintain 3D printing systems.

To address this gap, educational institutions and industry stakeholders must invest in training programs and curricula that focus on digital fabrication, AI-driven construction, and sustainable material innovation (Olawumi et al., 2023). Building a skilled workforce will be crucial for the future integration of 3D printing in mainstream construction practices.

2.2. Future Directions and Research Gaps

While existing research has demonstrated the potential of 3D printing in construction, several areas require further exploration to enhance its effectiveness and applicability:

- **Advancements in printable materials:** Research on sustainable, high-performance materials suitable for 3D printing applications.
- **Hybrid construction techniques:** Combining 3D printing with traditional methods to optimise construction speed, cost, and structural integrity.
- **Automation and robotics:** Developing fully automated 3D printing systems that require minimal human intervention.
- **Lifecycle analysis:** Investigating the long-term durability, maintenance requirements, and environmental impact of 3D-printed buildings.

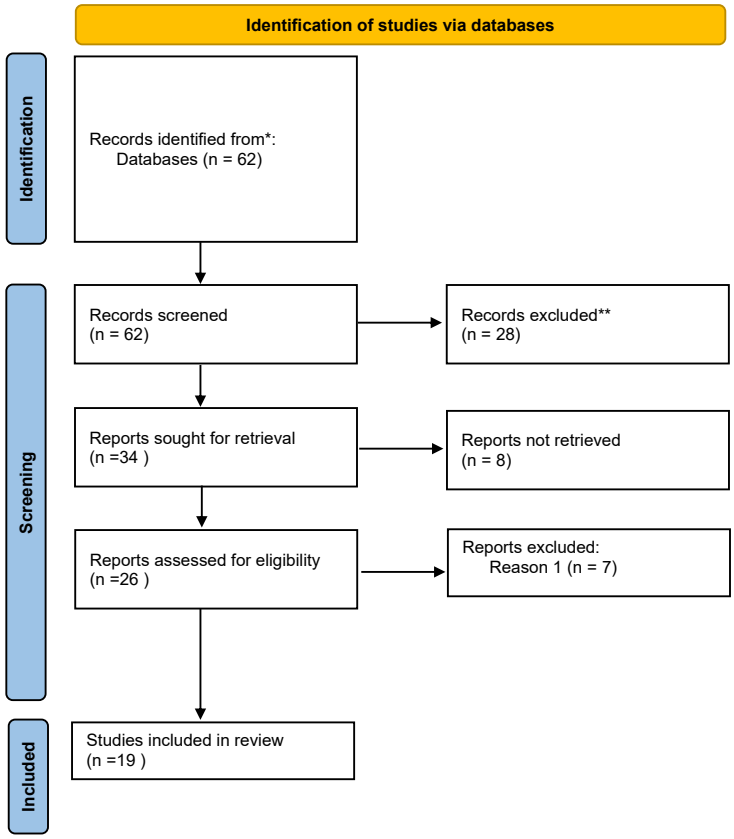


Figure 1: PRISMA Model

3. Research Methodology

A scoping review was chosen as the method for this study because it allowed for a comprehensive exploration of the research landscape, accommodates diverse study designs, identifies gaps and opportunities, facilitates knowledge translation, and contributes to the advancement of construction management education in the context of Industry 4.0 (Nkosi, 2024). By examining a broad range of literature, this review aimed to provide a comprehensive analysis, identify trends and challenges, and offer recommendations for future research and improvement in educational practices. The study sought to provide a comprehensive overview that can guide construction professionals, policymakers, and researchers in understanding the potential of 3D printing technology.

A systematic approach will be employed to gather and analyse sources. The review will utilise the following steps:

1. **Literature Search**: A wide range of sources, including peer-reviewed articles, conference papers, industry reports, and case studies, will be searched across academic databases such as Scopus.
2. **Keywords**: (3D AND printing AND in AND construction: AND revolutionising AND design AND reducing AND waste).
3. **Inclusion Criteria**: Studies published in English, focusing on 3D printing in the construction industry, will be considered. Only peer-reviewed articles, industry reports, and case studies from the last decade (2014 to the present) will be included to ensure relevance to current trends.
4. **Data Extraction**: Key data points, including 3D printing applications, technologies used, benefits, challenges, and outcomes related to design innovation and waste reduction, will be extracted and categorised.
5. **Analysis and Synthesis**: The findings will be analysed to identify emerging patterns, trends, and gaps in the literature. This synthesis will allow for an overview of the current state of 3D printing in construction, as well as practical implications for the industry.

4. Findings and Discussion

This section summarises the findings derived from the literature review, organised into two main themes: design innovation and waste reduction.

4.1. Design Innovation

Architectural Flexibility: 3D printing enables the creation of complex, customised designs that would be difficult or cost-prohibitive using traditional construction methods. This technology facilitates the production of intricate geometries and structures that optimise space utilisation and aesthetic appeal (Adaloudis & Roca, 2021).

Material Innovations: 3D printing has expanded the range of materials used in construction, including sustainable and composite materials, which can enhance the performance and durability of structures. Materials such as recycled plastics, bio-based concrete, and geopolymers are being explored in 3D printing, contributing to more sustainable construction practices (Adaloudis & Roca, 2021).

Customisation and Personalisation: 3D printing allows for designs that are tailored to specific site conditions, enabling architects and engineers to create bespoke, site-specific structures (Garg et al., 2023). This capability supports both residential and commercial applications.

4.2. Waste Reduction

Precision and Efficiency: One of the primary benefits of 3D printing in construction is its ability to minimise waste. Unlike traditional construction methods, which often involve cutting, shaping, and discarding excess material, 3D printing only uses the material required for the build. This results in more efficient use of resources (Adaloudis & Roca, 2021).

Sustainability: The technology also allows for the use of recycled and eco-friendly materials, reducing the demand for new raw materials and lowering carbon footprints (Garg et al., 2023). This aspect is crucial as the construction industry is one of the most significant contributors to global waste and emissions.

On-Demand Production: 3D printing enables on-site production of components, reducing transportation and logistics-related waste. Components can be printed as needed, avoiding overproduction and material stockpiling (Garg et al., 2023).

5. Conclusion and Further Research

5.1. Conclusion

This scoping review highlights the transformative potential of 3D printing in the construction industry, particularly in revolutionising design flexibility and reducing material waste. The findings reveal that 3D printing enhances architectural innovation through parametric design, generative modelling, and the ability to fabricate complex geometries with greater efficiency. Additionally, the technology supports sustainability efforts by minimising waste, optimising material use, and enabling the integration of recycled and eco-friendly materials.

Despite these advantages, several challenges hinder widespread adoption, including regulatory uncertainties, high initial investment costs, and scalability concerns. Addressing these barriers requires collaboration between industry stakeholders, policymakers, and researchers to develop standardised guidelines, improve cost efficiency, and expand training initiatives. As 3D printing continues to evolve, its integration with artificial intelligence, robotics, and sustainable materials holds great promise for shaping the future of construction.

5.2. Future Research

While this review identifies key benefits and challenges of 3D printing in construction, several areas require further investigation:

1. **Regulatory Frameworks and Standards** – More research is needed to develop universally accepted guidelines and codes to ensure the safety, durability, and structural integrity of 3D-printed buildings.

2. **Cost-Effectiveness and Economic Viability** – A deeper analysis of the long-term financial implications of 3D printing in construction, including lifecycle costs and return on investment, is necessary.

3. **Material Innovations and Sustainability** – Exploring alternative sustainable materials, such as recycled concrete, bio-based composites, and geopolymer cement, could further enhance environmental benefits.

4. **Integration with Emerging Technologies** – Investigating the role of AI, robotics, and IoT in optimising 3D printing processes could improve efficiency, precision, and automation in construction.

5. **Large-Scale Implementation and Case Studies** – More real-world applications and pilot projects need to be analysed to assess the feasibility, performance, and scalability of 3D printing in various construction environments.

1.

6. Acknowledgement

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Digital Solutions for the Management of Wastewater Storage for the Mining Industry

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Abstract

Managing wastewater in the mining sector presents considerable issues, with extensive ramifications for operations. This study seeks to provide a comprehensive digital solution to improve the effective management of wastewater storage, with a particular emphasis on Platinum Group Metals mining. Mining is a significant danger to water safety in arid places such as South Africa, necessitating new solutions. This study adopted qualitative methodologies to discern emergent themes. The findings indicate that technologies like big data and artificial intelligence may significantly enhance the efficiency of wastewater management. Significantly, technological failures often stem from fundamental difficulties like organisational and cultural obstacles, rather than the solutions themselves. Legal and regulatory compliance exacerbates treatment procedures. This study presents a conceptual framework that amalgamates digital technology with pragmatic solutions to tackle these difficulties. The framework improves management and compliance in wastewater operations via a systematic approach, encouraging the implementation of digital technologies in the mining industry to address present and future requirements.

Keywords: Compliance, digital technologies, operational efficiency, sustainability, wastewater storage management

1. Introduction

The few water resources in South Africa intensify difficulties for mining firms, especially with wastewater treatment (Northey *et al.*, 2019; Masindi *et al.*, 2022). Mining operations substantially increase pollution levels, with coal (Simpson *et al.*, 2019) and gold mining (Chetty *et al.*, 2021; Agboola *et al.*, 2020; Verlicchi & Grillini, 2020) polluting water resources long after the cessation of activities. This often results in acid mine drainage, which presents health hazards to adjacent communities (Yuan *et al.*, 2022). The mining sector is mainly dependent on water and is under growing pressure to manage wastewater efficiently as clean water resources diminish. This complexity underscores the pressing need for investment in effective technologies and approaches (Litvinenko, 2020). The use of digital technology in Chilean mining has improved operational efficiency and competitiveness, outpacing other sectors (Castillo-Vergara *et al.*, 2024). Nevertheless, some locations exhibit hesitance, referencing substantial initial expenses, integration difficulties, and a lack of qualified personnel (Sishi & Telukdarie, 2020; Nuur *et al.*, 2020). By prioritising innovation and using digital technology while mitigating environmental risks, mining companies may realise substantial advantages.

Efficient wastewater storage systems, a subset of wastewater systems, are essential for sustaining operational effectiveness and preserving the industry's social license to operate. Efficient wastewater management is essential for environmental preservation, adherence to regulations, and operational effectiveness (West & Brye, 2019; Tumane *et al.*, 2021). Appropriate storage safeguards adjacent land and water resources, alleviating environmental concerns. The mining sector encounters obstacles, including antiquated infrastructure (Sishi & Telukdarie, 2020), regulatory limitations and insufficient storage capacity, particularly for tailings. These issues may be resolved by improving wastewater storage management with digital technologies that provide real-time data analytics and automated controls. Digital solutions have shown efficacy in Lean Six Sigma initiatives (Pongboonchai-Empl *et al.*, 2024), international manufacturing endeavours (Ferreira *et al.*, 2023), and the construction sector in Ghana (Maqbool *et al.*, 2023). Advanced technologies such as digital twins, sensors, artificial intelligence, the Internet of Things, integrated digital models, and machine learning may enhance operational efficiency, responsiveness, and sustainability, therefore assuring long-term viability and showcasing a commitment to responsible resource management in the mining sector.

2. Literature Review

The digital technologies that were identified in the literature reviewed are grouped according to their application and purpose, under three classifications, namely data management and analysis, simulation and visualisation, and integration and operational management.

2.1. Data Management and Analysis

Data management and analysis are essential in wastewater management, big data, and analytics

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(Kannan *et al.*, 2024). Data management and analysis convert raw data into valuable insights for decision-making by operational teams (Jain *et al.*, 2021). Due to the large datasets that require storage, cloud computing enables efficient storing and processing (Kagan *et al.,* 2021), which is a precursor to the big data analytics process (Kagan *et al.,* 2021). In addition, the use of generative AI in data analysis enables organisations to forecast results, streamline operations, and refine decision-making processes, thus augmenting the efficiency and efficacy of wastewater systems (Garrido-Baserba *et al.*, 2020). Ghahramanieisalou and Sattarvand (2024) encourage the use of advanced analytics together with generative AI since it has the potential to foster collaboration across various industries. Artificial intelligence solutions are being developed to aggregate and analyse data from wastewater systems, facilitating resource recovery and source separation, which can benefit mining businesses (Sarc *et al.*, 2019). Further, Sarc *et al.* (2019) propagate the use of AI to optimise water operations and extract vital information on health and lifestyle patterns from wastewater data. Despite these promising benefits, the study of Boikanyo and Gomwe (2024) cautions that the integration of AI into overall business systems is complex, resource-intensive and time-consuming. A dichotomy exists in the practical operations of the mining business, requiring a balance between innovation, efficiency, and minimising operational disruptions.

2.2. Simulation and Visualisation

Simulation and visualisation tools accurately simulate wastewater storage management data and scenarios to increase system understanding (Cammarano *et al.*, 2023; Tain *et al.*, 2024). Operators can assess performance and forecast faults using real-time digital twins. GIS and robotics expand data collection and analysis, while AR and MR show complicated data and scenarios for training and decision-making. Advanced management tools assist stakeholders in improving efficiency and problem-solving. For mining applications like automated geological mapping and rockfall trajectory modelling, Cammarano *et al.* (2023) and Gahramanieisalou & Sattarvand (2024) use GIS to gather, assess, and integrate geographic data, and precise 3D models aid environmental analysis and decision-making (Ghahramanieisalou & Sattarvand, 2024). UAVs and robots simplify digital technologies (Ghahramanieisalou & Sattarvand, 2024). Human input varies for autonomous robots and UAVs—automation and optimisation in mining and manufacturing. Tian, Yu, & Gu (2024 suggest that industrial robots and humans may boost mining production and safety.

Real-time digital twins replicate, monitor, and optimise physical systems. Technology data is utilised to construct and assess predictive maintenance and decision-making models (Ghahramanieisalou & Sattarvand, 2024; Tian, Yu, & Gu, 2024). According to Cammarano *et al.* (2023), digital twins may integrate geotechnical analysis, fleet management, and risk evaluation for dynamic mining decision-making and risk assessment. Augmented and Mixed Reality (AR) technologies overlay digital information on the real environment, creating immersive experiences that improve training, visualisation, and operational efficiency for operating teams (Kunytska *et al.*, 2024). Mine crews learn complicated processes like wastewater management using these technologies, as explained by Kunytska *et al.* (2024).

2.3. Integration and Operational Management

Optimising wastewater management requires seamless coordination between systems and processes via integration and operations (Martini & Roni, 2021). Specifically, the streamlining of management and resource distribution across the many operational units, while concurrently guaranteeing the prompt provision of goods and services. The automation of activities enhances operational efficiency by reducing human involvement and mistakes.

In most instances, an Enterprise Resource Planning (ERP) system is the backbone of back-office processing of most operations, such as finance, human resources, and materials management (Sishi &Telukdarie, 2020). ERP systems oversee mining capital and resources. Industry 4.0 and ERP are being explored to create semi-autonomous mines characterised by real-time efficiency and communication (Sishi & Telukdarie, 2020). Sishi and Telukdarie (2020) identified two major flaws in ERP systems: their inability to interface with emerging technologies to improve process efficiency and control, as well as their limitation in presenting data to lower-level teams.

Bi *et al.* (2022) explain how mining supply chain management enhances the flow of materials and information from extraction to delivery, as well as how system integration enhances efficiency. The integration of supply chain management with ERP enhances data accuracy, decision-making, resource allocation, and process optimisation. Mining companies need connectivity for adaptability and profitability. IoT and Big Data-enabled supply chain management solutions may enhance mining efficiency and sustainability by increasing supply chain visibility and control. Supply chain management systems streamline data and supplies. Enterprise Resource Planning enhances data precision and decision-making efficacy. In contemporary supply chain management systems, the Internet of Things and Big Data enhance visibility and control, hence enhancing efficiency and sustainability. Onifade *et al.* (2023) advocate that automation enhances resource allocation and minimises work, hence increasing the benefit to operational efficiency. In the case of wastewater management, it assists in conserving, reducing non-production water, and preserving infrastructure. The overall benefit is that of

enhancing safety, productivity, and environmental impact that could be caused by human intervention, reducing expenses and augmenting revenues.

3. Theoretical Framework

The challenges and inefficiencies identified in the literature review are financial and cost barriers; technology and infrastructure limitations; people change management and skills development; and legislative and regulatory. As a result, the theoretical frameworks identified in the literature reviewed are discussed in relation to the challenges and inefficiencies identified.

3.1. Financial and Cost Barriers

Both Real Options (RO) and Multi-Criteria Decision Making (MCDM) theories provide unique but complementary viewpoints in overcoming financial and cost barriers to the adoption of digital solutions. RO is defined as a financial decision-making and investment framework that views investment initiatives as options rather than obligations (Ismael *et al.*, 2024). This method acknowledges investment uncertainty and provides a systematic framework for analysing management flexibility over time.RO, as explained by Ismail *et al.* (2024), emphasises both adaptability and risk mitigation in decision-making concerning capital projects, such as the adoption of digital solutions. In contrast, (Sarc *et al.*, 2019) implied that MCDM proposes a holistic approach that promotes the participation of various stakeholders, resulting in various viewpoints in the evaluation of measures such as cost, benefits, risks, and compliance with regulations in initiatives such as the adoption of digital solutions.

3.2. Technology and Infrastructure Limitations

The theoretical frameworks identified are Technology Organisation Environment (TOE) for the contextual analysis; Diffusion of Innovation (DOI) to investigate the innovation characteristics; Unified Theory of Acceptance and Use of Technology (UTAUT) to establish user acceptance as well as usage; Risk Management theory for risk analysis and mitigation thereof and DeLone and McLean IS Success Model for the evaluation of deployment success. Min *et al.* (2021) explained the transmission of innovation through new ideas and technologies using DIT. Corporate employees accept technology due to innovation, communication, introduction, and social institutions (Musa & Gugong, 2024). These variables affect digital technology adoption by altering perceptions of the innovation's value and use.

Internal and external aspects must be considered when analysing technology adoption in a business (Crabbe, 2023). According to Ediriweera & Wiewiora, the 2021 TOE framework highlights technical, organisational, and environmental factors that are key in influencing technology adoption. TOE emphasises organisational processes, structures, and tactics that influence technology adoption. Agile and digital organisations boost value chain collaboration and efficiency, which is crucial to success (Li *et al.*, 2022; Sanda & Johansson, 2011). Effective use of open data platforms and stakeholder involvement in environmental risk management show how external impacts may promote innovation (Taborda et al., 2024; Li *et al.*, 2022). The TOE framework provides a structured view of innovation adoption. However, success depends on technology, organisational agility, and environmental adaptability (Ediriweera & Wiewiora, 2021), emphasising the need for a balanced approach to digital transformation in the mining industry.

The UTAUT is widely used to evaluate digital solution adoption across various industries (Ismail *et al.*, 2024). UTAUT integrates the Theory of Reasoned Action, Technology Adoption Model, and Theory of Planned Behaviour to describe the technology adoption dynamics. According to Kwarteng *et al.* (2022), UTAUT emphasises performance expectation, which evaluates users' perceptions of how technology will enhance their work performance. Secondly, effort expectation measures the ease of use of technology. Thirdly, social influence measures the perceived approval of technology use by peers and authority figures. Lastly, conducive circumstances measure the perceived organisational support and available technological infrastructure. These four constructs may influence technology usage and behaviour in technology adoption initiatives. The technology implementation situation may impact each dimension's relative effect. Subsequently, according to Schorr (2023), UTAUT2 was introduced, and it added consumer-oriented elements to the original model, making it more applicable and offering more insights into user behaviour in different circumstances. Ismail *et al.* (2024) highlighted criticism of the UTAUT that includes issues of complexity, contextual constraints, stability, disregard for emotional aspects, methodological rigour, and an emphasis on post-adoption behaviour.

The ISSM is a key theoretical framework for evaluating information systems in business intelligence, e-learning, and risk management. The ISSM takes a multi-dimensional approach to system, information, service, user satisfaction, net benefits, and user engagement, building on DeLone and McLean (Dash *et al.*, 2023). This complete model shows how these aspects affect information system success and their interdependence. Dash *et al.* (2023) further explain how ISSM blends the TAM and Expectation-Confirmation Theory and adapts to current difficulties by adding elements and resolving applicability concerns. According to Dash *et al.* (2023), several studies have used the ISSM to assess system performance in real-world settings, proving its applicability and usefulness.

Despite criticism about the need for more dimensions and robustness of measuring instruments, the ISSM remains a crucial tool for organisations seeking to improve their information systems and results. Ismail *et al.* (2024) posit that regular use of ISSM in technology adoption initiatives aided businesses in identifying areas for improvement as well as enhancing both user demands and the alignment of technology solutions to organisational strategies.

3.3. People Change Management and Skills Development

Effective change management must include both organisational strategy and individual staff requirements as explained by Tomičić-Pupek *et al.* (2023). Further, this dual emphasis guarantees that businesses can adjust while simultaneously supporting workers throughout the change. At the organisational level, leaders play a pivotal role in shaping attributes that support the successful deployment of technology as posited by Tomičić-Pupek *et al.* (2023), Dash *et al.* (2023) and Arumugam *et al.* (2023). Further, Arumugam *et al.* (2023) outlined critical attributes essential for successful leadership in technology adoption initiatives, encompassing robust communication faculties, proficient leadership practices, the confidence leaders instil in their workforce, and the primary quality of leadership. With these attributes, both Arumugam *et al.* (2023) and Dash *et al.* (2023) advocate that employees are likely to be appropriately supported in acquiring the relevant capabilities by leaders.

3.4. Legislative and Regulatory Challenges

RBV of a firm is a pivotal strategic management framework emphasising the critical role of a firm's internal resources and capabilities in achieving competitive advantage and superior performance (Fedorovna *et al.*, 2022). Emerging in the mid-1980s, RBV has been widely applied across disciplines such as marketing, supply chain management, and the creative industries. Bals and Rosca (2022) explain how the theory posits that sustainable competitive advantage arises from resources that are valuable, rare, inimitable, and non-substitutable (VRIN). This perspective provides a foundation for understanding how firms can leverage unique assets to outperform competitors. Further, by focusing on strategic capacity, RBV underscores the importance of a company's unique expertise and capabilities in enhancing competitiveness, particularly in industrial sectors (Lubis, 2022). Fedorovna *et al.* (2022) explain how the transformation of resource allocation processes using digital technologies connects with the RBV framework by emphasising the strategic use of digital resources to boost organisational growth and competitiveness. Despite its robustness, RBV faces criticism for potentially overlooking external factors like market dynamics and competition, and for not fully addressing rapid technological and consumer preference changes. Nevertheless, it remains a foundational theory in strategic management, offering valuable insights into the central role of resources in firm success.

Institutions impact social, organisational, and political conduct (Kahupi *et al.*, 2024). Beyond constitutional and legal settings, historical, sociological, and rational choice views benefit political analysis, sports management, strategic management, and the digital economy (Agyei-Ababio *et al.*, 2023). Institutional theory explains how laws, industry standards, and societal norms influence the adoption of technology. Kemal and Shah (2023) say institutions may overlook human agency and rapid digital development. Agyei-Ababio *et al.* (2023) claim the theory shows external institutional impacts but overlooks the dynamic nature of organisational innovation and regional culture.

RBV and TOE (Agyei-Ababio *et al.*, 2023) highlight individual actors and their ability to transform organisations (Kemal & Shah,2023). TOE shows how employees and decision-makers react to technological and environmental changes, impacting new technology adoption. According to Kemal and Shah (2023), TOE includes dynamic interactions between technology, organisation, and environment, making it more straightforward to adapt to fast-paced changes and comprehend how organisations react to breakthroughs. RBV asserts that workers compete using their skills, knowledge, and social capital, making human agents vital for resource activation and management. Reducing these limits may maintain institutional theory relevant to the mining sector's social and organisational processes.

4. Research Methodology

The study subject involves defining the conceptual framework for the adoption of digital solutions in tackling the persistent issues of wastewater storage management in the mining industry, focusing on enhancing operational efficiency, guaranteeing regulatory compliance, and promoting sustainability. The study used a qualitative, exploratory approach first to identify the relevant theoretical frameworks that underpin the study; then identify the challenges and inefficiencies in the application of digital technologies for wastewater management within the mining industry; and then to examine the various technologies employed in wastewater management and the mining sector; and finally to define the conceptual framework to guide mining businesses through the complexities of integrating digital solutions into their wastewater management practices. A systematic literature review was performed by scanning the EBSCOhost database and Google Scholar for publications published between 2019 and 2025. The search string for the first round was wastewater management. Excluded articles were those authored in languages other than English, duplicate submissions, and book chapters. Articles were filtered

based on the digital technologies used in wastewater management and those utilised by the mining sector. The systematic literature review included an examination of existing literature to synthesise available information, which is intrinsically challenging due to the fragmented nature of current research and the multidisciplinary aspects of the issue (Snyder, 2019) (Figure 1).

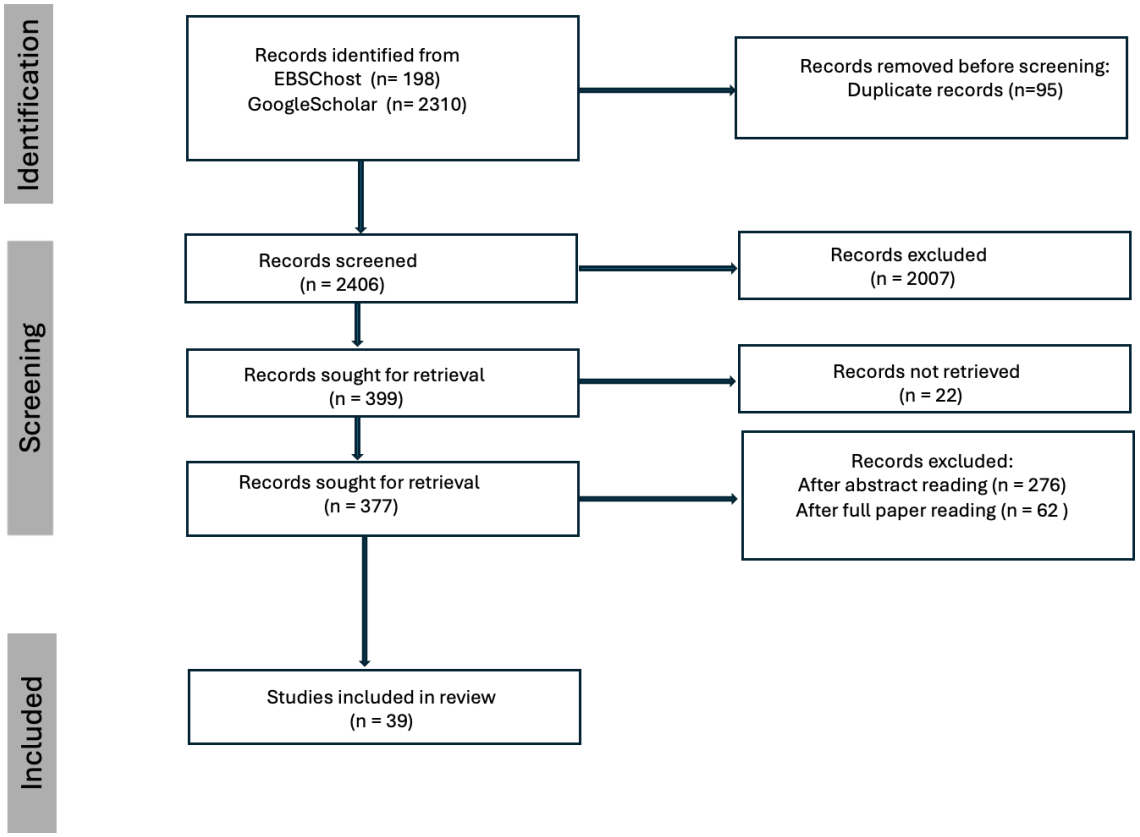


Figure 1: Prisma 2020 flow diagram for identification of studies for review

This study's literature review strategy provided a comprehensive foundation for understanding the current state of digital solutions in wastewater storage management in the mining industry. This strategy not only identifies existing knowledge gaps but also lays the groundwork for future research initiatives aimed at enhancing operational efficiency and sustainability in wastewater storage management.

5. Findings and Discussion

The consensus in the articles reviewed is that there is a benefit to digital solutions in managing wastewater, although the specifics of wastewater storage management are not addressed. Discussions were primarily for the deployment of digital technologies within the water management, wastewater treatment and overall mining operations. These digital technologies are classified into three areas, namely data management and analysis, simulation and visualisation, and integration and operation management. Technologies such as big data, AI, and data management are transformational by improving operational efficiency and decision-making (Kannan *et al.*, 2024; Jain, 2021). In the adoption of these technologies, the barriers and challenges identified are financial and cost barriers (Ediriweera & Wiewiora, 2021); technology and infrastructure limitations (Crabbe *et al.*, 2022); people change management, and skills development (Mokganya *et al.*, 2024); and legislative and regulatory challenges (Crabbe *et al.*, 2022).

In overcoming the identified challenges, a conceptual framework based on theoretical frameworks identified in the literature review is essential for the deployment of digital technologies in wastewater management, especially in the mining industry. Figure 2 depicts such a framework by indicating how each theoretical framework addresses the challenge identified in the literature review.

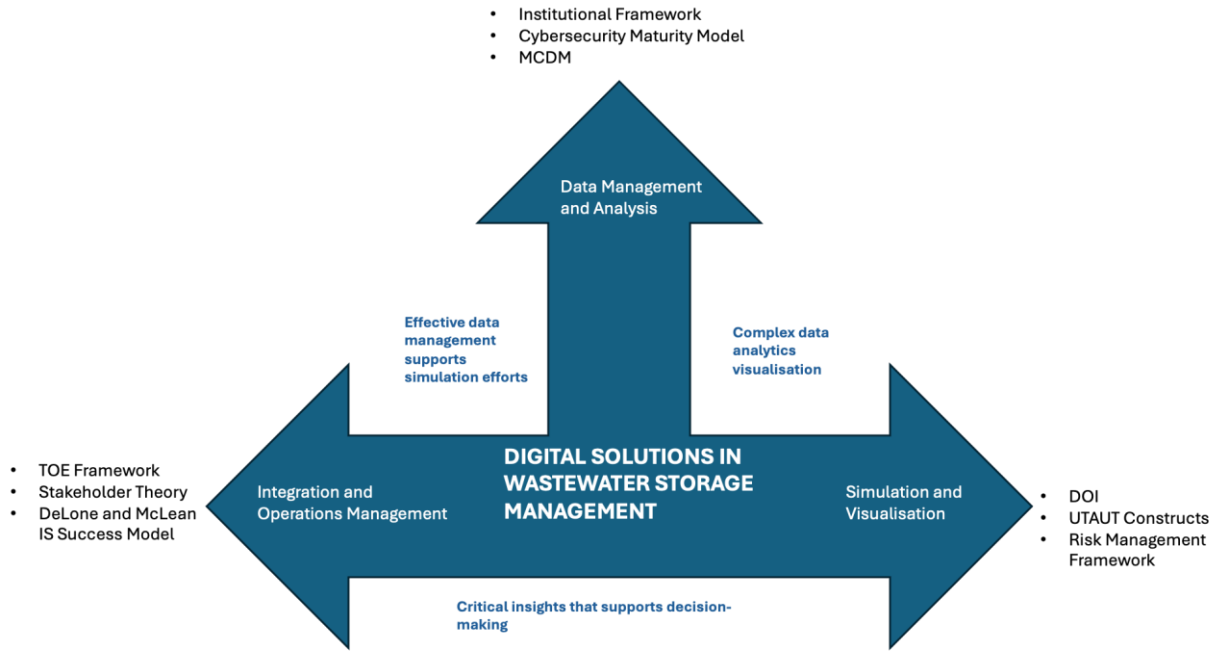


Figure 2: Conceptual Framework for the adoption of digital solutions in the management of wastewater storage management

6. Conclusion and Further Research

The environmental impacts of mining activities depend on wastewater storage management. This study shows that digital technologies may improve wastewater management inefficiencies. Many mining businesses are incorporating new technology into their current frameworks. While industry, telecommunications, and tourism have profited from digital revolutions, caution is advised. Staff alignment and support are crucial to such projects' success. Thus, revolutionary programs must emphasise technology-personnel partnership for meaningful outcomes. This study's conceptual framework helps organisations navigate the intricacies of digital wastewater management systems. This study uses TOE, TAM, DOI, Institutional Theory, and RBV to show the complexity of the challenges. Interdisciplinary qualitative and quantitative research is needed to discover crucial success factors that may enable these transitions and to identify which digital solutions can be successfully integrated to achieve desired results. The scarcity of literature on digital technology in wastewater management highlights the need for more research. Innovation and sustainability in wastewater management need collaboration between major and small-scale miners and government agencies. A strong conceptual framework will improve understanding of these dynamics and guide practical implementation tactics, helping the mining sector manage wastewater storage.

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Energy-Efficient Upgrades for Educational Buildings: A Roadmap to Carbon Neutrality

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Abstract

Educational buildings consume significant energy, leading to high costs and carbon emissions. Upgrading these buildings with energy-efficient solutions can reduce their environmental impact and move them toward carbon neutrality. This study outlines practical strategies, including improved insulation, energy-efficient lighting, smart heating and cooling systems, and renewable energy integration. By following these steps, schools and universities can create healthier learning environments while cutting energy use. A survey research design was employed for this study, where questionnaires were administered among key stakeholders in the built environment. One hundred sixty questionnaires were distributed, and 102 were returned and considered fit for analysis. The data was analysed using descriptive statistics, mean score, and standard deviation. Findings reveal that improvements such as insulation upgrades, LED lighting, smart HVAC systems, and renewable energy adoption significantly reduce energy use and operational costs. The study concludes that a structured approach to energy efficiency accelerates carbon neutrality in educational institutions. This is a practical tool for institutions aiming to achieve carbon neutrality through smart, cost-effective upgrades. The study, therefore, recommends policy incentives, financial support, and stakeholder engagement to enhance implementation and long-term sustainability.

Keywords: Carbon neutrality, educational buildings, energy efficiency, energy-efficient upgrade, sustainability

1. Introduction

Educational buildings are among the largest energy consumers in the public sector, requiring substantial energy for heating, cooling, lighting, and the operation of electronic devices (Gul & Patidar, 2015). Many schools and universities rely on outdated infrastructure that consumes excessive energy, leading to high operational costs and increased carbon emissions (Omer, 2009). Chowdhury et al. (2021) revealed that as climate change and environmental sustainability concerns grow, institutions must take proactive steps to reduce their energy consumption. Energy-efficient upgrades present a practical solution, enabling schools and universities to reduce energy waste, cut costs, and contribute to a cleaner environment (Papadakis & Katsaprakakis, 2023). Transitioning to energy-efficient systems is an environmental necessity and a financial and educational opportunity for institutions worldwide.

The energy cost in educational buildings represents a significant portion of institutional budgets (Dyussembekova et al., 2022). Many schools struggle with rising electricity bills, diverting resources from academic programs, faculty salaries, and student services. Investing in energy-efficient solutions such as LED lighting, smart heating and cooling systems, and modernised insulation can significantly lower energy expenses (Kovalchuk & Shcherbakova, 2024). By reducing operational costs, schools can reallocate funds to improve educational infrastructure and enhance student learning experiences (Gershberg, 2015). Institutions that adopt energy-saving measures also become more financially resilient, ensuring long-term sustainability in the face of fluctuating energy prices (Sarkar & Singh, 2010).

Beyond financial benefits, reducing energy use in educational buildings is essential for minimising environmental impact (Harvey, 2009). Johnsson, Kjärstad, and Rootzén (2019) revealed that many institutions still rely on fossil fuel-based energy sources, contributing to greenhouse gas emissions and climate change. Shifting to renewable energy sources, such as solar or wind power, can significantly decrease the carbon footprint of educational facilities (Outka, 2011). Schools and universities that embrace energy-efficient solutions meet regulatory requirements for sustainability and set a positive example for students and the broader community. Encouraging sustainability within educational institutions helps instil environmentally responsible values in future generations (Altassan, 2023).

Achieving carbon neutrality in educational institutions requires a structured and strategic approach. Institutions that develop clear energy efficiency plans and follow systematic implementation processes

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achieve better outcomes. Long-term planning, proper funding, and active stakeholder involvement must support the transition to energy-efficient systems (Chai & Yeo, 2012). School administrators, policymakers, and facility managers must work together to prioritise energy efficiency and overcome barriers to implementation. By adopting a phased approach, institutions can gradually upgrade their infrastructure while minimising disruption to daily operations.

2. Literature Review

Energy efficiency in educational buildings has gained significant attention in recent years due to rising energy costs and environmental concerns (Papadakis & Katsaprakakis, 2023). Many researchers emphasise the need for schools and universities to adopt energy-saving technologies to reduce consumption and lower carbon emissions. According to Idowu et al. (2024), educational buildings account for a substantial portion of public sector energy use, making them key targets for efficiency improvements. Their study highlights retrofitting outdated systems with modern, energy-efficient alternatives. Lighting is one of the main contributors to energy use in schools. Traditional incandescent and fluorescent lights consume large amounts of electricity, leading to high utility costs (Reames, Reiner & Stacey, 2018). Brown et al. (2022) found that switching to LED lighting reduces energy consumption by up to 50% while improving the quality of indoor lighting. LED lights also last longer, lowering maintenance costs for institutions. Schools implementing automatic lighting controls increase energy savings by ensuring lights are only used when needed.

Heating, ventilation, and air conditioning (HVAC) systems are another significant source of energy use in educational buildings (Asim et al., 2022). Research by Teke and Timur (2014) shows that outdated HVAC systems waste energy due to inefficient heating and cooling processes. Upgrading to smart, programmable thermostats and energy-efficient HVAC units reduces energy demand (Li, De La Ree & Gong, 2018). Proper insulation and weatherproofing also prevent heat loss in winter and keep buildings cool in summer, improving overall efficiency.

Renewable energy sources in educational institutions have also been widely studied. Solar energy is one of the most popular options, providing a clean and sustainable power source (Hayat et al., 2019). Schools that install solar panels can generate a significant portion of their electricity on-site, reducing reliance on traditional energy sources (Altassan, 2023). Building automation systems play a crucial role in improving energy efficiency. Smart energy management systems help schools monitor and control energy use in real-time (Amaxilatis et al., 2017). Idowu et al. (2024) found that institutions with automated energy management systems reduce waste by optimising energy use based on occupancy and demand. These systems also provide detailed energy usage reports, helping facility managers identify areas for further improvement.

Indoor air quality and natural ventilation strategies have gained attention in recent studies. Poor indoor air quality negatively affects student health and academic performance (Stafford, 2015). Martinez and Lopez (2021) found that schools using energy-efficient ventilation systems with air filtration improve student concentration and reduce absenteeism due to illness (Toyinbo, 2023). Natural ventilation, such as operable windows and ventilated facades, further reduces the need for mechanical cooling, lowering energy costs.

Several studies highlight the role of government policies and financial incentives in promoting energy-efficient upgrades. Mills and Schleich (2012) emphasise that many schools struggle to afford energy-efficient technologies despite their long-term benefits. Government grants, subsidies, and low-interest loans help institutions invest in sustainable solutions. Their research suggests that more substantial policy support encourages more schools to adopt energy-efficient practices. Behavioural change and sustainability education also contribute to energy efficiency in schools. Research by Atlassan (2023) shows that schools with energy conservation programs encourage students and staff to adopt sustainable habits. Simple actions, such as turning off lights and unplugging devices when not in use, significantly reduce energy waste. Integrating sustainability topics into the curriculum further strengthens environmental awareness among students.

2.1. Strategies for Energy-Efficient Upgrades

Educational institutions use different strategies to improve energy efficiency. One common approach is upgrading lighting systems. Many schools replace traditional incandescent and fluorescent bulbs with LED lighting. Research by Mills and Jacobson (2011) shows that LED lights consume less energy and last longer, reducing electricity costs and maintenance efforts. Schools also install motion sensors and automated lighting controls to prevent unnecessary energy use. Another key strategy is improving heating, ventilation, and air conditioning (HVAC) systems (Idowu et al, 2024). Many educational buildings have outdated HVAC systems that waste energy.

Brown et al. (2022) found that smart thermostats and energy-efficient HVAC units help schools maintain comfortable temperatures while reducing energy consumption. Proper insulation and sealing of doors and windows further improve heating and cooling efficiency. Renewable energy integration is another important strategy. Many schools install solar panels to generate clean electricity on-site. Research by Amaxilatis et al. (2017) shows that solar energy reduces

dependence on fossil fuels and lowers electricity bills. Some institutions also use wind or geothermal heating to cut energy use further. These renewable sources provide long-term savings and environmental benefits.

Building automation and smart energy management systems also improve energy efficiency. Schools use automated systems to monitor and control energy use in real time. According to Adekunle et al. (2024), these systems adjust lighting, heating, and cooling based on occupancy, preventing energy waste. Smart meters help facility managers track energy usage and identify areas for improvement. Water conservation strategies also support energy efficiency. Many schools install low-flow faucets, toilets, and rainwater collection systems to reduce water waste. Gherheș and Cernicova-Buca, M. (2025) revealed that reducing water use lowers energy demand for heating and pumping. Schools can also educate students and staff about water-saving habits to enhance efficiency. The study conducted by Agbajor et al. (2023) explored and analysed the Building Energy Management Systems (BEMS) in South Africa, drawing insights from five key areas: building typology, building services systems, methodological approach, and testbed, applied BEMS strategies, and targeted energy management system tasks.

2.2. Benefits of Energy-Efficient Upgrades

Energy-efficient upgrades provide significant cost savings for educational institutions. Schools that adopt energy-saving technologies experience lower electricity and maintenance costs. Brown et al. (2022) found that LED lighting, smart HVAC systems, and automated energy management reduce utility bills by up to 40%. These savings allow schools to invest in better learning resources and facilities. Improved indoor air quality is another significant benefit. Outdated HVAC systems often circulate dust and pollutants, affecting student health. Research by Idowu et al. (2024) found that energy-efficient ventilation systems improve air circulation and remove harmful particles. Better air quality leads to fewer respiratory issues and higher student concentration.

Energy-efficient upgrades also contribute to environmental sustainability. Schools that use less energy reduce their carbon footprint. Abdallah and El-Shennawy (2013) found that institutions with solar panels and smart energy systems significantly lower greenhouse gas emissions. Schools help fight climate change and protect natural resources by adopting sustainable practices. Enhanced learning environments are another key benefit (Stephen et al., 2024). Schools with proper lighting, temperature control, and ventilation create comfortable spaces for students and teachers. According to Mills and Schleich (2012), students perform better in classrooms with stable temperatures and good air quality. Comfortable learning spaces lead to higher engagement and academic success. Energy-efficient schools serve as models for sustainability. When schools implement green technologies, they teach students about environmental responsibility. Altassan (2023) revealed that students in energy-efficient schools develop a stronger awareness of sustainability issues. These schools encourage young people to adopt eco-friendly habits, creating a long-term positive impact on society.

3. Research Methodology

This study employed a survey research design to examine the impact of energy-efficient upgrades in educational buildings. A purposive sampling approach is used to select four educational institutions in Gauteng province of South Africa that have implemented energy-saving technologies such as LED lighting, smart HVAC systems, and renewable energy sources. The schools include the University of Johannesburg, the University of South Africa, the University of Witwatersrand, and the Tshwane University of Technology. The questionnaires were distributed to school facility managers and construction professionals to assess the strategies and benefits of energy-efficient upgrades. Ethical considerations, including informed consent and data confidentiality, are observed throughout the study, and the findings provide valuable insights into the effectiveness and feasibility of energy-efficient upgrades in schools. Data was collected using structured questionnaires targeting professionals in the selected educational buildings. A total population of 550 was arrived at after collating the professionals in the built environment in the selected school. Using Cochran's formula, a sample size of 160 was considered suitable for the study. One hundred sixty questionnaires were distributed, with 102 successfully retrieved and analysed. Using descriptive and inferential statistical methods, a quantitative approach was adopted to analyse the collected data. The paper identified the various energy-efficient upgrading strategies and their benefits in achieving a carbon-neutral building.

4. Findings and Discussion

4.1. Background Information of Respondent

The demographic summary of survey respondents in the study area indicates that 20% are Quantity Surveyors, 25% are Architects, 24% are Engineers, 26% are Facility Managers, and 5% are Project Managers. A significant proportion of the respondents have at least 10 years of experience. Regarding professional qualifications, 80% are corporate members of their respective professional bodies, while 20% are probationer members. Regarding post-professional qualification experience, 50% have between 1 and 5 years, 25% have 6 and 10 years, and another 25% have 11 and 15 years, with an average of 6.67 years. The predominance of experienced respondents enhances the reliability of the data for this research.

4.2. Strategies for Energy-Efficient Upgrades

Table 1 shows the strategies for energy-efficient upgrades. Ranking first is upgrading the lighting system with a mean score (MS) of 4.47 and Standard deviation (SD) of 0.742, followed by improving the HVAC system (MS = 4.43, SD=0.778) and renewable energy integration (MS=4.34, SD 0.838). Building automation ranked fourth with (MS=4.33, SD= 0.903), smart energy management systems ranked fifth with (MS=4.33, SD=0.829), greywater recycling ranked sixth with (MS=4.26, SD=0.9=891), sustainability awareness ranked seventh with (MS=4.25, 0.893), installing low-flow fixtures ranked eighth with (MS=3.35, SD= 1.248), using occupancy-based controls ranked ninth with (MS=3.24, SD = 1.096), improving insulation and weatherproofing ranked tenth with (MS=3.22, SD=1.092), upgrading to smart thermostats ranked eleventh with (MS=3.19, SD=1.062). Installing motion sensors and timers ranked least with (MS=3.05, SD=0.999), followed by using natural light optimisation and replacing old HVAC units with energy-efficient models with (MS=3.05, SD=1.092) and (MS=3.06, SD=1.164) respectively.

4.3. Benefits of Energy-Efficient Upgrades

Table 2 shows the benefits of implementing energy-efficient upgrades in educational buildings. From the table, cost savings ranked first with (MS=4.38, SD=0.926), achieving carbon neutrality ranked second with (MS=4.33, SD=0.980), reduction in carbon emission ranked third with (MS=4.32, SD=1.045), improved learning environment ranked fourth with (MS=4.30, SD=0.964), improved building resilience ranked fifth with (MS=4.29, SD=0.971), improved energy efficiency ranked sixth with (MS=4.27, SD=1.058). Ranking least is improved indoor air quality with (MS=3.51, SD=1.074), followed by long-term energy savings and increased environmental responsibility with (MS=3.37, SD=1.021) and (MS=3.57, SD=1.134) respectively.

Table 1: Strategies for Energy-Efficient Upgrades

Strategies	**Mean**	**SD**	**Rank**
Upgrading lighting systems.	4.47	0.742	1
Improving the heating, ventilation, and air conditioning (HVAC) system	4.43	0.778	2
Renewable energy integration	4.34	0.838	4
Building automation	4.33	0.903	3
Smart energy management systems	4.33	0.829	5
Greywater recycling	4.26	0.891	6
Sustainability awareness	4.25	0.893	7
Installing Low-Flow Fixtures	3.35	1.248	8
Using Occupancy-Based Controls	3.24	1.096	9
Improving Insulation and Weatherproofing	3.22	1.092	10
Upgrading to Smart Thermostats:	3.19	1.062	11
Replacing Old HVAC Units with Energy-Efficient Models	3.06	1.164	12
Using Natural Light Optimisation	3.05	1.092	13
Installing Motion Sensors and Timers	3.05	0.999	14

(Source: Authors')

Table 2: Benefits of Energy-Efficient Upgrades

Benefits	**Mean**	**SD**	**Rank**
Cost savings	4.38	0.926	1
Achieving carbon neutrality	4.33	0.980	2
Reduced carbon emissions,	4.32	1.045	3
Improved learning environments	4.30	0.964	4
Improved building resilience	4.29	0.971	5
Improved energy efficiency	4.27	1.058	6
Improved building performance	4.22	0.988	7
Improved HVAC system	4.07	1.003	8
Reduction in utility bills	4.05	0.934	9
Increased environmental responsibility	3.57	1.134	10
long-term energy savings	3.57	1.021	11
Improved indoor air quality	3.51	1.074	12

(Source: Authors')

4.4. Discussion

The findings from the questionnaire survey reveal significant insights into the effectiveness of energy-efficient upgrades in educational buildings. The results indicate that institutions implementing energy-saving technologies experienced noticeable reductions in energy consumption and operational costs. Most respondents reported that LED lighting upgrades led to a 30–50% decrease in electricity usage, confirming previous studies highlighting LEDs as a cost-effective solution for educational institutions (Idowu et al., 2024). Additionally, schools that installed motion sensors and automated lighting controls reported further savings by ensuring lights were only used when necessary. The study also found that HVAC system upgrades were crucial in improving energy efficiency. Schools that replaced outdated heating and cooling systems with energy-efficient HVAC units and smart thermostats reported 15–35% reductions in energy use.

Additionally, institutions that improved insulation and weatherproofing experienced better indoor temperature regulation, leading to reduced dependence on heating and cooling systems. This aligns with research by Idowu et al. (2024), emphasising the importance of proper insulation in minimising energy waste. Building automation and smart energy management systems also contributed to efficiency improvements. Schools that implemented real-time energy monitoring systems and occupancy-based controls reported better energy optimisation, as these systems adjusted heating, cooling, and lighting based on actual demand (Altassan, 2023). Respondents noted that automated systems reduced human error in energy management and helped facility managers identify further areas for improvement.

Respondents highlighted significant cost savings, with many schools reallocating funds from energy expenses to academic resources and infrastructure improvements. Improved indoor air quality and thermal comfort were also widely reported, contributing to better student concentration, attendance, and overall learning conditions. Furthermore, schools that embraced energy-efficient upgrades served as models for sustainability, raising awareness among students and fostering a culture of environmental responsibility.

5. Conclusion and Further Studies

Energy-efficient upgrades present a clear path toward carbon neutrality for educational buildings. These upgrades reduce operational costs, minimise environmental impact, and create healthier and more sustainable learning environments. By investing in energy-efficient technologies, schools and universities can lead by example, fostering a culture of sustainability among students and the wider community. With the right strategies, policies, and financial support, the education sector can make significant progress in achieving energy efficiency and contributing to global efforts to combat climate change. The study recommends stronger policy incentives and financial support for educational institutions to facilitate the adoption of energy-efficient solutions. Governments and private organisations should offer grants, subsidies, and low-interest loans to make energy-efficient upgrades more accessible. Additionally, partnerships between educational institutions and industry experts can drive innovation and knowledge-sharing in sustainable infrastructure. Schools and universities should also engage in collaborative initiatives that allow them to share resources, expertise, and best practices.

The study is limited to Gauteng province, South Africa. A broader geographic scope beyond the province could offer a more comprehensive understanding of the required strategies.

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Port Efficiency: The Implication of Blockchain Technology in the Construction Material Supply Chain

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Abstract

The Port of Durban has recently been experiencing operational delays that are affecting its performance. Delays at the port adversely affect the timely completion of projects in the construction sector of South Africa. This exploratory research focuses on identifying through literature the application and implications of blockchain technology in facilitating the supply chain of construction materials. Furthermore, the drivers of port productivity for the Port of Durban are compared with those of the Port of Rotterdam. This research adopts a Quantitative Research Approach. For Data analysis, the Data Envelopment Analysis is a non-parametric tool used to evaluate port efficiency. The Malmquist Productivity Index will be used to determine the drivers of Port Productivity for the selected Ports from 2017 to 2023. The heterogeneity of the port cases limits the generalisation of findings. This study informs policymakers, project managers, investment planners, and operational practitioners about the possibilities of blockchain technology in enhancing the supply chain of construction materials. Technology is a major driver of port productivity for the port of Rotterdam. The application of various customised and specific technologies has improved the productivity of the Port of Rotterdam. The application of smart contracts in Blockchain technology will assist in improving the construction material supply chain.

Keywords: Blockchain, Construction Material Supply Chain Management, Efficiency, Port Congestion, South African Ports

1. Introduction

The Port of Durban has recently been experiencing operational delays, which affect its performance. According to the World Bank CPPI (2023), the ports of Cape Town, Durban, and Port Elizabeth in South Africa have been ranked among the world's worst-performing container ports. Griessel (2024) states that along the shores of Durban and Richards Bay in South Africa, almost a hundred cargo vessels, laden with fuel, bulk dry goods, containers, and cars, are held up because of delays attributed to a combination of adverse weather conditions and ageing terminal equipment. The implication of port congestion on the construction sector and the challenges thereof is the rapid increase in material and labour costs (Griessel, 2024). Delays at the port can adversely affect the timely completion of projects in the construction sector of South Africa (Nemakhavhani et al., 2024). This is known as time overruns in the construction sector, specifically delays attributed to the importation of construction materials. The implication of bottlenecks at the port has a multiplier effect not only on the Construction sector but on the South African economy at large. This exploratory research focuses on identifying through literature the application of blockchain technology (BCT) in facilitating the supply chain of construction materials.

Furthermore, the research also focuses on the drivers of port productivity for both the Port of Durban and the Port of Rotterdam. The Port of Rotterdam is used as a benchmark because of its proven success in the application of blockchain Technology. Soni et al. (2023) opine that the construction sector plays a significant role in the development of the South African Economy because it contributes to the development of infrastructure, amongst others. Port Efficiency is a significant parameter for the success of the construction material supply chain (Obasi et al. 2024). Nikjow et. al. (2021) also attest that one of the major causes of delays in the procurement of construction materials is inefficient logistics and supply chain. An inefficient port should examine other options, such as blockchain Technology, which can assist in expediting the entire process. The implication of bottlenecks at the port has a multiplier effect not only on the Construction sector but on the South African economy at large.

Leah (2024) elaborates further by citing examples that can affect the construction materials supply chains, such as shortages of construction materials, disruptions in the supply chain, inflation, and delays due to customs procedures. The following are the aims and purpose of the research: identification of the application of blockchain technology in facilitating the supply chain of construction materials; to determine the drivers of port productivity for the Port of Durban and the Port of Rotterdam; and the comparison of the various applications of technology at the Port of Durban and Rotterdam. The study employs a quantitative research design that utilises secondary data extracted from the respective port websites. Kao (2023) states that efficiency is calculated as the ratio of output to input.

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The heterogeneity of the port cases limits the generalisation of findings.

This study informs policymakers, project managers, investment planners, and operational practitioners about the possibilities of blockchain technology in enhancing the supply chain of construction materials in South Africa. Due to time constraints, the data is limited to the period of 2017-2023. The research findings show that technology is a major driver of port productivity for the port of Rotterdam. The application of various customised and specific technologies has improved the productivity of the Port of Rotterdam. The construction sector is in dire need of an effective and efficient supply chain. The application of blockchain technology to contracts will improve the construction material supply chain. The following is the outline of the paper. Section 2 describes fundamental concepts in detail in the Literature Review, Section 3 examines the research methods, Section 4 discusses the findings and discussion, and Section 5 concludes with future research.

2. Literature Review

According to Meersman et al. (2012), a Port is congested when it cannot meet the demand of the port users either at the quayside, crane, yard side, or the gate. Congestion is a major restricting element of international trade and economic development, especially during the COVID-19 epidemic (Lin et al., 2022). Container ships tend to wait less time in ports in developed economies than in developing countries, due to a combination of faster clearance times, better infrastructure, and higher labour productivity (UNCTAD, 2023). Herein lies the importance of blockchain technology. The application of blockchain technology in the maritime industry can improve customs clearance efficiency and logistics transparency in the various container cargo supply chains (Wang et al., 2021). Ports are adversely affected by procedural complexities, redundancy, unintegrated information and document flow, which affects various port users and stakeholders involved in seaport operations (Mthembu and Chasomeris, 2024). According to the USDA Report (2024), the South African ports have, over the years, been experiencing chronic and acute operational challenges. Blockchain technology has emerged as a focal point of attention among these technological innovations (Guan *et al.* 2024). This section examines the various concepts that provide the essence of this study. The various concepts include the construction sector, port, port efficiency, the implications of port inefficiency, and the application of blockchain technology.

2.1. The Construction Sector and the Construction Material Supply Chain

According to the Department of Trade, Industry, and Competition (2024), the construction industry is a driver of socio-economic development and a key employment multiplier, contributing 5.3% and 7.8% of South Africa's formal and informal sector employment, respectively. Ghamari et al. (2024) posit that the Construction Material Supply Chain is a network series that shows how construction materials are imported from origin to destination. In the construction sector, the supply chain manager has a critical role in strategically planning the consignment from the port of origin to the port of destination. Steel is a critical component for materials in the construction sector (Putri and Firmansyah, 2020). For instance, South Africa imports steel from the United States and Cement from China. Other imported construction materials include sand, gravel, crushed stone, Plywood, Hardboard, Pine, eucalyptus transmission poles, and Industrial electrical cables (STATS SA, 2024). South Africa's leading international trading partners include China, the United States, Germany, and Japan, which send shipments via the ports.

2.2. The Ports: South Africa and Rotterdam

Peng et al (2023) affirm that the Ports are central to the maritime supply chain. The implication of this is that without the port, the maritime supply chain is spineless and scattered. Ayesu and Boateng (2024) posit that Ports are pivotal in serving as vital corridors for the movement of goods across the African continent and beyond. Not only are ports of essential value to the global supply chain, but their productivity is also critical. Therefore, seaports and their efficiency remain essential for the success of global international trade (Ayesu et al, 2024). Mazibuko et al. (2024) assert that a container port's competitiveness depends on the productivity of its container terminal. Port evaluation serves as an impetus for port management to make informed strategic decisions. Port Evaluation reveals the actual state of the Port and enables Port management to make a decisive decision on how to improve port efficiency. The Ports in South Africa are critical to the South African export-led strategy (Transnet, 2024). According to Statista (2022), in 2022, 67% of South African International trade was done via sea. International Trade Administration (2024) opines that the South African geographical location presents a considerable opportunity for investing in a diversified maritime market. Nevertheless, the South African ports have been sinking with challenges that are accentuating delays in operations and causing financial losses (United States Department of Agriculture -USDA, 2024).

The World Shipping Council (2022) states that the port of Rotterdam is ranked as the 10th amongst the top 60 container ports globally, and it is the largest port in Europe. The Port of Rotterdam website (2024) asserts that the Port of Rotterdam is deliberate and committed to digitisation and port efficiency. According to Farah et al (2024), the Port of Rotterdam has used blockchain technology since 2016 to facilitate the tracking and

tracing of container shipments of flowers. The service allows for a seamless flow of information with customs authorities, hence allowing exporters to have the full ability to track and trace shipments (Farah et al., 2024).

2.2.1. The Ports: Efficiency and Inefficiency

Yen and Mulley (2023) state that Transport Efficiency is critical in transport. The evaluation of port performance is primarily aimed at assisting in improving port operations and providing useful information for port development planning and strategy (Suárez-Alemán et al., 2016). When a Port is efficient, it is obvious because there are limited delays at the Port, especially at the various operational levels. The operational areas include the quayside, crane, yard, and gate operations. According to Pallis and Rodrigue (2022), Port efficiency is multidimensional and it describes operational performance with emphasis on output maximisation and cost minimisation. Efficiency drives port competitiveness (Danladi et al, 2024).

According to Danladi et al. (2024), various indices, such as delays, show that ports are inefficient. Congestion resulting from poor management of seaports can also affect shipping lines, manufacturers, distributors, freight forwarders, warehouses, consumers, and everyone else along the supply chain (Prasad and Gavirneni, 2010). Port congestion is one of the many factors that can disrupt schedules and, as such, negatively affect schedule reliability (Notteboom, 2006). Delays have a substantial impact on money. The performance of the container process affects the amount of time a ship is required to stay at the port (Wong and Kozan 2010).

2.2.2. Blockchain Technology

According to Farah et al. (2024), Blockchain technology is a credible and essential solution to address the cry for enhancing security, transparency, and efficiency in the maritime industry, where increasing reliance on digital systems and data prevails. According to Monrat et al. (2019), Blockchain has the following features: decentralisation, immutability, transparency, and auditability. These features make transactions more secure and tamper-proof (Monrat et al, 2019). A predominant feature of the maritime supply chain is prolonged service cycles, complex structures, and information generated from multiple sources (Liu et al, 2021).

3. Research Methodology

This research employs a monomethod, the Quantitative Research Approach, to calculate efficiency, which is the ratio of the outputs to the inputs. The measurable parameters of inputs are obtained for the respective port statistics. The inputs are the number of container berths, the number of tug boats, the number of terminals, the number of cranes, the number of port employees, and the length of the quay, whilst the outputs are vessel visits and container throughput. This secondary data for 2017-2023 is sourced from the Port of Rotterdam and Transnet Port statistics. This data set has been confirmed and validated by another source, such as the World Bank CPPI (2023) report. The sampling technique used is nested purposive sampling because the Port of Rotterdam is among the few smart ports that have applied blockchain technology.

This research adopts the Malmquist Productivity Index to measure efficiency over time. The Malmquist index (MI) evaluates the efficiency change over time. It is a non-parametric framework that is measured as the product of catch-up (or recovery) and frontier-shift (or innovation) terms, both coming from the DEA technologies (Tone, 2004). This research uses the Malmquist Productivity Index of the data envelopment analysis to evaluate port efficiency and productivity for South African ports. MPI deals with efficiency over time, instead of examining the snapshot of performance at one specific time, MPI considers performance (changes) across different periods (Ohene-Asare, 2018). The following shows the importance of the inputs and outputs:

Inputs: Number of Container Terminals: This is critical as they provide the main infrastructure responsible for loading and unloading the containers full of materials (Martinez-Moya, 2025). **Number of Container Berths**: The very first place of arrival at the port is the berth, where offloading and unloading container terminal operations begin (Jiang et al., 2024). Hence, to prevent delays, there must be more berths or a process of improving vessel flow. **Number of Cranes:** The number of cranes is hinged to port productivity (Ningrat et al., 2024). **Number of Tugs**: Tugs are essential navigational tools for Vessels entering the ports (Bošnjak, et al, 2021). **Length of Quay:** This determines the type and size of a ship, which can be granted an allocation at a particular time for an unused berth and is crucial for port productivity (Jeong et al, 2024). **Port Employees:** This has a positive impact on port productivity (Ayesu et al, 2024).

Outputs: Container Throughput: The output of a container terminal is critical for port employment. (Ayesu et al, 2024). **Vessel Visits:** Chu et al (2023) posit that the punctuality of vessel visits or calls is crucial for port operations.

According to Negar and Rostamy-Malkhalifeh (2017), MPI shows the regression and progression of decision-making units, such as ports, over time. The two periods are the efficiency change and the technology change. Negar and Rostamy-Malkhalifeh, (2017) state that the MPI expresses that the regression and progress of a unit from one period to the next depends not only on its efficiency changes during these two periods, but also on technological changes in the population, or

boundary shift of the evaluated population in the same period Equation 1 is the MPI formula. The Pim-Dea V.3.0 software, developed by Emrouznejad and Thanassoulis (2011), calculates the efficiency change for the selected ports from 2017 to 2023.

$$M(Y_{t+1}, X_{t+1}, X_t) = \underbrace{\frac{D^t(Y_{t+1}, X_{t+1})}{D^t(Y_t, X_t)}}_{Efficiency\ change} \quad \underbrace{\frac{D^t(Y_{t+1}, X_{t+1})}{D^{t+1}(Y_{t+1}, X_{t+1})} X \frac{D^t(Y_t, X_t)}{D^{t+1}(Y_t, X_t)}}_{Technology\ change}$$

Equation (1): The Malmquist Productivity Index Formula. Source: Malmquist (1953).

Where: Xt and Xt+1 are the input vectors of dimension at time t and t +1, respectively, and Yt and Yt+1 are the corresponding k-output vectors.

Dt and Dt+1 denote an input

D(x,y)= max(ρ: ($s/\rho s \in L(y)$ (1)

Where L(y) represents the number of all input vectors with which a particular output vector y can be produced, that is, L(y) = (x: y can be produced with x).

P in equation (2) can be understood as a reciprocal value of the factor by which the total inputs could be maximally reduced without reducing output.

M= measures the productivity change between periods t and t+1. Productivity declines if M<1, remains unchanged if M=1, and improves if M>1.

4. Findings and Discussion

This section is categorised into three major sections based on the research objectives: the application of BCT on CMSC, the Application of Blockchain Technology at the Port of Rotterdam, and determining the drivers of port productivity for the Port of Durban and the Port of Rotterdam.

4.1. The Application of BCT in the Construction Materials Supply Chain

Blockchain technology is suitable for facilitating the construction material supply chain. Based on a literature search of over 50 articles using keywords like BCT and construction materials supply chain. The Application of blockchain has been streamlined into four major categories. These are smart contracts, track and trace, acceleration of document flow, and authentication and validation of documentation and stakeholders. Shojaei (2019) posits that the implementation of blockchain technology in the construction industry can also result in the use of smart contracts, which will reduce administrative struggles and improve the flow of the project, materials, and service delivery. Elmay et al. (2022) attest that blockchain accelerates the inefficient shipping process by digitising ownership transfer and process documentation. Wang et al (2021) posit that blockchain enables simultaneous auditing and makes real-time optimisation possible for partners and organisations. Nasih et.al. (2024) confirm the use of BCT to improve tracking and tracing services, ensuring data integrity, transparency, and traceability across supply chains.

4.2. Application of Blockchain Technology at the Port of Rotterdam.

Wang et al. (2021) posit that the application of blockchain technology in the maritime industry can improve customs clearance efficiency and logistics transparency in the container cargo supply chains. Quay Connect was born out of the challenges of importing and exporting between the Netherlands and the United Kingdom. It was developed as an independent blockchain platform to facilitate the exportation of shipments from the Netherlands to the United Kingdom (Port of Rotterdam, 2025). The benefit of this application is the automatic exchange of information with the customs authorities at ports in the United Kingdom (Farah et al., 2024). The implication is that exporters from the Netherlands can digitise and streamline the export and customs process. This results in a savings of 30% on the cost of each customs clearance (Port of Rotterdam, 2025).

4.3. Determine the drivers of port productivity for the Port of Durban and the Port of Rotterdam

Port productivity is an important measure of port stakeholders (Gonzalez, 2022). The port productivity of both the port of Rotterdam and Durban is analysed for 2017 to 2023. The results of these analyses are categorised into efficiency change and technology change. The product of the efficiency changes and technology makes up the Malmquist Productivity Index. The Pim-Dea V.3.0 software developed by Emrouznejad and Thanassoulis (2011) calculates the efficiency change for the selected ports from 2017 to 2023.

4.3.1. Efficiency Change and Technology Change

The efficiency change component measures how well a firm, in this case the Port of Durban and Rotterdam, makes use of its resources to produce a given level of output. Both the Port of Durban and Rotterdam make use of their resources optimally, as indicated by level 1. Technological change measures how the production frontier shifts over time. As the frontier shifts upward, more outputs can be obtained from the same level of inputs. Technology is a major driver of productivity. There is a clear-cut demarcation of the impact of technology on port productivity for the Port of Rotterdam. The Port of Durban still has much room for improvement in terms of the application of suitable and customised technology on port performance.

4.3.2. The Malmquist Productivity Index

According to Negar and Rostamy-Malkhalifeh (2017), when the Decision-making unit has an MPI value of greater than one, as in the case of the Port of Rotterdam, it means that progress occurred consistently in the period 2017 to 2023, as indicated for 2017/2018 for the Port of Durban. However, if the decision-making unit has an MPI of less than 1, as in the case of the Port of Durban for the year 2019/2020, a regression occurs in the period. When the Port of Durban experienced MPU 1 in 2020/21 and 2022/23, it means that no progress or regression occurred. From Figure 1, the Port of Rotterdam has a higher Malmquist Productivity Index than the Port of Durban. The Technology factor plays a crucial role in the performance of the Port of Rotterdam. Figure 1 shows the implications of technology on the Port of Productivity for the Port of Rotterdam. Over the years, we have examined except for 2018-2019. The Port of Rotterdam has improved in its productivity due to the application of technology.

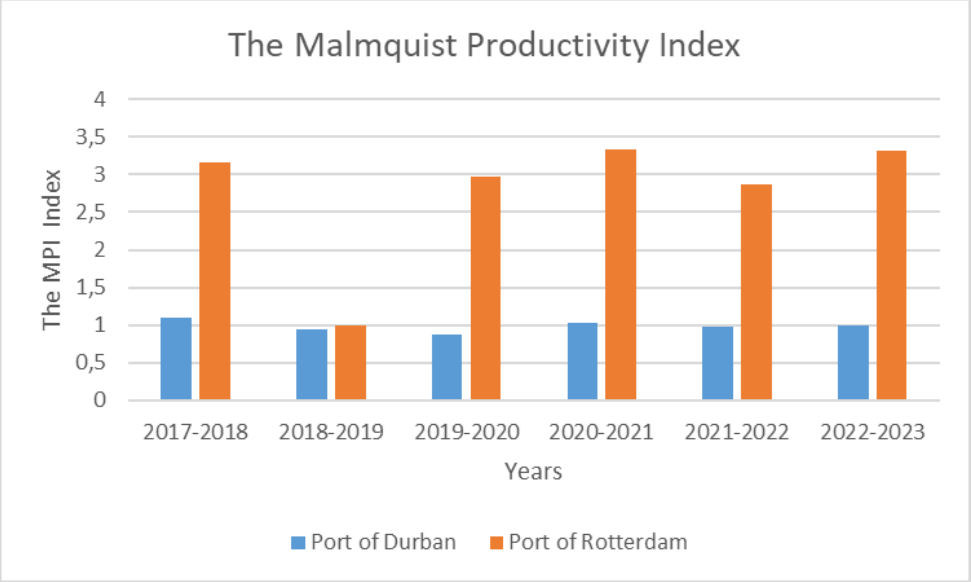


Figure 1: The Malmquist Productivity Index
(Source: Author's 2024)

4.4. Compare the various applications of technology at the Port of Durban and the Port of Rotterdam

The Port of Rotterdam is heavily automated and uses several technologies such as Blockchain (Quay Connect), HAMIS- Haven Management Information System, Artificial Intelligence and Twin Digitalisation to drive its operational efficiency (Farah et al, 2024). Elhussieny (2025) posits that the Port of Rotterdam is ranked highly in Europe and globally. However, CPPI (2023) indicates that the port of Durban is struggling in terms of its performance. The Port of Durban is still traditionally based, even though it uses various technologies such as Navis Sparcs N4, Electronic Data Interchange, General Cargo Operating System, and AVEVA Software to reduce the risk of load shedding (Transnet 2024).

5. Conclusion and Further Research

Gidado (2015) attests that congestion in ports is associated with delays, queuing, and extra time for the voyage and dwelling of ships and cargo at the port. This research was conducted because of the incessant delays experienced by importers of construction materials via the port of Durban. The research further used the Port of Rotterdam as a basis for comparison, as it is not only a smart port but has also made use of Blockchain Technology. This study identified the various applications of blockchain technology in facilitating the supply chain of construction materials. This lends credence to the importance of blockchain in the area of smart contracts, tracking and tracing of shipments, acceleration of document flow, and authentication and validation of documentation among stakeholders. The study proved that technology is a major driver of port productivity.

Furthermore, the gap in port productivity, as shown in Figure 1, shows the impact of technology on the MPI of the Port of Rotterdam. Finally, the study compares the various applications of technology at the Port of Durban and Rotterdam. The implication of this research is for the port authority, construction companies, and other stakeholders to know the benefits of blockchain in facilitating the construction material supply chain. For instance, Quay Connect is a collaboration between the Port of Rotterdam, Brexit, and Importers and Exporters. This customised BCT was developed to curb the struggles of importing and exporting between the European nations. Particularly since BCT provides a

way forward to handling port inefficiencies, for instance, Smart contracts can activate real-time actions or transactions, respectively, as soon as the pre-defined contractual clauses and rules are fulfilled (Phillip et al, 2019). The Port of Rotterdam engages its stakeholders in such a way that the technology used in the ports is well-suited to meet the needs of the port and its stakeholders. Further research can be pursued on the dynamics and criteria of collaboration amongst the critical stakeholders. It is also necessary to monitor the efficiency of the ports in subsequent years to see if there is an improvement or a further decline in port efficiency.

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Appraisal of Building Information Modelling Implementation on Construction Project Performance in Nigeria

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Abstract

The Nigerian construction industry continues to face challenges related to project inefficiencies, cost overruns, time delays, and low productivity. Despite the global advancement of Building Information Modelling (BIM) as a tool for improving construction project performance, its adoption and implementation in Nigeria remain limited. This study investigates BIM impact on construction project performance in Nigeria, addressing a significant gap in empirical research within the local context. To achieve the objective, a quantitative survey method was adopted following a pilot study to refine the research instrument. The study population comprised 85 key professionals, including principal partners, project quantity surveyors, architects, engineers, and project supervisors drawn from both private and public construction and consultancy firms. A census sampling technique was employed, and 63 valid responses were retrieved, yielding a response rate of 74.12%. Data were analyzed using Mean Item Score (MIS) and Relative Importance Index (RII) to rank the impact of BIM on various performance indicators. The results reveal that BIM significantly enhances project performance, with safety, labour productivity, customer satisfaction, and time management ranking highest in impact (RII = 0.86, 0.81, 0.76, and 0.75 respectively). Cost efficiency, supply chain management, sustainability, risk management, and quality control followed, with RII values ranging from 0.74 to 0.68. The study concludes that stakeholders generally perceive BIM positively, acknowledging its transformative potential for the Nigerian construction industry to what the study reveals, which is same as finding. It recommends that construction firms actively embrace BIM technologies and practices, as doing so would significantly enhance project outcomes, reduce inefficiencies, and promote sustainable development.

Keywords: Building, BIM, Construction Professionals, Project Performance, Stakeholders.

1. Introduction

Building Information Modeling (BIM) has been conceptualized and interpreted in various ways by different scholars. Karen (2014) characterizes BIM as an integrated and structured digital database utilized within the architecture, engineering, construction, and operations (AECO) industry. This database comprises 3D parametric objects and facilitates interoperability. Azhar *et al.* (2012) describe BIM as an advanced process and tool that incorporates virtual components, concepts, and systems of a facility within a unified digital environment. According to Sacks (2020), BIM involves using a database infrastructure to represent built facilities from the perspectives of different stakeholders, enabling them to query, simulate, estimate activities, and oversee the building lifecycle. Arayici and Aouad (2010) define BIM as the application of ICT technologies to streamline building lifecycle processes, ensuring a safer and more efficient environment for occupants while minimizing environmental impact and enhancing operational efficiency for owners. Similarly, Arayici and Coates (2012) simplify BIM as the use of a database infrastructure to encapsulate built environments with stakeholder-specific viewpoints, integrating digital representations of building objects and their relationships in a structured manner to facilitate informed decision-making throughout the building lifecycle.

Assessing BIM adoption in Nigeria presents a valuable opportunity to enhance the efficiency and competitiveness of the country's construction industry by leveraging ICT advancements and addressing existing challenges. Through strategic implementation, Nigeria can emerge as a leader in BIM adoption within Africa, fostering sustainable development and economic growth.

Given this context, there is a need to evaluate the influence of BIM implementation on construction project performance in Nigeria. This study aims to assess the current level of BIM adoption and its impact on construction project outcomes within the Nigerian construction industry, providing essential insights for industry stakeholders.

2. Literature Review

Performance is a crucial aspect of construction projects, as it often determines their overall success. The concept of performance has been defined in various ways, reflecting the diverse nature of construction activities. Ingle and Mahesh (2022) describe performance as the extent to which a project effectively meets its objectives in terms of time, cost, and quality,

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emphasizing efficiency in resource utilization. Similarly, Van Tam *et al.* (2023) define performance as the degree to which project goals are achieved, incorporating not only time, cost, and quality but also safety and client satisfaction. These definitions highlight performance as a multidimensional concept that integrates key parameters essential for evaluating construction project outcomes.

Performance in construction projects is fundamental to financial success. High performance ensures profitability, as projects completed on time and within budget are more likely to yield financial returns. Kerzner (2022) identifies effective resource management as a primary factor in maximizing profits and minimizing losses. Moreover, client satisfaction is closely linked to high performance, as meeting or exceeding expectations regarding time, cost, and quality fosters repeat business and positive referrals (Kerzner, 2022). Repeat clients and recommendations play a crucial role in the long-term sustainability of construction firms (Fewings & Henjewelw, 2019). Additionally, consistently high performance enhances a firm's reputation, attracting more clients and prestigious projects, thereby strengthening its market position. Many definitions of high performance also emphasize sustainability, which is increasingly demanded by clients and regulatory bodies. Sustainable construction practices not only benefit the environment but also reduce long-term operational costs and enhance project value (Maraveas, 2020).

Various metrics are used to assess performance in construction projects, each holding significant importance. The most common metrics are time, cost, and quality (Tunji-Olayeni *et al.,* 2016). Time performance refers to a project's ability to meet its scheduled completion date, as delays often lead to cost overruns and client dissatisfaction (Hussain *et al.,* 2019). Cost performance measures a project's ability to remain within its budget, which is crucial for financial stability and profitability (Jahan *et al.,* 2022). Quality performance evaluates whether the final project meets client requirements and expectations, ensuring client satisfaction and minimizing future maintenance costs (Hussain *et al.,* 2019).

Safety is another vital metric in project performance evaluation. It assesses adherence to safety regulations and the frequency of accidents or injuries on-site (Abas *et al.,* 2020). A strong safety record is essential for protecting workers, reducing legal liabilities, and maintaining a positive company image (Mohammadi *et al.,* 2018). Sustainability performance examines the environmental impact of a project and its alignment with sustainable practices. (Rajabi *et al.,* 2022) highlight that sustainable construction is crucial for regulatory compliance and cost reduction, ultimately enhancing project value. Client satisfaction is also a key performance indicator (Tunji-Olayeni *et al.,* 2016), measuring the overall experience and satisfaction level of clients regarding the final project outcome. High client satisfaction leads to repeat business and positive referrals, which are essential for a construction firm's long-term survival and growth in the industry.

2.1. BIM and the Construction Industry in Nigeria

The adoption of Building Information Modeling (BIM) within the Nigerian construction industry has been relatively slow. According to Monejo and Makinde (2020), BIM adoption in Nigeria is still in its early stages, though awareness of its benefits among industry stakeholders is gradually increasing. The Nigerian construction industry is highly fragmented, with many small and medium-sized enterprises (SMEs) operating independently. This fragmentation poses a major barrier to BIM adoption, as the methodology requires extensive collaboration and information sharing among project stakeholders (Olanrewaju *et al.,* 2020).

One of the key drivers of BIM adoption in Nigeria is its potential to enhance project performance. BIM improves project visualization, facilitates better coordination, and enhances cost estimation and scheduling accuracy. Many of the persistent challenges in the Nigerian construction industry, such as cost overruns, delays, and poor work quality, can be directly addressed through BIM. For instance, Bamgbose *et al.,* (2024) note that BIM adoption significantly reduces rework and errors in construction projects, leading to cost savings and timely project delivery.

However, several challenges hinder BIM adoption in Nigeria. A significant barrier is the shortage of skilled professionals proficient in BIM tools and technologies (Bamgbose *et al.,* 2024). The existing education and training infrastructure in Nigeria is insufficient to produce the required number of skilled personnel to drive BIM adoption meaningfully (Toyin & Mewomo, 2023). Additionally, the high cost of BIM software and associated training programs presents a significant financial burden for many construction firms, particularly SMEs (Olanrewaju *et al.,* 2020).

Infrastructure-related challenges also impact BIM adoption in Nigeria. The effective use of BIM relies on stable internet connectivity and robust technological infrastructure, yet many parts of Nigeria still suffer from poor internet access and inadequate digital infrastructure (Eze *et al.,* 2024). This limitation hinders the full utilization of BIM's collaborative and real-time capabilities.

Despite these challenges, several strategies can be implemented to promote BIM adoption and integration in Nigeria. One critical approach is strengthening BIM-related skills and capacities by incorporating BIM training into tertiary education curricula for construction-related courses. Construction firms can

also invest in continuous professional development programs to enhance their workforce's BIM proficiency (Olanrewaju *et al.,* 2020).

Increasing awareness about BIM's benefits and dispelling misconceptions that prevent firms from adopting it is also essential. Government intervention can play a significant role in promoting BIM adoption by developing policies and regulations that mandate its use, particularly for public construction projects (Saka *et al.,* 2022). Additionally, improving technological infrastructure, including internet connectivity, would further support BIM implementation (Eze *et al.,* 2024). Empirical studies indicate that BIM adoption has had a positive impact on project performance in Nigeria. For example, research conducted by Onungwa and Uduma-Olugu (2017) found that BIM significantly improves key project performance indicators such as completion time, client satisfaction, and quality. Similarly, Monejo and Makinde (2020) reported that BIM implementation enhances project control, improves collaboration, facilitates conflict resolution, and reduces labor inefficiencies.

Furthermore, BIM has the potential to enhance the sustainability of construction projects in Nigeria. According to Bamgbose (2024), BIM enables more accurate and detailed planning, optimizing resource utilization, minimizing waste, and reducing the environmental impact of construction activities. This is particularly relevant in Nigeria, where the growing rate of urbanization and environmental concerns necessitate the adoption of sustainable construction practices.

3. Research Methodology

The study area is Abuja, situated in North central Nigeria and the capital city of Nigeria. Survey design was adopted for the study, which involved collection of data through questionnaires administration. The population of the study was professionals, individuals in both private and public construction companies and consultancy firms in Abuja. The sample size is determined based on size of the study population and some other parameters such as desired confidence level and margin of error (Taherdoost, 2016). Due to the impracticality of reaching and collecting data from all professionals in the construction industry in Abuja, a sample that is representative of the population is taken in order to ensure that the findings of the study can be generalized to a larger industrial context. Taro Yamane's formula was used to determine the appropriate sample size for the study. This formula used for calculating the sample size is one of the most widely used among researchers since it is effective in determining sample sizes for studies. The Taro Yamane formula for calculating the sample size is given as.:

$$n = \frac{N}{1 + N * e^2}$$

Where;
n represents the sample size.
N presents the population size (estimated total number)
e represents the margin of error (0.05).

A total number of 80 individuals were given the questionnaire. However, out of the 80questionnaires, 63 (78.75%) were filled and submitted, indicating a high response rate. All the submitted questionnaires were used in the study analysis (Figure 1).

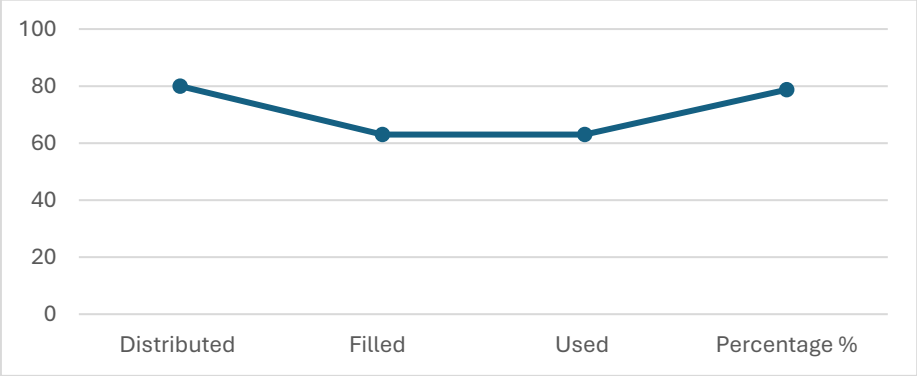


Figure 1: Number of Questionnaires

4. Findings and Discussions

Figures 2- 5 (see Appendix 1) presents the distribution of respondents' background information. Out of the 63 respondents, 71.4% were male and 28.6% were female, indicating that male was more than female in the study. Majority of the respondents were Master's degree holder (36.5%), followed by BSC/B-tech holder (34.9%), HND holder (17.5%) and PhD holder (11.1). Those with Masters and Doctorate degrees accounted for a reasonable number of total respondents, indicating that, most of the respondents have a higher level of educational qualification. On the profession of the

respondents, majority of the respondents were architects represented by 33.3%, this is followed by engineers (23.8%), Quantity Surveyors have representation of (20.6%), builders represented by 12.7% and project manager accounted for 9.5%. Furthermore, most of the respondents have 11-15 years professional experience, this is followed by 22.2% of the respondents with 6-10 years, another 12.7% have 16-20 years professional experience, 19.0% have 1-5 years of experience and 7.9% have over 20 years professional experience. The cumulative percentage of respondents with 11 years and above professional experience is 58.8% indicating that, the study is dominated by those with high level of professional experience in the Nigerian construction industry.

However, project performance using BIM does not perform better in terms of communication (8th) with their RII being 0.48. This result shows that the overall performance of project using BIM is higher compared to without using BIM i.e. BIM adoption has a higher positive impact on project performance.

4.2. Stakeholder Perception and Attitude towards BIM and its Benefits

Figure 7 presents the distribution of respondents' response on whether they believe BIM has potential benefits for the Nigerian construction industry. 9.52% claimed they do not believe BIM has potential benefits for the Nigerian construction industry while 90.48% claimed that BIM has potential benefits for the Nigerian construction industry. This shows that majority have a positive perception toward BIM potential benefits.

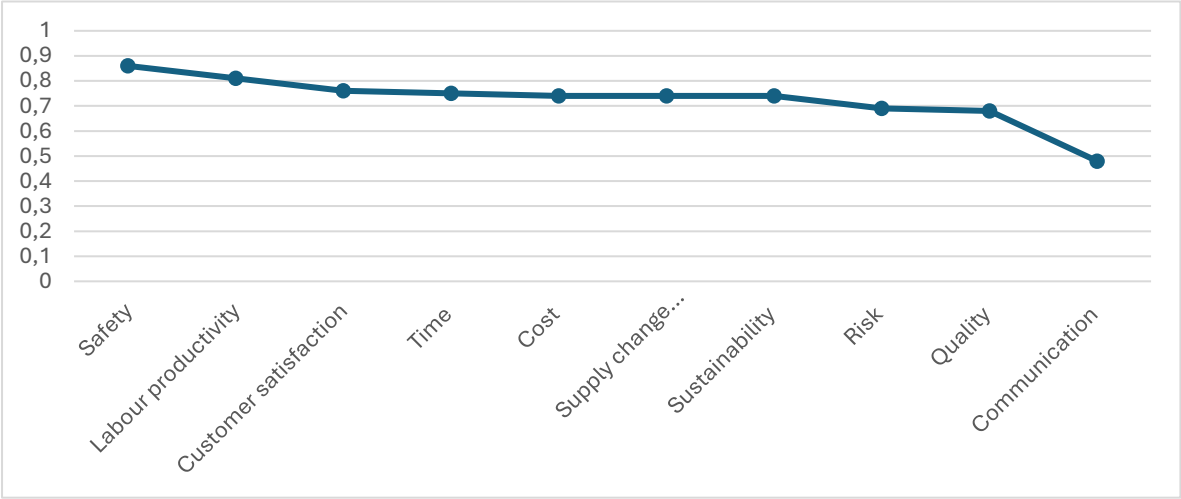


Figure 6: RII of Stakeholders Perception

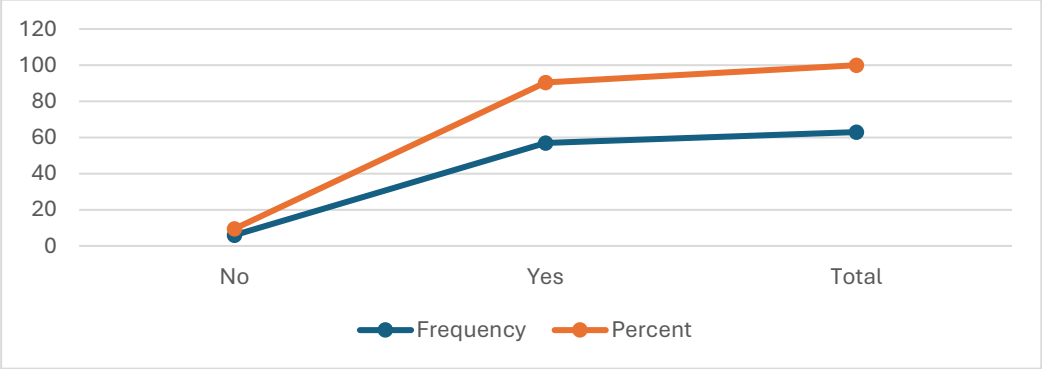


Figure 7: BIM Potential Benefits for the Nigerian Construction Industry

4.1. Impact of BIM on Project Performance

Figure 6 shows the rating of project performance using BIM compared to without using BIM. As shown, the project performed better using BIM in terms of safety (1st), labour productivity (2nd), customer satisfaction (3rd), time (4th), cost., supply change management, sustainability(5th), risk (6th), quality(7th) with RII of 0.86, 0.81, 0.76, 0.75, 0.74, 0.69 and 0.68 respectively.

The study investigated BIM adoption and implementation on construction project performance in Abuja, Nigeria. The objectives of the study were; To assess the current level of BIM adoption in the study areas construction industry; to identify the level of BIM implementation in FCT construction industry; to

evaluate the barriers hindering the successful implementation of BIM in construction projects in Abuja, Nigeria; to assess the impact of BIM adoption level on project performance metrics, and to investigate the perceptions and attitudes of stakeholders towards BIM and its potential benefits on construction projects.

5. Conclusion

The paper concluded that Stakeholders' perception of BIM is generally positive, with majority recognizing its potential benefits for the Nigerian construction industry. But, the variation in the stakeholders' willingness to recommend BIM indicates that more advocacy and evidence of its effectiveness are needed to build a wider base of support.

6. Recommendation

Based on the findings, the paper recommended appraisal the adoption and implementation of BIM in the Nigeria construction industry so that Investment should be made in training and development – comprehensive training programmes with certification for BIM proficiency should be organized for existing professionals. Increase research for BIM technology in institutions of higher learning, Government should provide support by offering financial incentives to companies that are investing in BIM and encourage its use in public sector projects Stakeholders should be educated on the capabilities and benefits of BIM through campaigns aimed at raising awareness, while universities and technical colleges should be mandated to incorporate BIM training into their programs, There should be platforms for professionals to share knowledge on BIM with each other and promote integrated project delivery methods, this will enhance collaboration among different stakeholders, To tackle financial barriers, Small and Medium Scale Enterprises (SMEs) should be encouraged to develop and adopt cost-effective BIM tools. Also, there should be establishment of funding mechanisms specifically for supporting adoption of BIM tools by SMEs.

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Appendix 1

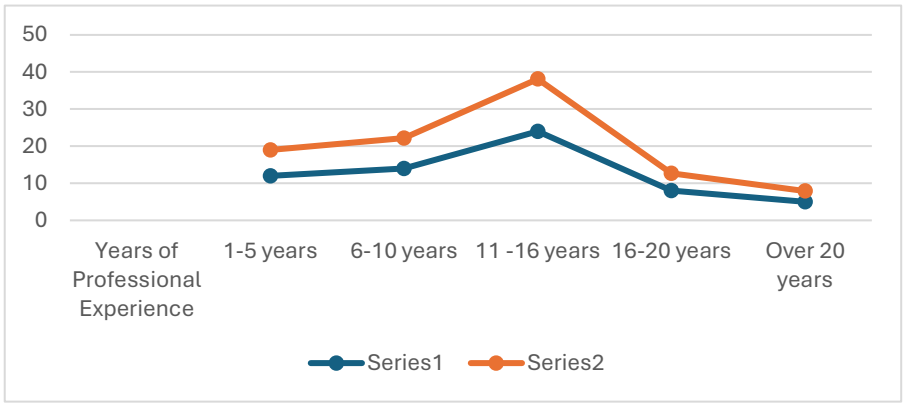


Figure 5: Year of Professional Experience

Figure 2: Gender

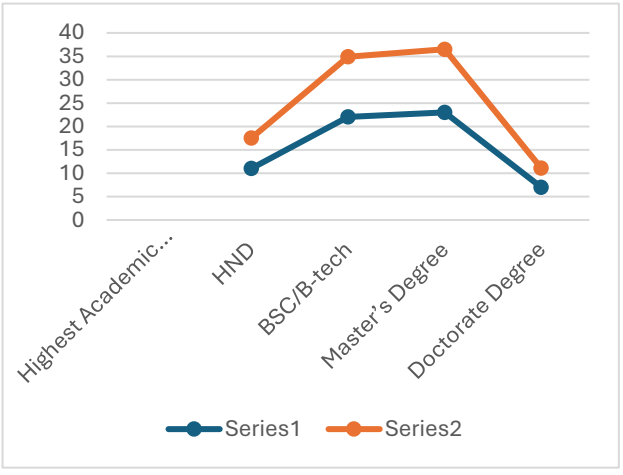


Figure 3: Highest Academic Qualification

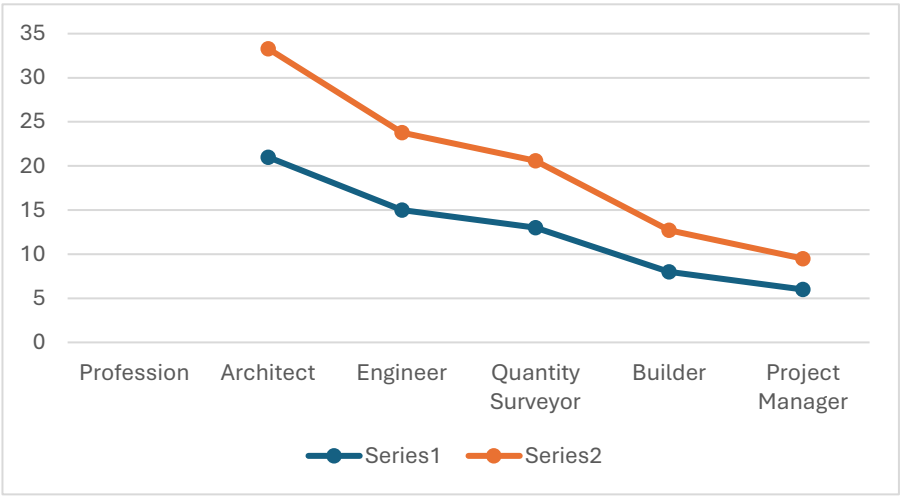


Figure 4: Profession

ACADEMIC PAPERS: THEME 2 - SUSTAINABLE CONSTRUCTION/NET-ZERO IN CONSTRUCTION

Leveraging on Sustainable Building Designs: Exploring the Drivers and Satisfaction of Smart Lighting in Student Housing in Ghana

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Abstract

Smart lighting continues to emerge in student housing in Africa. This study assesses the drivers and satisfaction of smart lighting in university housing in Southern Ghana. The study surveyed 334 student residents and interviewed 10 housing managers across five purpose-built student housing facilities at five selected public universities in Southern Ghana. Relative Importance Index and thematic analysis were data analytical techniques used. The findings reveal that accommodation needs primarily drove smart lighting in student housing. The satisfaction levels of smart lighting were limited to lighting controls in lavatories, bedrooms, study areas, the kitchen, and common areas. However, dissatisfaction with lighting was associated with adjustment to minimum light intensity and control of artificial lighting. Technically, the limited influence of facilities management factors in adopting smart lighting poses a significant risk to energy sustainability if left unaddressed. Interviews reveal that students' lack of knowledge impacts their satisfaction with and usage of smart lighting systems. At best, student housing managers and students would need education on smart lighting.

Keywords: Energy sustainability, smart lighting, sustainable design, student housing, Technology Acceptance Model

1. Introduction

In recent times, the widespread adoption of smart lighting in buildings has been hindered by a lack of robust total light quality control, average energy-saving returns that impact initial investment costs, and inadequate functionalities (Füchtenhans et al., 2023). Despite these obstacles, it is a multidisciplinary research area that has the potential to advance critical studies related to photobiology and human health, as well as commercial and residential buildings. Evidence within the built environment indicates that buildings with integrated energy-saving lighting control systems typically demonstrate savings of about 60% compared to traditional lighting control (Papinutto et al., 2022). Smart lighting can enhance productivity, spur growth, and improve light quality. As a consequence, most studies in this emerging field are currently focused on understanding maximum energy savings and efficiency, with limited focus on satisfaction from end-users' perspectives.

Over the past decade, challenges of high energy consumption and increases in energy costs have pushed most of the developing world to adopt sustainability practices related to smart buildings and technology. Within the sub-Saharan African countries, universities consume much energy. According to Appau et al. (2024), student housing is a unit that consumes high energy within the African university system. Despite this, most universities have developed sustainability policies that include not only environmental sustainability but also the implementation of smart lighting in both on-campus and off-campus facilities. In the context of student housing, innovative lighting with wireless control sensors and daylight-dependent dimming has already been evident in some student housing in South Africa, Egypt, Nigeria, and Ghana (Gentile et al., 2022). Within the Ghanaian context, the genesis of smart lighting adoption in student housing was due to empirical evidence of dissatisfaction with lighting services and increased energy consumption and efficiency (Appau et al., 2023).

Additionally, the limited adoption of smart lighting is due to a lack of understanding of smart energy solutions (Appau et al, 2023). Research has shown that the use of smart lighting in residential buildings is expected to increase by nearly 8% in 2025 (Zissis et al, 2020). Despite this, scholars have yet to examine the satisfaction, usability, and acceptance levels of smart lighting systems. According to some student housing studies (Appau et al., 2024; Soheilian et al., 2021; Kwong, 2020), indoor visual comfort and general student well-being are achieved when smart lighting systems are combined with some level of personal control. Even though several smart lighting systems are emerging in the student housing market, the satisfaction in use and drivers have not been explored, especially in West Africa. Therefore, this study aimed to assess the

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satisfaction levels of smart lighting and its drivers in the Ghanaian student housing market. The study is relevant in three ways. First, it provides feedback to facilities managers on the choices of smart lighting demand. Second, it ensures energy efficiency and reduces the energy cost burden on student housing investors. Finally, it contributes to sustainable indoor environmental quality and the well-being of students.

2. Literature Review

2.1. Technology Acceptance Model

Davis (1989) developed the Technology Acceptance Model (TAM) as an extension of Ajzen's Theory of Reasoned Action. The model suggests that users' acceptance of technology is primarily influenced by two factors: perceived ease of use and perceived usefulness. Davis also highlighted that external variables, such as social influence, can play a significant role in shaping an individual's acceptance and usage of new technology. These foundational ideas are crucial for understanding how students may perceive and adopt smart lighting in student housing, as they provide insights into the factors that could influence their attitudes and behaviours toward this technology.

2.2. Smart lighting systems: integration, benefits, and drivers in buildings

Smart buildings incorporate smart lighting systems. The concept of smart buildings, from a vision in the 1980s to prototypes and basic implementations by the early 2000s, was driven by advancements in technology. Smart lighting utilises sensing and automation technologies to reduce the need for manual control by occupants, enhance indoor environmental conditions and safety, and regulate energy consumption patterns in buildings. While scholars have examined various factors influencing the adoption of smart lighting, these studies often focus on different contexts, such as market-driven factors and facilities management. For instance, Füchtenhans et al. (2023) argue that the perceived benefits of smart lighting, including reduced energy consumption and cost savings, contribute to improving the environmental footprint of buildings. Gøthesen et al. (2023) support this view but emphasise the role of social influence and perceived price value in the adoption of smart lighting. Kumar et al. (2021), through simulation studies, found that integrating smart lighting can reduce energy consumption by 30.9%.

On the other hand, Saleem et al. (2023) argue that the adoption of smart lighting is influenced by users' knowledge of its ability to leverage real-time monitoring and advanced algorithms, offering several advantages over traditional systems. Tekler et al. (2022) highlight the potential of plug load automation, influenced by user preferences, non-intrusive indoor localisation systems, and personalised interfaces, in driving smart lighting demand. While many studies focus on perceived benefits and user knowledge, Putrada et al. (2022) stress that user safety, comfort, and lighting utilisation security also play a significant role in smart lighting adoption, citing factors such as high lighting ratios and power reduction rates. Despite the growing body of literature on smart lighting, there is still debate about its implementation across different types of buildings.

While there is evidence of significant penetration of smart lighting in buildings, scholars have pointed out that user preferences vary widely across different building systems (Al Dakheel et al., 2020; Hassanain et al., 2022). Empirical studies highlight varying satisfaction levels with smart lighting in student housing. For example, Bae et al. (2021) found dissatisfaction with lighting and daylighting in dormitories, which could impact classrooms. Dong et al. (2022) reported high satisfaction with the lighting environment in rooms but dissatisfaction with lighting performance levels in university dormitories. Conversely, Osei-Poku et al. (2020) found high satisfaction with natural lighting in rooms in two types of on-campus accommodation at Takoradi Technical University. Orman et al. (2022) also found high satisfaction with lighting conditions in bedrooms and reported normal productivity among students at Poznan University, Poland. Jakubiec et al. (2019) found 80% satisfaction with daylighting in bedrooms compared to kitchens, driven by spatial values of annual sensor mean illuminance. On the other hand, Song et al. (2021) found low satisfaction with lighting quality in campus public spaces. Vosoughkhosravi et al. (2022) found high satisfaction with comfort in non-LEED-certified buildings but higher energy consumption in LEED-certified buildings. While these studies suggest varying levels of satisfaction with lighting conditions, they also highlight the potential of smart lighting to improve the work environment in university campuses. For instance, Hassanain et al. (2022) found that the amount of natural lighting through low-E windows was satisfactory, and the adoption of smart lighting could enhance the work environment. Al Dakheel et al. (2020) also support this, adding that integrating smart lighting with innovative shading systems leads to increased user satisfaction and greater energy savings. However, despite these findings, there is a clear gap in the literature regarding the satisfaction and drivers of smart lighting adoption, particularly in developing regions. While much of the existing research focuses on developed countries, limited attention has been given to the specific context of developing nations, especially in Africa. This study aims to fill this gap by exploring the perspective of student housing in Ghana, where smart lighting adoption and user satisfaction are underexplored.

3. Research Methodology

The study used the embedded mixed research methods. Thus, qualitative data were used to explain the quantitative findings. This method was used to understand students' satisfaction with the use of smart lighting in student housing. The study used two stages to sample respondents. First, the study conveniently sampled 5 out of 9 purpose-built on-campus university student housing in southern Ghana. The purpose was limited to a lack of accessibility to the remaining 4. Further, using the Yamane (1967) formula for sample size determination, a sample frame (N) of 2544, 50% of the population proportion, 5% margin of error €, and 95% confidence level:

$$n = \frac{N}{1 + N(e^2)}$$

$$n = \frac{2544}{\{1 + 2544(0.05^2)\}}$$

A sample of 334 was determined and used. Secondly, the study sampled two student housing managers, each from one of the five selected student housing facilities. The purpose of selecting these respondents is first to understand the satisfaction levels from the student perspective and, second, to understand the rationale of student satisfaction from the student housing manager's perspective. To ascertain the satisfaction levels, students were asked to describe their satisfaction with smart lighting based on illumination levels in bedrooms, kitchens, study areas, common areas, and lavatories (see Table 1). Again, the drivers of smart student housing were ascertained from the student housing investors' perspectives (see Table 2). Face-to-face questionnaires and semi-structured interview guides were the data collection instruments used for students and student housing managers.

Table 1: Measurement of smart lighting systems satisfaction

Construct	Indicators	Mode of measurement
SLM1	End-users' control for indoor lighting (bedroom)	1=very dissatisfied, 5=very satisfied
SLM2	End-users' control for indoor lighting (study area)	1=very dissatisfied, 5=very satisfied
SLM3	End-users' control for indoor lighting (kitchen)	1=very dissatisfied, 5=very satisfied
SLM4	End-users' control for indoor lighting (lavatories)	1=very dissatisfied, 5=very satisfied
SLM5	End-users' control for indoor lighting (common areas)	1=very dissatisfied, 5=very satisfied
SLM6	End-users' artificial lighting power based on daylight levels	1=very dissatisfied, 5=very satisfied
SLM7	End-users' adjustment to minimum light intensity	1=very dissatisfied, 5=very satisfied
SML8	End-users' adjustment to control of natural lighting.	1=very dissatisfied, 5=very satisfied
SLM9	End-users' satisfaction with outdoor lighting illumination	1=very dissatisfied, 5=very satisfied

(Source: authors' construct, 2024)

Table 2: Drivers of the smart lighting adaptation

Variables	Indicators	Construct	Mode of measurement
Facilities management aspect	Student housing managers perceived the benefit of using smart lighting	ADD3	1=very low high influence, 5=very high influence
	Security and safety control	FMD1	1=very low high influence, 5=very high influence
	High energy cost	FMD2	1=very low high influence, 5=very high influence
	Maintenance budgeting	FMD3	1=very low high influence, 5=very high influence
	Availability of the smart lighting control manual	FMD4	1=very low high influence, 5=very high influence
Market-driven factors	Emergence of smart lighting in the student housing market	MDF1	1=very low high influence, 5=very high influence
	Student housing marketing appeal	MDF2	1=very low high influence, 5=very high influence
Accommodation demand-driven factors	High occupancy	ADD1	1=very low high influence, 5=very high influence
	User knowledge of the smart lighting control device	ADD2	1=very low high influence, 5=very high influence

4. Data analysis

The data analysis involved two stages. First, the study analysed the average means of the indicators in Table 1 to ascertain the satisfaction levels. Second, the study used the Relative Importance Index (RII) to derive the drivers of smart student housing. Here, ranks were assigned to averages of the levels of influence of adopting smart lighting in student housing. Where;

$$RII = \frac{\sum w}{A * N} = \frac{1n_1 + 2n_2 + 3n_n + 4n_4 + 5n_5}{5 * N}$$

$where\ (0 \leq RII \leq 1)$

Weight was given to each respondent, ranging from 1n as Very low influence, 2n as low influence, 3n as moderate influence, 4n as high influence, and 5n as very high influence. A and N, on the other hand, show the highest weight and the overall number of respondents. Further, the results were ranked in ascending order of importance. Moreover, the interviews were thematically analysed. Here, recorded data were transcribed into words and grouped into themes based on similar responses. Codes were assigned to student housing managers to ensure ethical data presentations. Finally, data saturation was achieved through gathering similar perspectives related to the challenges of smart. lighting usage from different student housing managers.

5. Findings

5.1. Descriptive results

Table 3 shows the descriptive results of the study. Out of the 334 student housing samples, 331 participated in the survey, which represents 99.1%. This indicates a high participation rate. The study also found a higher participation rate among male students (53.8%) than females (46.2%), with most of them being undergraduate students (82.5%).

5.2. Satisfaction with smart lighting adaptation

Table 4 presents the satisfaction of smart lighting systems in student housing. Table 4 reports five satisfactory levels of using smart lighting systems in Ghana. These include, mean scores higher than the

Table 3: Descriptive results

Age	18-20	21-23	24-26	27-29	30-32	33-35	36-38	39+
student housing 1	12	11	10	9	5	1	1	0
student housing 2	17	15	22	10	9	5	2	1
student housing 3	10	21	18	11	7	2	3	0
student housing 4	20	13	17	7	6	0	1	0
student housing 5	14	19	18	8	4	1	0	1
TOTAL	73	79	85	45	31	9	7	2
Gender								
Male	178	53.8						
Female	153	46.2						
TOTAL	331	100						
Levels in Class								
Undergraduate	273	82.5						
Postgraduate	58	17.5						
TOTAL	331	100						

(Source: field data, 2024)

Table 4: Satisfaction with smart lighting in student housing

S/No	Factor category	Factor	Impact on productivity
1	Project-Level Factors	Design & Planning	High
2	Project-Level Factors	Material Management	High
3	Project-Level Factors	Technology & Equipment	Medium
4	Project-Level Factors	Workforce	High
5	Management-Level Factors	Supervision & Leadership	High
6	Management-Level Factors	Organisational Factors	Medium
7	Management-Level Factors	Incentives & Motivation	High
8	External Factors	Economic Conditions	Medium
9	External Factors	Political & Regulatory Factors	Medium
10	External Factors	Environmental Factors	Medium

average mean scores (end-users' control for indoor lighting (bedroom), End- users' control for indoor lighting (study area), End-users' control for indoor lighting (kitchen), End-users' control for indoor lighting (lavatories), end-users' control for indoor lighting (common areas). On the flip side, student housing users expressed high dissatisfaction related to end-users' artificial lighting power based on daylight levels (end-users' adjustment to minimum light intensity, end-users' adjustment to control of natural lighting, and end-users' satisfaction with outdoor lighting illumination). These are critical areas of concern that student housing managers must address to ensure inclusive, sustainable use of lighting in student housing. However, interviews with student housing managers highlighted the lack of knowledge as a critical challenge for students in using smart lighting. According to student housing managers:

[….] It appears students are unaware of how these lights operate; maybe we need to educate them. Sometimes, the need to instruct some of them to close their windows are visible when the lights are on. This increases the energy cost to us [*sic*] (SHM8).

[….] We have energy-saving lighting systems in place. However, most students, especially at levels 100 and 200, do not know when to use daylighting and save energy. Maybe, we may need to get a lighting system which automatically goes off when they open their windows [*sic*] (SHM3).

Another group of student housing managers expressed that:

[….] We only manage what is there. We think the student housing owners would need to make further enquiries before introducing these smart lighting systems in the housing because they think that it serves as a marketing strategy to increase student numbers in the hostel [*sic*] (SHM8).
[….] I think because some student housing managers have started using some, my boss also introduced some here. For me, it is a good idea provided it will serve the purpose of the students [*sic*] (SHM8).

5.3. Drivers of smart lighting adaptation in student housing

Table 5 identifies the critical drivers of smart lighting adaptation in student housing in Ghana. Student housing managers support the view that Accommodation demand-driven factors, Facilities management aspects, and Market-driven factors primarily drive smart lighting adaptation. The Relative Importance Index (RII) analysis shows that accommodation-driven indicators largely influence the adaptation of smart lighting, with the two highest ranks (1 and 3). Thus, Student housing managers perceived the benefit of using smart lighting (1st) and High occupancy rate (3rd). Also, among the facilities management factors, high energy costs influenced student housing managers to adopt smart lighting in student housing compared to security and safety control, student housing maintenance budgeting, and the availability of smart lighting control manuals.

Table 5: Drivers of smart lighting adaptation in student housing

Indicators	1	2	3	4	5	Total (H)	Total Respondent (I)	HR (J)	I*J (K)	H/K	RANK
ADD1	1	2	0	12	15	30	10	5	50	0.6	3
ADD2	1	6	4	8	5	24	10	5	50	0.47	5
ADD3	0	2	3	16	20	41	10	5	50	0.82	1
FMD1	4	4	6	4	5	23	10	5	50	0.46	6
FMD2	1	4	9	8	10	32	10	5	50	0.64	2
FMD3	2	10	3	4	5	24	10	5	50	0.48	4
FMD4	3	8	6	0	5	22	10	5	50	0.44	7
MDF1	3	10	3	0	0	16	10	5	50	0.32	8
MDF2	2	10	6	4	0	22	10	5	50	0.44	7

(Source: field data, 2024)

Furthermore, the study observed that market-driven factors had a limited influence on smart lighting adaptation. Generally, the study can deduce that Student housing managers' perceived benefits of using smart lighting, high energy cost, high occupancy rate, security and safety control, and user knowledge of smart lighting control devices are the 5-top critical factors that influence smart lighting adaptation in student housing in Ghana. According to student housing managers, the benefits associated with the longevity of smart lighting and its ability to reduce student housing operational costs were reasons for its perceived benefit. Regarding the aspects of high energy cost, student housing managers believe that the adaptation of smart lighting was not meant to control user access but to reduce energy consumption and ensure high savings. Aside from this, student housing managers associated high lighting usage with the exterior part of their buildings, which works throughout the night. These have a significant impact on student housing managers' decisions to adopt smart lighting.

Aside from the two higher ranks, student housing managers reported that high occupancy rates put immense pressure on lighting usage in rooms. It was important to observe that student housing with room occupancy of 1 4 had its lights on throughout the day.

6. Discussion

The study assessed the satisfaction with smart lighting and factors that influence smart lighting adaptation in student housing in Ghana. The study reported high mean scores of end-users' control for indoor lighting in bedrooms, which is in line with Dong et al (2022); Orman et al (2022); and Osei-Poku et al. (2020), who also found high satisfaction with lighting environment in rooms, and high satisfaction with level of natural lighting in rooms of residents. However, other studies did not provide satisfaction levels of smart lighting in the kitchen, study, and common areas. Contrary findings in this study found high dissatisfaction among end-users with the artificial lighting power based on daylight levels (End-users' adjustment to minimum light intensity). This finding is similar to Bae et al (2021), who found dissatisfaction with the amount of lighting and daylighting in the dormitories. End-users' adjustment to control of artificial lighting and end-users' dissatisfaction with outdoor lighting illumination are other critical dissatisfaction determinants not commonly found in other studies. However, due to the diversity of user preferences for smart lighting across different building systems, it is important to consider these indicators in other emerging studies (Al Dakheel et al., 2020; Hassanain et al., 2022).

Considering the ranks of determinants of smart lighting adaptation, the perceived benefit of using smart lighting was recorded as highest, which supports Füchtenhans et al (2023) who found that the perceived benefit of smart lighting systems was to reduce energy consumption and savings and Gøthesen et al (2023) who found the perceived price value as critical accommodation determinant. These studies are synonymous with the reduction in operational cost and perceived longevity expectations of adopting smart student housing. The increasing perception of high energy costs in this study aligns with Kumar et al. (2021), who found that integrating smart lighting reduces energy consumption by 30.9%. An instance of a high occupancy rate in this study determines smart lighting adaptation, a feature not commonly found in other studies. However, it can serve as a determinant in housing studies that have similar features.
Notwithstanding the high student occupancy, the findings observed safety and security control as the fourth factor, which aligns with Putrada et al. (2022), where user safety and comfort through high lighting ratio, power reduction rate, and user lighting utilisation security influences smart lighting decisions. More broadly, witnessing user knowledge of smart lighting control devices as the fifth determinant showcases support for Tekler et al (2022). However, student managers perception of user knowledge related to smart energy as "energy efficiency" and "cost saving", deviates from Tekler et al (2022) who posit user rationale based on that the potential of plug load automation, non-intrusive indoor localisation system, diverse control preferences through a personalised user interface of smart lighting, and advanced plug load identification features

7. Conclusions and recommendations

Using a mixed method, the study assessed the satisfaction and critical drivers of smart lighting in student housing in Ghana. Findings show that smart lighting in student housing was primarily driven by perceived benefit, high energy cost, high student occupancy rate, safety and security, and knowledge of using smart lighting, which aligns with the premise of the Technology Acceptance Model. These determinants are largely accommodation-driven and facilities management-related. Aside from these factors, post-occupancy evaluation of the use of smart lighting shows a higher satisfaction for the use of smart lighting in bedrooms, study areas, kitchens, and common areas than dissatisfaction for artificial lighting power based on daylight levels, adjustment to minimum light intensity, adjustment to control of natural lighting, and outdoor lighting illumination.

Considering the perceived benefit of adopting smart lighting, student housing managers must invest in high-quality smart lighting to achieve the expected benefit of energy efficiency and cost savings. Aside from that, student housing managers must invest in smart lighting that automatically goes off when students open windows for natural lighting. However, student housing users need to be educated on adjusting smart lighting to complement natural lighting and ensure energy sustainability. Managing outdoor lighting illumination levels will require an increase in smart lighting with high voltage, especially with student housing using solar panels for outdoor lighting.

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A Review of Model Building By-Laws for Incorporating Sustainable Construction Material Utilisation in Zimbabwe

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Abstract

Environmental challenges associated with the use of traditional construction materials are widespread in Zimbabwe. Despite the existence of sustainable construction materials, the failure to migrate from the traditional Model Buildings by-law of 1977 has stagnated the promotion of strategic interventions. Hence, the study determined pertinent modifications to the Model building by-laws that could allow for the utilisation of sustainable construction materials—the interpretivist philosophy employed semi-structured interviews. Purposive sampling was applied to solicit views from construction professionals, academics, and relevant local government officials with sustainable construction experience. Suggested modifications include the generation of modern by-laws with relevant, sustainable material specifications, design-related and adopting green building principles or methodologies. A comprehensive stakeholder engagement was recommended to ensure that any modifications are practical and implementable. Using sustainable construction materials requires a policy intervention incorporating a comprehensive stakeholder support framework from manufacture to material disposal. The paper highlights modifications required to the model-building by-laws for integrating sustainable construction material utilisation in Zimbabwe. This is valuable to all stakeholders in the construction industry as it aligns with the Sustainable Development Goals of climate action and responsible production and consumption. The main limitation was the exclusive use of a qualitative approach. However, the exploratory nature of the study supported the approach.

Keywords: Building regulations, Model building by-laws, Sustainable construction materials, Zimbabwe

1. Introduction

According to the United Nations Sustainable Development Agenda (2020), sustainable development is an advancement that meets the needs of the present without compromising the ability of future generations to meet their own needs (United Nations, 2020). In addition, at the core of sustainability are three elements: economic growth, social inclusion, and environmental protection. Hence, sustainability aims to ensure that every development allows the availability of resources to everyone, meets human rights and basic needs, and consumes natural resources at a rate at which they can replenish themselves to guarantee balanced ecosystems. Sustainable construction is a subset of sustainable development concentrating on managing a healthy built environment based on resource-efficient and ecological principles (Baloi, 2003). The built environment shapes the context of most human activities and takes up a significant percentage of any economy; moreover, construction leaves behind environmental and carbon footprints (Brennan, 2014). The construction industry has an enormous impact on the economy, environment and health of a nation as it is the leading universal user of materials and one of the significant primary energy-consuming sectors contributing significantly to atmospheric emissions (Demir & Dogan, 2020). However, due to urbanisation and globalisation, environmental deterioration and resource depletion have increased, leading to the need to alleviate resource depletion (Mathiyazhagan et al., 2019). Moreover, the amplified consciousness of global environmental threats such as climate change has led to additional interest in low embodied carbon building materials for the provision of sustainable buildings (Agyekum et al., 2022). Sustainable construction has been observed as the solution, requiring sustainable materials. This is because sustainable construction materials have zero impact on the environment and are reusable and recyclable (Onyegiri & Ugochukwu, 2016), which results in benefits across the economic, social and environmental dimensions of sustainability (Eze et al., 2023).

However, incorporating sustainable construction materials to achieve a sustainable built environment is low in developing countries, such as Zimbabwe, and they need help with the extensive adoption. Chari and Chiriseri (2014) noted that sustainability principles must be factored into procurement decisions within both private and public entities in Zimbabwe. According to the Global Climate Risk Index (2021), Zimbabwe was among the world's ten most affected countries by climate change in 2019 (United Nations Climate Technology Centre and Network (CTCN), 2022), a significant result of unsustainable construction practices. Due to this, Altuma and Ghasemlounia (2021) relay that, as the construction industry continues

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to grow, it is essential to use innovative technology and creative ways of choosing construction materials to conserve resources. According to Eze et al. (2023), more studies are needed on adopting sustainable construction materials in Africa, beyond Nigeria.

Therefore, this study suggested modifications to the Model building by-laws to incorporate sustainable construction material utilisation in Zimbabwe. Sustainable construction materials are environmentally friendly and minimise environmental difficulties such as disparities in the ecosystems, pollution, greenhouse gas (GHG) emissions and other issues that develop from conventional building materials, which are hostile to the ecosystem, unsustainable and harmful to the environment (Eze et al., 2021). It is critical for policymakers to create a robust and sustainable economy (Mathiyazhagan et al., 2019). The following sections consider the literature review, methodology, results, discussion, and the study's conclusions.

2. Literature Review

This section concentrated on the study's theoretical framework and the role of Model Building By-laws for incorporating sustainable construction material utilisation, as suggested by previous studies.

2.1. Theoretical framework: Diffusion of Innovation Theory (DOI)

Widén (2006) states that the Diffusion of Innovation Theory (DOI) is built on well-established sociology, psychology, and communication theories. In addition, diffusion is regarded as the process by which innovation is communicated over time through specific channels among the members of a social group. Further, the construction industry differs from other industries in that innovation depends upon adoption or implementation and problem-solving based on organisational learning. Four critical aspects make up DOI: innovation, communication channels, time and social systems through a five-staged innovation process comprising knowledge, persuasion, decision, implementation, and confirmation (Tran et al, 2020). Unfortunately, the project-based nature of the industry, short-term relationships and decentralised organisational structures do not foster learning, meaning the adoption of innovation is subject to evaluations of individuals in the same context as opposed to scientific studies (Widén, 2006). Tran et al. (2020) remark that under DOI, the external social and political contexts are considered critical factors in influencing the adoption of innovation and, in this case, sustainable materials. To achieve sustainable building by-laws, there must be cooperative effort amongst interrelated units that include developers, designers, contractors, subcontractors, suppliers, government and users or clients.

2.2. Modern Building By-laws for the adoption of sustainable construction materials

Among the various planning tools that include development plans, town planning schemes, and building by-laws, the building by-laws are the most effective in shaping the built environment and achieving sustainable development (Chirisa, 2014). Regulatory barriers that prevent adopting sustainable materials are also prevalent in developed countries, resulting from unsuitable and non-comprehensive by-laws (Hoxha & Lecaj, 2023). However, Mogaji et al. (2024b) identified the importance of government regulations in advancing the adoption of innovative building materials. Including sustainability in the by-laws without specifying conformity guidelines for sustainable materials does not motivate their adoption in construction practice, but ends at an experimental level.

In Zimbabwe, the Ministry of Local Government and Housing published the Model Building By-laws in 1977 according to the Urban Councils Act Chapter 214, section 183 and Section 83A of the Rural Councils Act (Chirisa, 2014). The document covers structural design, foundations, masonry, walling, and construction of miscellaneous materials. These include that building by-laws often contain clauses that do not enable the adoption and implementation of sustainable construction materials. In addition, there is also a general need for more regulatory testing and inspection requirements for sustainable construction to ensure law enforcement. Also, green labelling of building materials, green building technologies and sustainable buildings where they have been applied is critical. Including the labelling in drafting by-laws will make consumers easily identify sustainable products and technologies. Noted deficiencies in the existing Model building by-laws include the absence of sustainable construction materials and the by-laws' rigidity, lack of alternatives to traditional materials, a lack of information on the sustainability of included materials, and inadequate reference to sustainable designs.

In Kosovo, it was noted that spatial planning laws were silent on goals such as sustainable design, cities, infrastructure, and construction to ensure rational economic use of land (Hoxha & Lecaj, 2023). Fini and Akbarnezhad (2019) support the promotion of responsible procurement of materials by considering their economic, environmental and social impacts. However, this can only be achieved if the necessary technical support systems have been established and operationalised. In addition, Nasier (2021) argues that the major constraint is that the selection of sustainable construction material must be practical, specific and aligned with budget needs. Hoxha & Lecaj (2023) highlight constraints concerning by-laws that align with Mogaji et al. (2024a)'s findings about lack of awareness and knowledge, and lack of end-user involvement. As such, Kylili (2017) advocates for the increased use of

sustainable construction materials by promulgating well-supported policies. This also means that materials are to be labelled based not only on their structural or mechanical performance but also on their energy performance, carbon footprint, health effect, thermal performance, indoor comfort effect, and environmental effect. To guarantee enforcement of labelled materials in practice, by-laws should include tax levies and information for end users on labelled materials (Hoxha & Lecaj, 2023).

3. Research Methodology

This study adopted an interpretive philosophy and a qualitative research design method to review the model-building by-laws for incorporating sustainable construction material utilisation in Zimbabwe, like a study by Hoxha and Lecaj (2023). The researcher applied expert sampling (Saunders et al., 2016) to solicit views from local authorities, government officials, researchers, and green building experts, as these were individuals with known or demonstrable experience and expertise in the area. When soliciting consultant views, the sampling technique was a type of quota sampling termed heterogeneity sampling. The basics of this technique include all opinions or views, and therefore, representation was not about proportions but views or ideas. The critical aspect of this technique is to get varied consultants instead of several consultants, aiming for diversity through concept mapping.

According to Saunders et al. (2016) and Hennink et al. (2017), a minimum of four and a maximum of 24 interviews are deemed sufficient for an exploratory study. In addition, interviews must be done until saturation is achieved. While the study targeted at least four interviewees, interviews were conducted till saturation was achieved, that is, when no additional information on strategies was forthcoming. To achieve this, 20 potential interviewees were requested to participate. Interviews were done over 90 days at different times, in different situations and settings, and with respondents from various backgrounds, increasing the reliability of the results. Member checking was undertaken to ensure the validity of the study. The interviewees were asked to confirm their transcribed contribution. Data analysis was done using thematic analysis, a method for systematically identifying, organising, and offering insight into themes or meaning patterns across a dataset (Braun and Clarke, 2012). The process involved familiarising with data associated with modifications to the Model building by-laws, coding interesting interventions of the data, generating a theme map, defining themes, and finally producing the report relating to the research question and literature (Vaismoradi, 2013)

4. Findings and Discussion

4.1. Response rate and Profile of respondents

Interview invitations were sent to 20 respondents, and 16 were successfully conducted via phone calls and virtual meeting platforms. This gave an interview response rate of 80%. According to Hennink et al. (2017), 16-24 interviews are adequate to achieve meaning saturation for an in-depth understanding of issues. Therefore, the response rate achieved is acceptable for this study. The profile of the respondents is shown in Table 1. Regarding educational qualifications, the analysis shows that 75% of the respondents had postgraduate qualifications, whilst 25% had an Honours degree. In terms of experience, 31.25% had more than 20 years of experience, followed by those between 16-20 years and 6 to 10 years, and only 6.25% had 0-5 years of experience. The percentage distribution was ideal because there were diverse perspectives from diverse professional backgrounds, as Burton (2021) echoed.

4.2. Modifications to Zimbabwe's Modern Building By-Laws (MBBL)

Interview participants were requested to suggest ways that they felt the local Model Building By-Laws could be altered to increase the adoption of construction materials. The extracted themes included the position that the Model Building By-Laws (MBBL) of 1977 were unsuitable and non-comprehensive to achieve sustainable construction goals that needed more comprehensive consultation. The other themes included adopting a mandatory approach for incorporating sustainable construction materials in every design and applying a green rating system to aid material selection within the by-laws. The theme and categories are discussed hereafter.

4.2.1. Generation of a modern MBBL with relevant, sustainable material specifications

There is consensus that the MBBL document aligns with modern-day construction practices. MBBL should address challenges that may not have existed when they were formulated in 1977. In addition, the by-laws must address current concerns as highlighted by Interviewee 2 and 13.

Interviewee 2: …… by-laws should speak to climate resilient infrastructure……

Interviewee 13: Model Building By Laws must be revised and modernised to adapt to current trends, standards and practices in the construction sector.

These views align with Hoxha and Lecaj (2023), who argue that planning laws must adapt to current

Table 1: Demographic profile of respondents

Interviewee	Level of education	Experience	Organisation	Position
1	Bachelor's degree	8	Green Building Council	Chief Executive Officer
2	Master's degree	20	Scientific Research Centre	Chief Executive Officer
3	Professor	38	Research Consultancy firm	Chief Executive Officer
4	Masters Urban Planning	11	Architectural firm	Chief Executive Officer
5	Bachelor's degree in engineering	11	Architectural firm	Projects Manager
6	Master's: Energy Engineering	4	Research Consultancy firm	Environmental Engineering/Sustainability Consultant
7	Bachelor's degree	10	Non-profit community-based organisation.	Co-founder, project development/training
8	Masters in Architecture	7	Architectural firm	Energy and Sustainability Auditor
9	Professor of Urban and Regional Planning	17	University	Pro Vice-Chancellor, Academic Affairs
10	Professor of Architecture	40	Architectural firm	Principal Architect
11	PhD Construction Management	21	University	Dean
12	Masters of Architecture	15	Architectural firm	Principal Architect
13	MSc Water Resources Engineering and Management	19	Civil Engineering Firm	Manager
14	Masters of Architecture	15	Entrepreneur	Director
15	Masters of Architecture	9	Architectural Firm	Director
16	Bachelor's degree	10	Ministry of Local Government and Public Works	Acting Deputy Director, Architectural Services

trajectories of sustainability development. MBBL should specify material performance instead of specifying materials to allow flexibility. Some interviewees emphasised that by-laws should speak to climate-resilient infrastructure and alternative materials, encouraging their exploration as an addendum. Respondents suggested that minimal bureaucratic processes and procedures should be included within an addendum for approval and adoption of sustainable materials. Implementation and reference to addenda are critical (Chirisa, 2014). However, such addenda must be well supported by progressive policies (Kylili, 2017).

4.2.2. Design-related modifications

Interviewees suggested it be made mandatory for designers to incorporate sustainable building materials and introduce stiff penalties for non-compliance, as alluded to by Interviewee 7.

Interviewee 7: ….a must for developers to use alternative sustainable materials in the approved plans….

However, the modifications can only be made after testing and approving sustainable materials and technologies. Fini and Akbarnezhad (2019) support such modifications if they are cognisant of the impacts of such sustainable material considerations. This will make it easier for expert construction industry professionals to recommend and construct using sustainable materials. The MBBL were too prescriptive and needed to test and encourage new methods, thus allowing professionals to propose new materials that could be included in standards, as highlighted by interviewees 10 and 3.

Interviewee 10: I find that the Model Building By-laws need to be more prescriptive on how to build. They should have standards that test and encourage new methods. I mean, architects should be allowed to propose new materials after proper testing to include them in the standards and by-laws.

Interviewee 3: So, I think they need to drop the reference to cement altogether and just have things

about performance. Can your material do this? Then you can do this with it.

The general view is that flexibility in terms of designs may be more effective, as designers can add value by selecting alternative materials for their clients. This view is supported by Nasier (2021), who supported practical material selections. In addition, designers must be permitted to implement circular principles in their designs if the material's performance is guaranteed. This approach is reinforced by India's Ministry of Urban Development (2016) through its by-laws that provide for reducing, reusing, and recycling to achieve zero landfills. A recommendation for incentives within the by-laws was suggested for designers and developers, according to Interviewee 12.

Interviewee 12: "In practice, the major issue around practice is compliance with regulations that are set. You need to go back to those regulations, not some annexure or deviation committee. Very few people know about these, and no one is willing to go through all that. Imagine spending three years trying to get your material approved. You will not have the money to build afterwards. Let's fix the regulations. It could be a carrot and stick; you do not have to force everyone, but you can say, "If you protect the environment, you get so many credits or tax rebates." Incentivise the adoption of sustainable materials. There is a need to deliberate at all levels throughout the building chain and reduce the energy demand through adopting sustainable construction materials."

A section is suggested by the respondents that stipulates rewards or incentives for sustainable practices to motivate developers and professionals. Hoxha and Lecaj (2023) supported this notion by highlighting that to guarantee the enforcement of labelled materials in practice, bylaws should include tax levies and information for end users on labelled materials.

4.2.3. The adoption of green building methodologies in MBBLs

Some respondents recommended attention to green building principles, including interviewees 4 and 5. As suggested by Fini and Akbarnezhad (2019), the consideration of the impact of the material on the environment, like carbon footprint analysis and energy efficiency, is pertinent. As such, embodied carbon is measurable and can be easily regulated by local standards. Also, energy efficiency is to be included in the MBBLs with accompanying embodied carbon calculations as a critical material performance criterion.

Interviewee 4: Speaking to energy efficiency in the MBBLs; working on affordable housing building guidelines; availing them of carbon calculations; stakeholder engagements

Interviewee 5: The MBBLs should include embodied carbon, which is measurable, easily regulated by local standards under building performance requirements……

Other respondents also felt a chapter on sustainable design, with credits on using sustainable construction materials, was necessary, as reported by Interviewee 16. India's Model Building By-laws of 2016 contain green buildings and sustainability provisions, which encompass sections on provisions and applicability, sanction provisions, and various green rating system guidelines (Ministry of Urban Development, 2016). However, Hoxha and Lecaj (2023) revealed that including sustainability in the by-laws without specifying conformity guidelines for sustainable materials would not motivate their adoption in construction practice but rather ended at an experimental level.

Interviewee 16: A green building code may also be formulated, adopted and enforced as an addendum to the Model Building By-laws.

Along with this, there were supposed to be affordable housing building guidelines and public building guidelines that speak to the use of sustainable materials, so that the government led from the front. This is a practice supported by Hoxha and Lecaj (2023) in that the inclusion of green labelling in drafting by-laws makes consumers easily identify sustainable products and technologies. In India, all buildings on plot sizes above 100m2 are to comply with green norms and requirements while using the listed rating systems (Ministry of Urban Development, 2016). Associated with this, the importance of training construction professionals on green building principles and technologies and the need for research and standardisation of green building materials is paramount.

Interviewee 9: Use existing policies, demo structures, for training,…

Interviewee 13: Buy-in from all stakeholders, …… Increase funding for research in such construction technologies. Increase visibility and marketing of such products. Make sure such materials go through a standardisation process.

Adequate technical support systems are essential if green building principles are to be adopted. Kylili (2017) and Hoxha and Lecaj (2023) allude to the importance of supporting the implementation of green building technologies through enhancing awareness and encouraging competent standardisation processes for practical solutions.

5. Conclusion and Further Research

The review of literature and interviews indicated that the by-laws were limiting, to a large extent, the adoption of sustainable construction materials. As such, recommendations to generate modern MBBL with relevant, sustainable material specifications must be made as part of the key strategies. The other modifications recommended are design-related, including the adoption of green building principles or methodologies in MBBLs. There was insistence that all modifications be made through extensive stakeholder consultations and participation to ensure buy-in to the regulations, which in turn would make implementation easier. A comparison with the literature review supported these suggestions. However, the challenges peculiar to Zimbabwe limit the uptake of these recommendations to bring it up to speed with current global discussions, challenges, and trends. The study contributed pertinent strategies that can be incorporated within the modification of the existing Model Building by-laws so they can drive the sustainable construction agenda. Aligned with the Diffusion of Innovation theory, the study recommends that the Government of Zimbabwe, through the Ministry of Local Government, Public Works and National Housing, should create a new and updated Model Building By-laws document based on a stakeholder participation programme.

The adoption of any innovations regarding sustainable construction material must be founded on inclusive, well-established communication channels, timeously responded to and have a positive impact on existing social systems. A comprehensive stakeholder-initiated review of the existing model-building bylaws that align with holistic sustainability goals is also recommended. Further studies can examine how these suggested modifications to the Model Building By-Laws align with the available and alternative sustainable construction materials peculiar to the Zimbabwe construction industry. The main limitation was the exclusive use of a qualitative methodology. However, the exploratory nature of the study supported the approach.

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Untapped Resources: Locally Available Building Materials in South-Western Nigeria

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Abstract

Although Nigeria is endowed with a plethora of local building materials that have low carbon prints and are environmentally friendly, the materials remain largely untapped. Instead, the nation's construction industry is fraught with high-cost imported materials, most of which are non-eco-friendly, heightening environmental degradation, and undesirable in the local climate and culture. Against this backdrop, this study examined reasons for the underutilisation of local building materials resources that could have positively impacted the nation's construction industry. The research method is quantitative, using primary data from community members and stakeholders in the construction industry. The data were collected through online survey questionnaires and analysed for descriptive statistics across the six (6) south-western states. The sample size was calculated from selected urban districts of the study area, taking the acceptable error 'e' to be 0.05, and 'z', the standard variate at 95% as 1.96. Members of the construction industry were sought through the faculties of built-environment and engineering in the six states. Responses were downloaded and analysed into tables and charts with Microsoft Excel. The study showed that despite the abundance of local building resources in south-western Nigeria, they are not readily available in usable form and that users' perception of them has adversely impacted their use. The study, however, showed that the materials are affordable and require only limited skills for construction. In this way, policy interventions and discussions can enhance the use of local building materials to promote housing development.

Keywords: Local building materials, south-western Nigeria, untapped, perception, bamboo

1. Introduction

Local buildings are environmentally friendly buildings that employ functional and technical solutions that are in harmony with the regenerative capacity of the environment. The materials are natural and have been known in ways based on tradition and experience (Akadiri et al, 2012). The construction method employs traditions and construction know-how of generations that take into consideration passive opportunities. Such opportunities derive from the characteristic properties of wind, sun, currents of air, vegetation, water surfaces, and natural sources of light (Toriola-Coker et al., 2021; Olorunnisola, 2019), hence locally available. Lembi et al. (2021) highlight that they also demand less energy for production, fewer additive chemicals, good compliance with global warming standards, and a smaller carbon footprint.

Ojo and Kayode (2006) observed that Nigeria is enriched with an abundance of these local building materials and that it has the potential to revolutionise the construction industry and promote sustainable development across the country.

Bage (2014) stressed that the significance of utilising local materials in construction cannot be overstated. Local construction is crucial for Nigeria's development, as it can lead to resource-efficient and ecologically sound sustainable built environments (Toriola-Coker et al., 2021). Sambucci (2021) pointed out that harnessing these local materials is the best way to contribute positively to the environment, mainly because the rapid population growth in the country has led to a surge in construction activities, often at the expense of the environment. Oloruntoba and Ayodele (2013) observed that such materials are within reach and, when compared to imported materials, are cheaper and more affordable. Despite these, Ugochukwu and Chioma (2015) noted that Nigeria, though endowed with these resources, still depends mainly on imported building materials to meet construction needs. Abdulmageed and Ogwuche (2014) went further and pointed out that the potential of local building materials remains vastly underutilised. Given this, several studies have examined local building materials and associated problems with their adoption in specific towns or cities in Nigeria. Very few, however, examine this in the context of geopolitical zones. This study bridged this gap. It focused on the South West geopolitical zone of Nigeria, comprising Ekiti, Lagos, Ogun, Osun, Ondo, and Oyo states.

2. Literature Review

2.1. The South-west of Nigeria

South-west Nigeria is one of the geopolitical zones in Nigeria, comprising six states: Ogun, Oyo, Osun, Ondo, Ekiti, and Lagos. It is a region known for its rich cultural heritage, economic activities, and significant historical contributions to Nigeria. The South-west region of Nigeria has a population of 47 million people,

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which is about 22% of the total population of the country (Adegbehingbe, 2011). The approximate area of land covered by each state in the south-western region of Nigeria is indicated in Table 1.

Table 1: Land area covered by the South-West Nigerian states

Local Building Materials	Approximate land area (sq. km)		
	Sq. m	million	Ratio (approx.)
Lagos	3,577	16.5	4
Ekiti	6,353	3.5	1
Osun	9,251	4.7	1
Ondo	15,500	5.3	2
Ogun	16,980	6.4	2
Oyo	28,454	8.0	3

The south-west is also an area typically accepted as most urbanised in Nigeria (Fasakin, 2000). Its housing infrastructure, thus the need for building construction and materials, compares favourably with other geopolitical zones of the federation. Instances of this become copious considering that the south-west has over 40 per cent of government residential estates in the country (Adegbehingbe, 2011). It is worth noting that all other states of Nigeria shared the remaining 60%. South-west Nigeria is also distinguished amongst other geopolitical zones for its economic significance, as it hosts the largest city and commercial hub of Nigeria, Lagos. The view that housing is often seen as a barometer for the state of the economy suggests that the South-west has attracted the construction industry in a manner comparable to other parts of the country. Moreover, owing to its rich tapestry of burgeoning culture, the region is unfit for imported construction materials, most of which are non-organic and unsuitable for tropical climates. Aside, it owns a vibrant agricultural sector producing arable and perennial crops including cassava, yams, maize, rice, plantain, banana, cocoa, rubber, palm oil, and timber. Their by-products are natural fibre composites applicable as local building materials for construction. On this account, this study examined the underuse of local building materials for construction in South-West Nigeria.

2.2. Some Local building materials, characteristics, and benefits

A plethora of local building materials, such as bamboo, laterite, and fibre across Nigeria, offers a wealth of possibilities for innovative and eco-friendly construction practices. The applications of some of these in construction are as follows:

2.2.1. Laterite and bamboo

Laterite is rich in iron and aluminium oxides (Ojo & Kayode, 2006). Using locally sourced laterite in construction can be viable and economical (Ifeanyichukwu et. al., 2021; Kehinde, Adedeji and Nnamaka, 2018). Bamboo is light, has strong compressive strength and is fire-resistant (Tunji-Olayeni et al., 2018).

2.2.2. Fibres

Fibres can be derived from natural sources such as plants or animals (Mayomi et al., 2018). Plant fibres can be extracted from cereal straw, corn stalk, or cotton stalk (Adedeji, 2011; Fagorite et al., 2019). Fibre composites have proved to have wide applications in building construction (Abdulmageed & Ogwuche, 2014; Kaushik et al., 2017; Hadi et al., 2021).

3. Research Methodology

The study area is south-western Nigeria. The data used were obtained through primary and secondary sources. Primary data were obtained through questionnaires and interviews with stakeholders in the construction industry, namely architects, masons, joiners, engineers, and other members of the community. An online survey was carried out via Google Forms and distributed through Facebook to various respondents across the six south-western states. The questionnaire was divided into three sections. The first section was used to obtain demographic information on respondents, their length of stay in South-West Nigeria, and their experience in construction. The second probe into respondents' knowledge of local material(s) and the factors that may influence the use of these material(s) in their state. The third examined the perception of respondents on the principle of sustainability and how the use of local materials can enhance it. The census population of selected urban districts of the study area is 125,524 (FGN, 2022). Thus, a sample size of 2,192 was calculated, taking the acceptable error 'e' to be 0.05, and 'z' (value of the standard variate at a given confidence level) as 1.96 from the table under normal curve distribution at 95% confidence level. A total of 5072 responses were obtained through the Facebook media survey. This constitutes the pool from which the sample size was drawn. Hence, 2,192 questionnaires were randomly selected and downloaded from this pool. At each selection, the six states were tossed between nos. 1-6.

Depending on which number each state falls under, the selection was carried out from the pool. For instance, if

Ondo state falls to number 1 and Lagos to 2 at a particular random toss, the first download from the pool will be attributed to Ondo state, while the second goes to Lagos, and so on. Moreover, the downloads per state are in the ratios of their populations (see Table 1). For instance, for 1 (one) download of Ekiti state, 2 goes to Ondo, 3 to Oyo, and 4 to Lagos state. This is according to their population ratio (see Table 1). This is also to achieve fair distribution. Members of the construction industry were sought through the faculties of built environment and engineering in universities in the six states through the Facebook media platform. Responses were analysed into tables and charts with Microsoft Excel.

4. Findings and Discussion

The analysis shows that 72.9% of respondents are familiar with local building materials (Figure 1) and that 84.2% of respondents have lived in their state for more than 10 years (suggesting the likelihood of owning their residential properties). Aside, 74.4% are between 51-60 years, buttressing that they own their residential properties. However, a large percentage (65.4%) of the respondents received only a primary six certificate qualification, with a modicum of respondents (3.8%) receiving NCE/ND/HND education (Nigerian Certificate in Education, National Diploma and Higher National Diploma, respectively). This is an indication that they are unlikely to have their own houses since they are likely to be at lower income levels. Buttressing this, Onyike (2007) examined housing affordability in Owerri, Nigeria, under a new salary and allowance regime, considering a market value survey of 66 bungalows and houses.

Onyike (2007) found that only those on salary grade levels 13 and above in the federal public service and grade levels 16 and above in the state civil service can afford the cheapest adequate bungalows at 6% interest rate. At an 18% interest rate, only those on grade level 17 and above in the federal service, but not in the state civil service, can afford adequate housing. In his conclusion, he pointed out that income disparities are a significant determinant of house ownership. Likewise, Constant, Roberts, and Zimmermann (2007), in their study on home ownership, highlighted access to home financing as a significant determinant of homeownership in developing countries. Considering the income distribution of Figure 2, 35% of the respondents earn less than 20,000 per month, and 33.3% earn between 20,000 and 50,000 per month. This is grossly below the African poverty line of 2.3 Dollars per day as defined by the African Development Bank (PPP, 2011). This buttresses the point that they are unlikely to have their properties. However, it

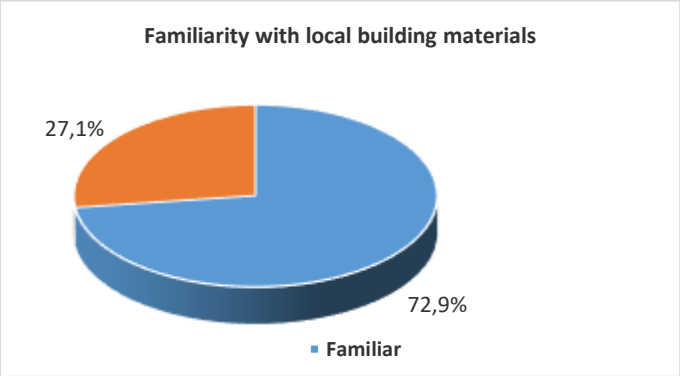


Figure 1: Familiarity with local building materials

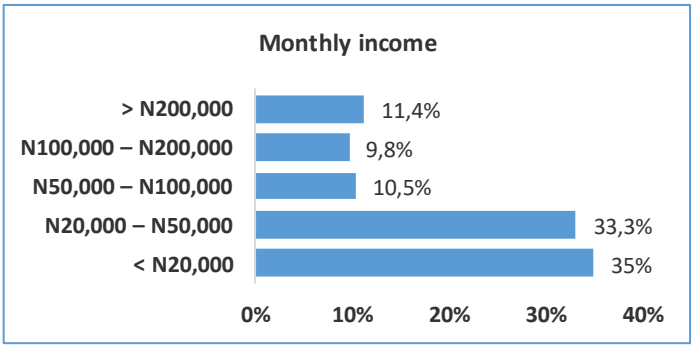


Figure 2: Income distribution

strengthens the point that they are likely to use local building materials since this is cheaper.

Regarding experience in the use of the local building materials, the study highlights that 24.8% of construction workers including architects, engineers, contractors, builders, and researchers have no experience, that 32.3% have less than a year experience, and 14.3% have between 2-5 years' experience (Figure 3). Only 2.3% and 9.8% have 5-10 years' experience and more than 10 years, respectively. Hence, most construction workers are relatively inexperienced.

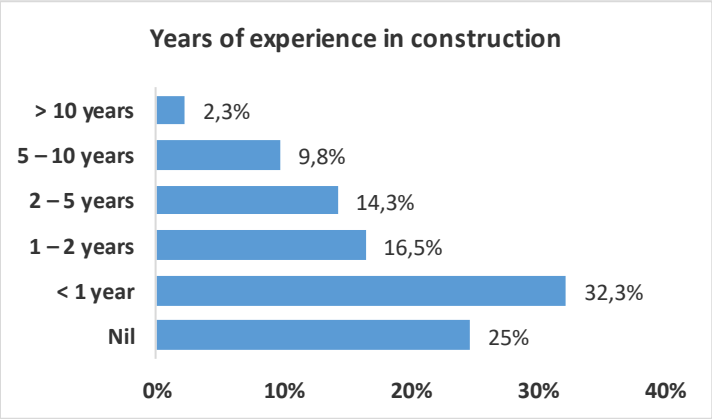


Figure 3: Years of experience in the construction industry

However, considering that 72.9% of respondents are familiar with local building materials (Figure 1), it can be construed that the poor experience of the construction workers in local building construction is informed by the sparse use of the locally available building materials for construction and the limited local skilled handlers. Osasona (2007) shed some light on the local construction methods and handlers. She highlighted that before the building process generated specialisation and produced these handlers, it was a community craft, featuring men, women, and children, each group having their specific area of expertise. Over time, certain individuals who became recognised as being extra-skilful in various aspects of building construction became known as handlers, resulting in the formation of guilds and the birth of the apprenticeship. Numerous studies have, however, demonstrated that there was a shortage of local skilled workers because of a decline in apprenticeship culture owing to the emergence of modern and late modern architecture after infiltrating the country (Prucnal-Ogunsote, 2007).

Despite the decline in use, Figure 4 shows that the difficulty with construction in local materials is low. 41% of respondents agree that low technical know-how is required, and 18% agree that no technical know-how is required, suggesting that even the poor experiences of the construction workers may not affect the use of the local construction materials.

However, unlike the difficulty in construction, 41% of respondents agree that the impact of local materials on the quality of buildings is high (Figure 4). Respondents therefore agree that the quality of buildings is strongly impacted by the use of local materials, showing that their perception is strongly impacted by buildings constructed with local materials. This view is in tandem with Baiche, Osmani, Hadjri, and Chifunda (2008). According to them, earth buildings are perceived as aesthetically unpleasant, not durable, a sign of poverty, and an indication of backwardness. Along this line, Zami and Lee (2011) reported that earth materials and techniques are perceived as second-tier or substandard, while modern construction methods and materials are seen as symbols of affluence or 'civilised'. Additionally, designers and contractors were reluctant to specify and select earth materials due to their technical and performance limitations.

Going further, 42 and 41 per cent agree that the availability and accessibility of local materials highly impact the use of local building materials. This shows that despite the availability of the local materials in their natural deposits, they have not been made accessible and usable for construction. Part of the

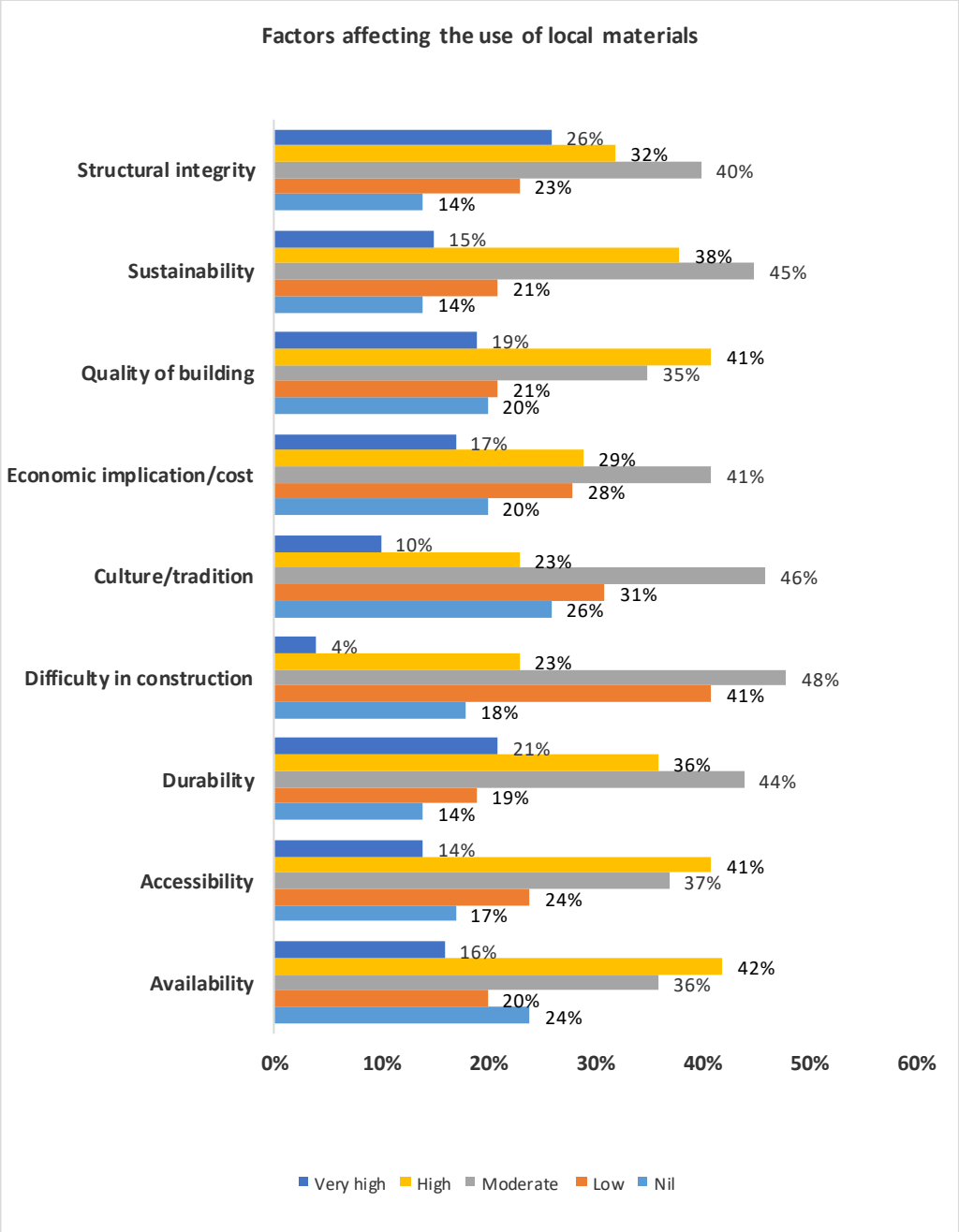


Figure 4: Factors affecting the use of local materials

reason for this may relate to the perception of these materials in buildings. Regarding the economic variable, Figure 4 shows that only 29% of respondents consider it high. This is relatively low compared to the 42, 41, 41, 41, and 38 per cent impacted by availability, accessibility, difficulty in construction, quality of buildings, and durability, respectively. Several studies agree with this (Jibrin et al., 2018; Akadiri et al, 2012). Accordingly, Oloruntoba and Ayodele (2013) asserted that the setback in housing provision is linked to the high cost of imported construction materials compared to the local. They stressed that the local building materials offer unique opportunities for home ownership to the lower-income groups and enhance housing affordability. Omole and Bako (2013) observed that while local building materials can enhance foreign exchange, they simultaneously reduce the cost of housing delivery. Ultimately, Figure 4 shows that the impact of the economic variable on the use of local materials in the study area is low, indicating that the local building materials are affordable. However, it also shows that structural integrity has a significant adverse impact on the use of local materials. Accordingly, this has a value of 26% compared to "very high" in others: 16, 14, 10, and 4% for availability, accessibility, culture, and construction, respectively. Accordingly, local building resources remain untapped owing to users' perceptions about them.

Notwithstanding this, policy interventions, as well as campaigns by governmental and non-governmental organisations, can be employed to enhance its use and to take advantage of its affordability.

Summing up, the study shows that local materials are low-cost, require low skills for production, and are abundantly available in their natural, unrefined state, yet not available in the form required for construction. Moreover, the study posits that user perception impacted its availability.

5. Conclusion and Further Research

Although the study observed that professionals in the construction industry lack experience in the study area, the study showed that local construction handlers require low technical skills for construction. The study further showed that economic impacts on the use of local materials are the least of the variables examined. The study also showed that accessibility to local building materials is not readily available. This is despite the rich deposits of the materials in Southwestern Nigeria. Lastly, the study showed that users' perception of the quality of local building materials adversely affected their acceptability. Accordingly, this study posits that despite the rich availability of local building materials in their natural state, the resources remain untapped primarily because of users' perceptions. The study recommends a public awareness campaign to mitigate the negative perception of local materials. NGOs and government agencies can perpetuate this. Moreover, the government should recognise local building materials as a resource for affordable housing and, as a result, expedite actions and policy interventions to enhance the availability of the materials in usable form. This will require industrial production on a large scale and as a result, can serve employment generation for low-income and the urban poor. Further studies on the material properties and strength of the local materials are encouraged, particularly because the study showed that the impact of structural integrity on the use of the material is highest compared to other variables.

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A Systematic Review on the Use of Quarry Dust in the South African Construction Industry

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Abstract

The construction industry's environmental impact has led to growing interest in alternative materials, and this paper reviews quarry dust by evaluating its effectiveness in concrete, road construction, and other applications while addressing its enabling factors within the South African construction industry. A systematic review of literature was conducted by analysing relevant publications from four databases (Academia, ResearchGate, ScienceDirect, and Springer Link) published between 2015 and 2024. The research is limited to the complexities of using quarry dust in South Africa, and the findings aim to inform the feasibility of adopting similar materials in other regions. The review highlights the effectiveness of quarry dust in construction applications, emphasising its significant contribution to both economic and environmental sustainability as a viable alternative material. Quarry dust not only enhances concrete strength and durability as an acceptable aggregate replacement but also stabilises soil in road construction, improving road durability. Additionally, it reduces the carbon footprint by replacing cement and traditional aggregates, which helps lower construction costs and offers an eco-friendly and readily available solution. However, it is important to note that there is an optimal replacement ratio for quarry dust in various studies, beyond which further increases may adversely affect concrete performance. Policy support and the establishment of standards could further promote its adoption in South Africa, unlocking its full potential in the construction industry. This study provides actionable insights for policymakers, construction professionals, and researchers, promoting the sustainable use of quarry dust and fostering environmentally friendly construction practices in South Africa.

Keywords: Construction industry, Construction materials, Policy support, Quarry dust, South Africa, Sustainability, Systematic Literature Review

1. Introduction

The construction industry is essential for the advancement of the contemporary world, but it also possesses considerable environmental challenges. The substantial demand for construction materials, along with resource-intensive methods, leads to significant carbon emissions, resource depletion, and environmental damage (Chakraborty and Elzarka 2019). To resolve these difficulties, it is imperative to implement sustainable construction procedures that reduce the sector's ecological footprint. An essential element in this initiative is the extensive utilisation of eco-friendly and sustainable construction materials. Selecting these resources significantly reduces the industry's ecological footprint, enhances resource conservation, and fosters a more sustainable future (Xie, Huo, Qi, and Zhu, 2016). Quarry dust has become a feasible alternative to sand and cement, potentially mitigating material shortages and environmental issues (Prakash, 2017). It can be employed in concrete manufacturing, soil stabilisation, brick fabrication, and mortar production, among other applications. In all these uses, quarry dust partially or fully replaces traditional materials. Opara and Eziefula (2018) and Karim, Samueel, and Jassem (2020) assert that these advantages can be attributed to the superior qualities of the materials employed; quarry dust was utilised in place of conventional materials to produce more sustainable, cost-effective, and efficient outcomes. This systematic analysis aims to deliver a thorough assessment of quarry dust within the South African construction sector, emphasising the elements that can promote its incorporation into construction methodologies. This review seeks to enhance the discourse on sustainable construction materials and practices in South Africa by integrating existing research and pinpointing knowledge gaps from materials in selected databases. This review's findings will inform industry stakeholders and offer valuable insights for policymakers and researchers focused on advancing sustainable development in South Africa's construction sector.

2. Literature Review

2.1. Environmental Challenges and the Need for Sustainable Construction in South Africa.

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The South African construction industry faces significant environmental challenges, such as carbon emissions, resource depletion, and environmental degradation due to traditional resource-intensive practices (Chakraborty and Elzarka, 2019). Quarry dust offers a viable alternative to traditional materials like sand and cement, potentially alleviating material shortages and reducing environmental impact (Prakash, 2017). Nevertheless, research on strategies for systematically adopting quarry dust across the country's industry remains limited.

2.2. Economic Importance and the Role of Sustainable Materials

The construction sector is vital to South Africa's economy, driving employment and infrastructure development (Alagidede, 2021). Despite its importance, the sector is vulnerable to cyclical fluctuations, making the integration of sustainable materials like quarry dust essential for economic stability (Thwala, 2022). However, research on how quarry dust can support economic resilience and be scaled in the South African market is still lacking.

2.3. Benefits and Barriers to Quarry Dust Adoption

Quarry dust contributes to sustainable construction by reducing waste and improving concrete properties, such as compressive and flexural strengths (Alabduljabbar, Huseien, Sam, Alyouef, Algaifi, & Alaskar 2020). While its environmental and mechanical advantages are well-documented, there is insufficient analysis on barriers to its widespread adoption in South Africa, including cost-effectiveness, availability, industry standards, and the regulatory framework (Sarvade and Nayak, 2014; Panchal and Mathew, 2015). Moreover, quarry dust adoption strategies can be outlined from its adoption barriers. Therefore, overcoming these challenges and integrating quarry dust at a broader industry level requires more research.

3. Methodology

This paper consists of a literature overview and analysis of current research findings about the utilisation of quarry dust in South Africa. Nwokocha, Okorafor and Ikegwuoha cited prior research and discoveries concerning the application of quarry dust in developing nations. The review evaluated the efficacy of quarry dust utilisation in diverse construction activities relative to traditional construction methods. The review analysed the tactics employed for the adoption of quarry dust utilisation in South Africa. A systematic literature review differs from and is favoured above the traditional or narrative review methodology. A systematic literature review necessitates a thorough, complete, and exhaustive examination of all pertinent articles and is characterised by objectivity, balance, and impartiality.

Conversely, the conventional review process is excessively open and adaptable, and the reviewer is not required to furnish a methodological report (Jesson et al. 2011). Fink (2014) presents a systematic, explicit, and thorough approach for discovering, analysing, and summarising the current literature. This approach delineates the search strategy, inclusion and exclusion criteria, standards for assessing study quality, and methods for summarising and analysing findings comprehensively. This provides valuable direction for crafting a cutting-edge review. Consequently, the literature review of this study adheres to Fink's (2014) methodology.

3.1. Searched for Study selection

The systematic literature review (SLR) of the publications related to the use of quarry dust in the SA construction industry comprises four stages.

Stage One encompassed selecting research questions, databases, and websites, along with defining search phrases. This systematic research aims to elucidate the role of quarry dust as an alternative construction material in South Africa, with an emphasis on adoption strategies. The primary research question for this analysis was: *What are the adoption strategies for employing quarry dust in the South African construction sector?*

Stage Two consisted of screening titles and abstracts for relevance through an initial appraisal. Publications deemed repetitive or irrelevant were excluded. Abstracts were reviewed to ensure the focus was on quarry dust in the construction industry. General research was conducted to summarise studies (2015–2024) on quarry dust utilisation in construction, without excluding based on journal rankings to ensure a broad overview.

Stage Three involved a full text review of potential relevant studies to confirm their relevance, based on results and conclusions. Irrelevant papers were discarded after thorough reading. Inclusion and exclusion criteria were applied during this phase. Studies were included if they were published in English, focused on quarry dust in sustainable construction, and were peer-reviewed articles, conference proceedings, or government reports.

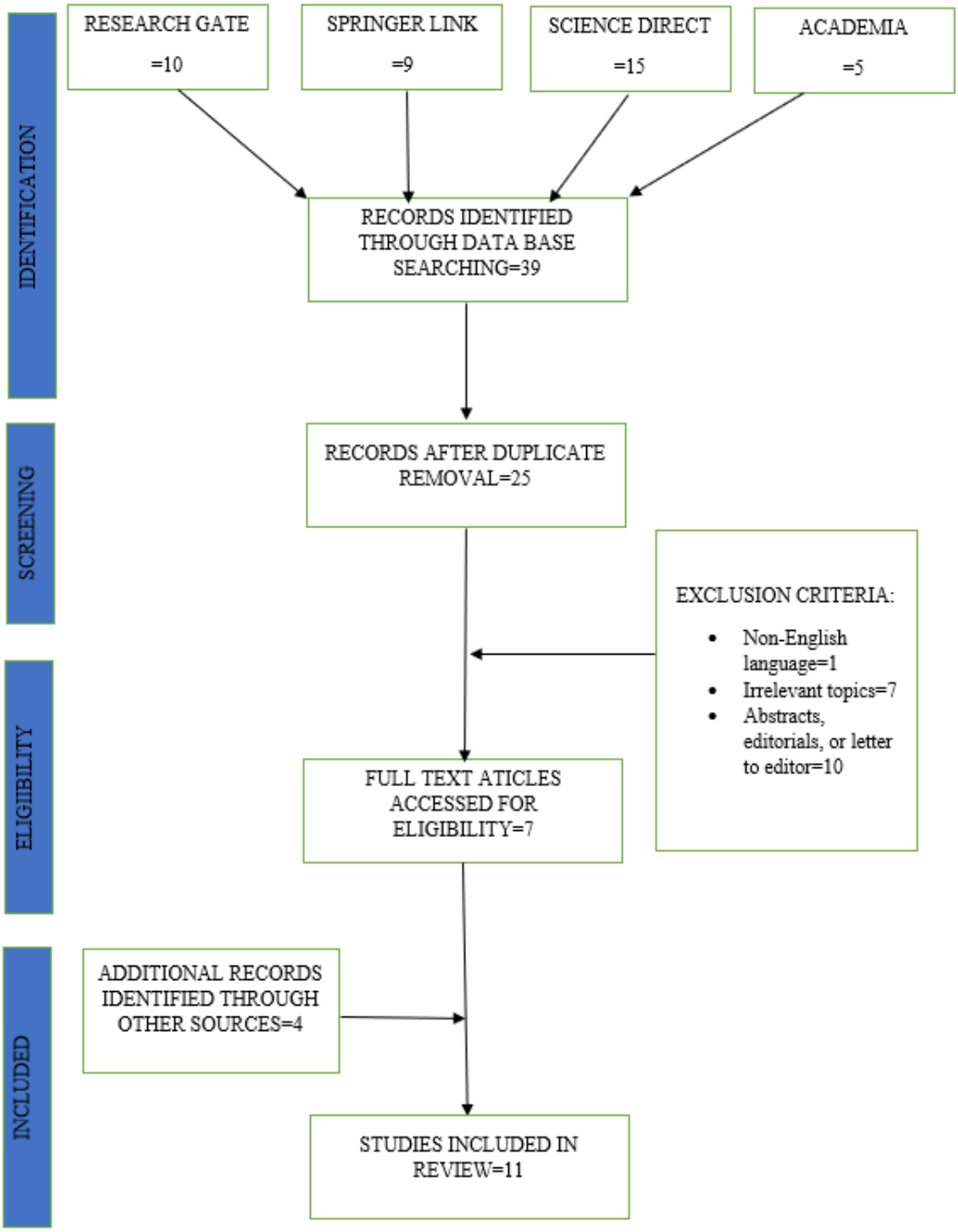


Figure 1: Flow diagram of the literature search
(Source: Authors: 2025)

Excluded studies were non-English, focused on unrelated topics, or were abstracts, editorials, or letters to the editor.

Stage Four concentrated on combining the gathered knowledge to establish the conclusive perspective. This phase entailed the identification of research deficiencies, prospective recommendations, and findings derived from the review process. The objective was to examine and synthesise findings to enhance the understanding of quarry dust's viability as a construction material in South Africa. Figure 1 presents a comprehensive overview of the processes involved in the systematic literature review.

3.2. Search Strategy

The academic publications reviewed in this study were sourced from four reputable databases: ResearchGate, Springer Link, Academia, and ScienceDirect, which are known for hosting high-quality, peer-reviewed content. These platforms offer extensive coverage across various fields, such as engineering, environmental

science, and construction management. This broad scope is crucial for capturing a wide range of literature related to quarry dust utilisation, sustainable construction materials, and the South African construction industry. To ensure the inclusion of recent research, studies from 2015 to 2024 were selected. Keywords tailored to the research questions, including "Review on the utilisation of quarry dust," "Sustainable construction materials," "Overview of the South African construction industry," "Quarry dust environmental impacts," and "Adoption strategies to quarry dust utilisation," were used for searches. In addition to these databases, hand searches of relevant journals, conference proceedings, and government reports were conducted to enrich the review. A variety of publication types, such as journal articles, books, conference papers, and reports, were included to ensure comprehensive coverage of the topic.

3.3. Data Extraction

As a result, 11 publications were eventually selected for further reading and analysis. Interestingly, most of them were found out from the Science Direct database, with the highest percentage and accounting for 55% of the total selected publications, followed by Internet search engine (30%), Research Gate (10%), Springer Link (7%), and Academia (3%)

4. Findings

4.1. Key Findings from Reviewed Studies on Quarry Dust in South African Construction

The study by Ajamu et al. (2020) found that replacing up to 50% of fine aggregate with quarry dust in concrete improved both compressive and tensile strength. However, higher replacements led to reduced workability. This supports previous research, emphasising quarry dust's potential to enhance strength while underscoring the importance of precise material proportions. Similarly, Sridharan et al. (2006) demonstrated that quarry dust significantly improved the shear strength of clayey soils, particularly with 60% replacement, further validating its effectiveness in soil stabilisation and infrastructure applications.

The integration of quarry dust as a partial replacement for traditional materials like sand and cement in concrete and sandcrete blocks has been explored in multiple studies, including those by Ma'aruf A., Abba S.I. and Nuruddeen (2017) and Akorli et al. (2023). These studies align with earlier findings and offer deeper insights into the optimal use of quarry dust in construction. Both studies identified a 20% replacement of cement or pit sand as the optimal level for achieving the highest compressive strength. Specifically, Ma'aruf A., Abba S.I. and Nuruddeen (2017) found that a 20% cement replacement led to the best compressive strength and durability, while greater replacements caused a reduction in strength. Similarly, Akorli et al. (2023) found that a 20% sand replacement resulted in a compressive strength of 1.46 N/mm², which met the Ghana Building Code for non-load-bearing walls.

However, both studies observed a decline in compressive strength when quarry dust replacements exceeded 20-30%. Ma'aruf A., Abba S.I. and Nuruddeen (2017) noted that quarry dust contents greater than 20% resulted in reduced strength, with noticeable strength loss at 30-40%. Akorli et al. (2023) found that at 30% replacement, the compressive strength was 1.41 N/mm², dropping to 1.32 N/mm² at 40%, and significantly decreasing to 0.60 N/mm² at 60-80% replacement. Additionally, Akorli et al. (2023) found that blocks made with only pit sand exhibited the highest compressive strength, while blocks made solely from quarry dust had the lowest strength, confirming that quarry dust is not an ideal substitute on its own. Ma'aruf A., Abba S.I. and Nuruddeen (2017) similarly observed that pure cement concrete was stronger than mixtures with high quarry dust content.

Beyond strength considerations, the durability of materials incorporating quarry dust has also been investigated. Ma'aruf A., Abba S.I. and Nuruddeen (2017) tested concrete durability against dilute sulfuric acid and found that concrete with quarry dust exhibited better abrasion resistance than pure materials, highlighting the material's potential for enhancing durability.

Supporting the trend toward sustainable construction, Febin et al. (2019) found that replacing 30% of the fine aggregate in concrete blocks with quarry dust not only improved strength but also reduced the environmental impact and cost, aligning with broader efforts to reduce construction costs and environmental footprints. Rahim et al. (2020) demonstrated that replacing up to 25% of cement with quarry dust enhanced concrete durability and reduced carbon emissions, reinforcing quarry dust's role in sustainable building practices and contributing to the global movement toward reducing the carbon footprint of construction materials.

Moreover, Silver et al. (2022) cautioned that the properties of quarry dust can vary significantly based on its origin, highlighting the need for local material testing before using it in construction projects. Additionally, Febin et al. (2019) (in a separate study) further emphasised the dual benefits of quarry dust in reducing both environmental impact and production costs in building block production, reinforcing its value in specialised construction applications.

4.2. Relation of the Findings to Existing Literature

Enhanced Mechanical Properties
The findings from Ajamu et al. (2020) regarding compressive and tensile strength improvements align with Panchal & Mathew (2015), who found that quarry dust enhances concrete strength. These studies emphasise the effectiveness of quarry dust when used in specific proportions, as noted by Rahim et al. (2020), who found that quarry dust could partially replace cement while maintaining concrete quality.

Soil Stabilisation
The Sridharan et al. (2006) findings about quarry dust improving shear strength in clayey soils resonate with the work of Karim, Samueel, and Jassem (2020) , who explored the role of quarry dust in soil stabilisation. This supports the idea that quarry dust can be used in applications beyond concrete, contributing to infrastructure development, such as road construction and embankments.

Cost-Effectiveness and Sustainability
Studies like Febin et al. (2019) and Rahim et al. (2020) indicate that quarry dust is an economically viable and environmentally sustainable alternative. These findings align with Prakash (2017), who suggested that quarry dust offers a cost-effective and eco-friendly solution to address material shortages, reduce waste, and lower carbon footprints in construction.

Material Variability
Silver et al. (2022) found that quarry dust's characteristics depend on its origin, highlighting the importance of material testing. This aligns with Chakraborty & Elzarka (2019), who emphasised the need for standardising quarry dust properties to ensure consistent performance in construction applications.

Specialised Applications
Febin et al. (2019) demonstrated quarry dust's role in concrete block production, offering an alternative to traditional materials. This extends the idea explored by Prakash (2017) and Sarvade & Nayak (2014), who noted the material's utility in both niche and mainstream construction applications.

4.3. Implications of the Findings for practice and policy in South Africa

The findings suggest that quarry dust can contribute to more sustainable and cost-effective construction in South Africa by reducing the environmental impact of cement and sand. Its use should be guided by local material testing to ensure quality, as its properties vary by origin. South African building codes could incorporate optimal replacement levels (20-30%) for strength and durability, especially in non-load-bearing applications. Quarry dust's cost-saving potential supports affordable housing projects, and its integration aligns with circular economy goals by reducing waste. Policymakers should promote education and training on proper quarry dust use to maximise benefits in construction. Table 1 (Appendix 1) summarises the systematic synthesis of the literature.

Table 1 shows the systematic synthesis revealing that quarry dust plays a pivotal role in enhancing environmental sustainability, economic feasibility, mechanical properties, and material performance in the South African construction industry. Key strategies for adoption include research & development, technical training, policy frameworks, and local testing to ensure successful integration. These findings align with previous studies and offer practical recommendations for stakeholders in the South African construction sector.

5. Discussion of Findings

This study reviews quarry dust's effectiveness in concrete, road construction, and other applications, addressing factors enabling its use in the South African construction industry. It highlights the need for a multi-stakeholder approach, involving government, industry, and academia, to overcome challenges such as limited awareness, technical expertise, and logistical barriers like supply consistency.

Key findings include optimal replacement levels for performance: up to 50% for fine aggregates (Ajamu et al., 2020) and 25% for cement (Rahim et al., 2020). The study also identifies workability challenges due to quarry dust, necessitating adjustments in mix design and water-cement ratios. Quarry dust's potential in soil stabilisation and road construction is highlighted, alongside its environmental and economic benefits, such as waste reduction and carbon emission lowering. However, variability in its properties based on origin requires local material testing and certification to ensure quality.
To fully utilise quarry dust in South Africa, the study recommends:

- Standardising guidelines and protocols.
- Conducting region-specific material characterisation studies.
- Enhancing technical capacity through training.
- Promoting policies and incentives that prioritise sustainable materials.
- These strategies will support the widespread and reliable use of quarry dust, advancing both economic and environmental goals in South Africa's construction sector.

5.1. Contribution to knowledge

This study enhances the body of knowledge by providing evidence on optimal quarry dust replacement levels (20-30%) for improving strength and durability

in concrete and sandcrete blocks. It highlights the need for local material testing due to variability in quarry dust properties, addressing gaps in current practices. The study also reinforces the environmental and cost benefits of quarry dust, supporting sustainable construction practices and resource efficiency. Additionally, it offers insights for updating policies and building codes to incorporate quarry dust safely, contributing to the broader push for sustainable construction and circular economy practices.

6. Conclusion

This literature review provides a comprehensive overview of quarry dust's effectiveness, applications, and enabling factors in the South African construction industry. Continued research and engagement with local stakeholders are crucial for maximising the potential of quarry dust and promoting its adoption as a sustainable construction material. Future studies should focus on creating standardised testing methods, assessing long-term material performance, and fostering awareness among construction professionals to encourage more widespread integration of quarry dust in various applications. However, the main objective of this review is to provide a comprehensive summary of the complexities associated with the use of quarry dust in the South African construction industry. The authors systematically reviewed 11 articles on the use of quarry dust in the South African construction industry. They classified the articles based on the main component, which is the research question: What strategies should be implemented to fully utilise the potential of quarry dust in the SA construction industry?

Furthermore, the systematic review highlights that while the technical and economic viability of quarry dust is established, its full utilisation in South Africa depends on targeted adoption strategies. These include R&D investments, supportive policies, capacity building, public awareness, supply chain optimisation, and alignment with sustainability frameworks. Implementing these strategies requires:

- Strong leadership and collaboration among policymakers, industry players, and researchers.
- Comprehensive performance validation and standardisation to ensure consistent material quality.
- Greater investment in supply chain infrastructure to ensure accessibility.
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Future efforts should focus on scaling up successful pilot projects, addressing logistical challenges, and integrating quarry dust into national construction policies. These steps will contribute to sustainable and cost-effective construction practices across South Africa.

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Appendix 1

Table 1: Summary of the systematic synthesis

Theme	Study Reference	Key Findings	Adoption Strategy/Enabling Factor	Relation to Existing Literature
Environmental Sustainability & Economic Feasibility	Febin et al., 2019; Rahim et al., 2020	Quarry dust reduces cement use, cutting carbon emissions and enhancing durability. It also reduces production costs and environmental impact in concrete block production.	**Environmental Sustainability Framework; Economic Feasibility**	Aligns with **Prakash (2017)** on quarry dust reducing carbon emissions and material costs. Supports **Ismail et al. (2017)**'s broader sustainability goals.
Mechanical Properties & Performance	Ajamu et al., 2020; Rahim et al., 2020	Quarry dust enhances compressive and tensile strength in concrete when used at optimal levels (25-30%). Excessive replacement (50%) reduces workability.	**Research & Development Investment; Technical Training**	Supports **Panchal & Mathew (2015)** on strength enhancement, and **Rahim et al. (2020)** on maintaining concrete quality with partial cement replacement.
Material Variability & Local Adaptation	Silver et al., 2022; Sridharan et al., 2006	Quarry dust's properties vary by source (granite, limestone, marble), impacting its effectiveness in construction and soil stabilisation.	**Supply Chain & Logistics Optimization; Local Material Testing**	Confirms **Chakraborty & Elzarka (2019)** on material variability, emphasising the need for local sourcing and testing.
Soil Stabilisation & Infrastructure Development	Sridharan et al., 2006; Corroborates Karim, Samueel, and Jassem, 2020	Quarry dust significantly improves shear strength in clayey soils, supporting road construction and infrastructure.	**Policy & Regulatory Framework; Public Awareness & Advocacy**	Corroborates **Karim, Samueel, and Jassem (2020)** on soil stabilisation and **Sridharan et al. (2006)** on infrastructure applications.
Specialised Applications & Sustainability	Febin et al., 2019 (additional study); Nayak, Sarvade, Patel & Yadav (2019)	Quarry dust is effective for niche applications like building blocks, offering economic and environmental benefits.	**Specialised Applications; Public Awareness & Advocacy**	Supports **Panchal & Mathew (2015)** and **Nayak, Sarvade, Patel & Yadav (2019)** on quarry dust's role in specialised construction applications.

Source: Authors 2025

ACADEMIC PAPERS: THEME 3 - SUSTAINABLE CONSTRUCTION/NET-ZERO IN CONSTRUCTION

Promoting the Adoption of Sustainable Environmental Technologies in Ghana's Construction Sector: A Quantitative Study of Key Drivers

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Abstract

This study aims to quantitatively assess the key drivers influencing the adoption of sustainable environmental construction technologies (ECTs) in Ghana's construction sector. A structured survey was conducted with 275 professionals from the Ghana Real Estate Developers Association (GREDA), the Ghana Institution of Engineering (GhIE), the Institution of Engineering and Technology (IET), and the Architects Registration Council (ARC). A five-point Likert scale was used in the evaluation. Data was analysed using descriptive statistics and correlation analyses to identify key enablers of ECT adoption. The study is constrained geographically, and future research should incorporate a wider variety of stakeholders and geographic regions to enhance the generalizability of the findings. The correlation analysis revealed strong associations between energy efficiency and regulatory policies ($\rho = 0.678$, $p < 0.01$) and between financial incentives and technological advancements ($\rho = 0.521$, $p < 0.01$), highlighting the critical role of policy and financial mechanisms in driving sustainable technology adoption. The study recommends the creation of more substantial financial incentives and clearer regulatory and policy frameworks to promote ECT adoption. Enhancing awareness campaigns on the economic and environmental benefits of these technologies is essential for aligning the sector with national and global sustainability goals. Future research should incorporate a wider variety of stakeholders and geographic regions to enhance the generalizability of the findings.

Keywords: Sustainability, Environmental Technologies, construction sector, Technology Adoption, Ghana.

1. Introduction

Ghana's rapid urbanisation, particularly in cities like Accra, Kumasi, and Takoradi, has significantly increased housing demand due to rising migration into these urban areas. As the most populous cities in the country, they have experienced heightened requirements for both residential and commercial spaces, creating dynamic opportunities in the construction sector. Investment avenues in Ghana's construction market include residential property development, Real Estate Investment Trusts (REITs), and land flipping (Ghana Investment Promotion Centre, 2020). Prominent developers offer investment options like buy-to-let properties, direct ownership, and leveraged ownership, providing diverse opportunities for portfolio diversification. Despite these opportunities, financing remains a critical challenge. Commercial banks, private equity funds, and pension funds are among the primary sources of construction project financing. However, commercial banks often mandate upfront contributions of up to 30% of a project's value, creating barriers for many developers (Ghana Investment Promotion Centre, 2020). To address these challenges, government interventions like the National Housing Policy, affordable housing initiatives, and land title registration reforms aim to mitigate the housing deficit and promote growth. While the sector continues to expand, its environmental impact cannot be overlooked. This study investigates the key drivers influencing the adoption of sustainable environmental technologies in Ghana's construction industry, emphasising strategies to balance economic growth with environmental sustainability.

2. Literature Review

Environmental management has gained prominence in the construction industry due to its critical role in addressing environmental degradation. Like many developing countries, Ghana is experiencing rapid urbanisation, which has led to a significant increase in construction activities, exacerbating environmental challenges. The construction industry's contribution to environmental degradation necessitates the integration of sustainable environmental practices (Office for National Statistics, 2018). This review examines the key drivers influencing the adoption of sustainable environmental technologies in Ghana's construction sector:

2.1. Regulatory Frameworks

Environmental regulations serve as a primary driver for sustainable practices, according to Darko and Chan (2018). In Ghana, the Environmental Protection Agency (EPA) enforces the Environmental Assessment Regulations, requiring developers to conduct Environmental Impact Assessments (EIA) before initiating construction projects. (Environmental Protection Agency, Ghana, n.d.).. Regulatory measures include mandatory reporting of energy usage, adherence to building codes, and compliance with

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carbon emissions standards (Iwaro and Mwasha, 2010). These regulations promote eco-innovations by encouraging the adoption of energy-efficient materials, waste reduction techniques, and resource optimisation. Furthermore, compliance with environmental regulations can enhance efficiency and reduce costs associated with material handling, energy consumption, and waste disposal (Iwaro and Mwasha, 2010).

2.2. Financial Incentives

Incorporating sustainable practices can result in significant cost savings over time. For example, using energy-efficient HVAC systems, lighting, and sustainable building materials reduces operational costs while enhancing the longevity of structures (Ekung *et al..,* 2022). Effective cost management is critical in achieving sustainable construction, requiring accurate estimation, cost control, and efficient financial planning. Proper risk assessment and feasibility studies are essential for minimising project costs and maximising environmental benefits (El-Sayegh *et al.*, 2018).

2.3. Corporate Social Responsibility (CSR) and Tenant Demand

Construction companies in Ghana are increasingly integrating environmental sustainability into their CSR policies to enhance their reputation and fulfil stakeholder expectations. Meeting CSR goals improves public perception and drives the adoption of eco-friendly technologies. Lawluvy *et al.* (2022) emphasise that CSR-driven environmental practices help organisations align with global sustainability standards. Consumer preferences play a pivotal role in driving sustainable development. Environmentally conscious tenants prefer buildings that incorporate green technologies, such as energy-efficient designs and sustainable materials and are often willing to pay a premium for these features (Lawluvy *et al.,* 2022). Developers aiming to meet these demands must focus on ergonomic designs, environmental friendliness, and functional spaces to enhance tenant satisfaction.

2.4. Competitive Advantage and Investor Pressure

Adopting sustainable practices provides construction companies with a competitive edge. Differentiation through green technologies attracts investors and environmentally conscious clients, boosting market performance (Chininga *et al.,* 2024). Investors are increasingly prioritising Environmental, Social, and Governance (ESG) criteria. Institutional investors demand sustainable practices from construction companies, linking these practices to long-term profitability. Additionally, developers who incorporate sustainable technologies often find it easier to access financing, as financial institutions are more inclined to fund projects with clear environmental benefits (Darko and Chan., 2018).

2.5. Technological Innovations

Technological advancements are key drivers of sustainability in real estate. These include energy-efficient systems, water conservation technologies, and renewable energy integration. For example, the adoption of solar water heating, rainwater harvesting, and greywater recycling systems enhances environmental performance. Innovations in HVAC systems, lighting technologies, and building envelope designs also contribute significantly to reducing greenhouse gas emissions and improving indoor environmental quality (Darko and Chan, 2018).

2.6. Stakeholder Engagement

The role of the construction team is critical in promoting sustainable practices. Key factors include effective project management, team integration, and innovative design processes (El-Sayegh *et al.,* 2018). Contractors who incorporate written environmental policies, organise training programs, and conduct environmental audits contribute significantly to the success of sustainable projects (Iwaro and Mwasha, 2010). Engaging stakeholders such as government authorities, investors, and community members fosters collaboration and ensures that environmental concerns are addressed effectively. Stakeholder pressures, including those from environmental groups and trade associations, compel developers to adopt best practices (Wu *et al.,* 2023).

2.7. Market Demand and Social Norms

The increasing market demand for sustainable buildings reflects a shift in consumer preferences toward eco-friendly products. Social norms also play a vital role, as public awareness and education campaigns can influence behaviour and attitudes toward green technologies (El-Sayegh *et al.,* 2018).

Despite the evident drivers, challenges such as high initial costs, limited market awareness, and insufficient policy enforcement hinder the adoption of sustainable technologies. Addressing these challenges requires targeted interventions, including policy incentives, public education, and capacity-building initiatives (Yeboah, 2024). Regulatory frameworks, cost considerations, CSR, consumer demand, and technological advancements influence the adoption of sustainable environmental technologies in Ghana's construction sector. By addressing barriers and leveraging these drivers, stakeholders can create a more sustainable construction industry that aligns with global environmental goals.

3. Research Methodology

This study adopts a quantitative methodology to explore the factors driving the adoption of sustainable environmental technologies within Ghana's construction sector. A structured survey was designed and administered to professionals across key

stakeholder groups. The sample size was determined using Yamane's (1967) formula for finite populations. To ensure a representative sample, the sample size was determined using Yamane's 1967 formula for finite populations:

$$n = \frac{N}{\{1 + Ne^{\wedge}2\}}$$

where n is the sample size, N is the total population, and e is the margin of error (set at 5% or 0.05 for a 95% confidence level). Applying this formula, the estimated sample sizes were 154 for the Ghana Real Estate Developers Association, 220 for the Ghana Institution of Engineering, 305 for the Institution of Engineering and Technology, and 243 for the Architects Registration Council. However, despite these estimates, only 275 responses were received and analysed, representing the final sample size for the study. While the response rate was lower than initially anticipated, it aligns with acceptable standards in survey research (Baruch & Holtom, 2008) and remains sufficient for statistical analysis. To address potential non-response bias, follow-ups were conducted via email and telephone reminders. Additionally, a wave analysis was performed, comparing early and late respondents across key variables. No significant differences were detected, suggesting minimal bias in the dataset. The instrument's reliability was assessed using Cronbach's alpha and Composite Reliability (CR). All constructs exhibited Cronbach's alpha values above 0.70 and CR values exceeding 0.80, confirming internal consistency. Convergent validity was established through Average Variance Extracted (AVE) values above 0.50. Ethical principles were strictly followed, ensuring informed consent, confidentiality, and anonymisation of data. Permissions were obtained from relevant professional associations to maintain research integrity (Kara, 2019; Polit and Beck, 2006).

The demographic profile of respondents reflected gender diversity (53.45% male, 46.55% female) and age variation (ranging from under 25 to over 55), ensuring a balanced representation of professionals across different experience levels. To examine relationships between factors influencing sustainable technology adoption, Spearman's correlation coefficient (ρ) was applied due to the dataset not meeting normality assumptions, ensuring robust statistical interpretation. Spearman's correlation is appropriate for measuring the strength and direction of monotonic relationships between variables, even when data distributions are non-normal (Kumar, 2019).

4. Findings and Discussions

Environmental management has become increasingly critical in Ghana's construction sector, where rapid urbanisation necessitates sustainable practices. Table 1 (see Appendix 1) presents the key drivers influencing environmental management, supported by mean scores, standard deviations, and responses from 275 participants.

The findings indicate strong agreement among respondents on the key drivers of environmental management in the construction sector. Among the most significant factors is the emphasis on energy efficiency, waste management, and greenhouse gas reduction, which received the highest mean score (4.5) with low variability (SD = 0.5). This highlights a strong consensus on the importance of environmental considerations in improving sustainability. Government interventions play a critical role in promoting environmental sustainability. Government support for research and development in sustainable construction technologies also received a high mean score (4.5), emphasising the importance of innovation in driving sustainability. These findings align with prior studies (Zhang *et al.*, 2020), reinforcing the need for government-led support mechanisms.

Additionally, environmental regulations and sustainable building certifications (e.g., EDGE, LEED, BREEAM) emerged as key enablers (mean = 4.4), reinforcing the importance of formal policies in guiding eco-friendly practices. Market forces significantly influence environmental management decisions. Technological advancements and market demand for sustainable construction (mean = 4.4) highlight the role of innovation and consumer awareness in driving sustainability. Similarly, consumer demand for green buildings (mean = 4.3) underscores the influence of public preferences on corporate environmental strategies. The findings also emphasise the importance of skilled professionals and financial resources in achieving sustainability goals. Employee competency and financial capacity (mean = 4.3) were identified as crucial enablers of environmental sustainability. Additionally, stakeholder awareness and education programs (mean = 4.4) demonstrate the need to actively engage key industry players. Collaboration among industry professionals, including networking and partnerships with environmental organisations (mean = 4.2–4.3), highlights the importance of collective action. Financial incentives also play a role in adoption, with financial support for sustainability initiatives scoring a mean of 4.1. The potential for cross-sectoral learning is evident, with access to product and process innovation (mean = 4.1, SD = 0.7) indicating a moderate level of importance. Similarly, learning from other industries (mean = 4.1, SD = 0.7) suggests an opportunity to leverage best practices from different sectors to improve environmental performance.

4.1. Correlation Analysis

This section presents the correlation analysis results. The correlation analysis examines the relationships between key factors influencing the adoption of sustainable Environmental Construction Technologies (ECTs) in Ghana's real estate industry. As the dataset did not meet the normality assumption, Spearman's

correlation was used instead of Pearson's correlation to examine the relationships among key factors influencing the adoption of Environmental Construction Technologies (ECTs) in Ghana's real estate industry (Table 2).

Table 2: Correlation Matrix of Key Enablers for ECT Adoption
(Spearman's correlation coefficients, n = 100)

Variables	1. Energy Efficiency	2. Financial Incentives	3. Technological Advancements	4. Regulatory Policies	5. Stakeholder Engagement
1. Energy Efficiency	1.000	0.582**	0.431**	0.678**	0.590**
2. Financial Incentives	0.582**	1.000	0.521**	0.612**	0.456**
3. Technological Advancements	0.431**	0.521**	1.000	0.489**	0.533**
4. Regulatory Policies	0.678**	0.612**	0.489**	1.000	0.617**
5. Stakeholder Engagement	0.590**	0.456**	0.533**	0.617**	1.000

Notes: Spearman's correlation coefficients reported.
Significance levels: $p < 0.01$ (coefficients with double asterisks indicate significant correlation).

The results indicate strong positive correlations among key enablers of ECT adoption in Ghana's real estate industry. This next section discusses four Key Constructs, namely: Regulatory Policies and Stakeholder Engagement, Financial Incentives and Economic Drivers, Technological Advancements and Market Demand, Stakeholder Engagement and Corporate Social Responsibility (CSR) that are necessary in adopting eco-friendly construction technologies in the construction industry:

4.1.1. Regulatory Policies and Stakeholder Engagement

Spearman's correlation analysis revealed significant relationships among key enablers of ECT adoption. Energy efficiency showed a strong correlation with regulatory policies ($\rho = 0.678$, $p < 0.01$), indicating the influence of government intervention. Financial incentives were moderately correlated with technological advancements ($\rho = 0.521$, $p < 0.01$), suggesting that financial support plays a key role in innovation adoption. Stricter building codes, mandatory green certifications (e.g., EDGE, LEED, and BREEAM), and compliance monitoring have significantly influenced the integration of energy-efficient technologies. Similar studies confirm that well-enforced policies lead to widespread adoption of sustainable practices (Darko & Chan, 2018). Furthermore, the positive correlation between stakeholder engagement and regulatory policies ($r = 0.617$, $p < 0.01$) underscores the importance of multi-stakeholder collaboration. Effective public-private partnerships (PPPs), industry regulations, and government incentives strengthen policy implementation. Engaging financial institutions, environmental agencies, and real estate stakeholders. ensures that sustainability policies are practical, enforceable, and widely accepted (Wang and Ma, 2021).

4.1.2. Financial Incentives and Economic Drivers

A moderate correlation between financial incentives and technological advancements ($r = 0.521$, $p < 0.01$) highlights the influence of financial mechanisms—such as subsidies, tax incentives, and green financing programs—on sustainability innovation. These incentives reduce investment risks, making it easier for developers to adopt eco-friendly construction technologies (Dzokoto *et al.*, 2014). Additionally, financial incentives align with market demand for green buildings, driving developers to prioritise energy efficiency, natural ventilation, and water conservation systems (Guribie et al., 2021). As consumer preferences shift toward sustainable housing, developers increasingly integrate smart building solutions and resource-efficient materials to maintain competitiveness. This confirms the role of financial policies in accelerating the transition to sustainable real estate.

4.1.3. Technological Advancements and Market Demand

While no direct correlation was observed between technological advancements and market demand, the findings indicate an indirect relationship through financial incentives and policy interventions. Modern energy-efficient technologies, renewable energy systems, and smart building solutions are reshaping Ghana's construction sector, aligning with global Fourth Industrial Revolution (4IR) trends (Dzokoto *et al.,* 2014). The positive correlation between financial incentives and technological innovation ($r = 0.521$, $p < 0.01$) suggests that government support and investment in R&D drive green construction technologies. As consumers increasingly demand eco-friendly real estate, developers are leveraging advancements in construction automation, smart energy management, and carbon-neutral building materials. This trend reinforces the need for continuous investment in sustainable technology to meet market expectations.

4.1.4. Stakeholder Engagement and Corporate Social Responsibility (CSR)

Stakeholder engagement plays a pivotal role in shaping sustainability policies and industry-wide environmental practices. The strong correlation between stakeholder engagement and regulatory policies ($r = 0.617$, $p < 0.01$) supports the view that government, investors, developers, and environmental organisations must collaborate to achieve sustainability goals. Corporate Social Responsibility (CSR) has also emerged as a key driver of stakeholder engagement in ECT adoption. Although not explicitly tested in this study, prior research highlights that real estate firms are increasingly integrating sustainability goals into CSR strategies (Ojo & Ogunsemi, 2019). Many companies implement carbon footprint reduction programs, energy-efficient building initiatives, and resource conservation strategies, strengthening partnerships with government regulators, financial institutions, and community stakeholders. These efforts enhance the adoption of sustainable construction technologies, reinforcing the broader sustainability agenda in Ghana's real estate sector.

5. Conclusions and Further Research

This study highlights regulatory frameworks, financial incentives, technological innovation, and stakeholder collaboration as key enablers of environmental sustainability in Ghana's real estate sector. Strengthening policies on emissions control, renewable energy, and waste management will enhance green building adoption. Financial mechanisms such as tax breaks, subsidies, and green financing promote sustainable investments while growing consumer demand encourages developers to integrate energy-efficient designs and smart technologies. Technological advancements, including smart building solutions and renewable energy systems, further drive sustainability. Private sector participation and CSR initiatives are crucial for aligning with global best practices. Collaboration among policymakers, financial institutions, and industry stakeholders fosters policy development and reinforces sustainability commitments. To achieve lasting progress, regulatory enforcement must be strengthened, developers should leverage financial incentives, and public awareness campaigns should promote eco-friendly real estate. Future research should explore long-term policy impacts and technological advancements to ensure sustained environmental progress.

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Appendix 1

Table 1: Descriptive Statistics on Key Drivers towards Environmental Management in the Construction Sector in Ghana:

Statements	Mean	Standard Deviation	N
Selecting the right construction team is vital in enhancing environmental performance.	4.2	0.6	275
Environmental issues such as energy efficiency, waste management, and greenhouse gas reduction are important considerations.	4.5	0.5	275
The organisation's access to product innovation and process innovation improves environmental performance.	4.1	0.7	275
Corporate social responsibility initiatives motivate construction companies to implement environmental management practices.	4.3	0.6	275
Environmental regulations imposed by the government encourage the adoption of eco-friendly practices.	4.4	0.5	275
External stakeholders, such as government authorities and society, have a significant level of influence and decision-making in the development of the construction industry.	4.2	0.6	275
Government support and funding for research and development of sustainable construction technologies would significantly encourage their adoption of environmental sustainability practices.	4.5	0.5	275
Factors like employee competency and financial resources would significantly impact environmental sustainability in the industry.	4.3	0.6	275
The availability of financial incentives would encourage construction companies to adopt environmentally friendly practices.	4.1	0.7	275
Market demand and technological advancements drive the adoption of sustainable practices in the construction industry.	4.4	0.5	275
Consumer demand for sustainable buildings drives construction companies to prioritise environmental management practices.	4.3	0.6	275
Social factors, such as public awareness and promotion of health and safety, would significantly influence environmental practices in real estate.	4.2	0.6	275
The construction industry can learn from the environmental practices implemented in other industries.	4.1	0.7	275
Networking and collaboration among different professionals would enhance key stakeholder experiences to contribute to good environmental management practices.	4.3	0.6	275
Integrating sustainable building materials and technologies would enhance the market competitiveness of construction projects in Ghana.	4.5	0.5	275
Sustainable building certifications (e.g., EDGE, LEED, and BREEAM) are considered key drivers for construction companies to pursue environmentally friendly practices.	4.4	0.5	275
Collaborative partnerships with environmental organisations promote the adoption of sustainable practices in the construction industry.	4.2	0.6	275
Industry recognition and awards for environmental management practices would motivate construction companies to strive for sustainability practices.	4.3	0.6	275
Employee and stakeholder awareness and education programs on sustainability would promote the implementation of environmental management practices among construction stakeholders.	4.4	0.5	275
Overall	**4.3**	**0.58**	**275**

Min =1, Max = 5

Source: Authors's computations, SPSS 22.

Quantitative Assessment of Environmental Challenges Hindering Sustainability in the Ghanaian Construction Industry: Implications for Sustainable Development

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Abstract

Environmental challenges in the construction sector pose significant obstacles to achieving sustainability in Ghana. This study quantitatively assesses these challenges, identifying systemic barriers that hinder environmental management practices. A structured survey was conducted with 275 industry stakeholders, including developers, bankers, environmental managers, and government agencies. Using a five-point Likert scale, responses were analysed through descriptive statistics, Spearman's correlation, and exploratory factor analysis (EFA) to categorise key challenges. The findings reveal four dominant challenge constructs: (1) Financial Barriers, (2) Regulatory Deficiencies, (3) Knowledge and Awareness Gaps, and (4) Infrastructure Constraints. Among these, financial barriers emerged as the most critical obstacle (mean = 4.5, SD = 0.5), with high costs of green technologies and limited access to financing deterring sustainability adoption. Weak regulatory enforcement (r = 0.65) further exacerbates non-compliance, while inadequate expertise (r = 0.57) hinders effective implementation. The study contributes to Institutional Theory by demonstrating that regulatory frameworks alone are insufficient, necessitating complementary financial and educational interventions. Policy recommendations include tax incentives, public-private partnerships for financing, mandatory sustainability training, and improved green infrastructure investments. These findings have broad implications for developing economies facing similar sustainability challenges. Future research should explore policy effectiveness and cross-country comparisons to benchmark Ghana's progress against global best practices.

Keywords: Sustainability, Real Estate, Environmental Challenges, Sustainable Development, Ghana.

1. Introduction

Ghana's construction sector has experienced significant transformation since colonial times, with rapid expansion observed from the early 2000s due to urbanisation, an expanding middle class, and oil discoveries (Locus Estate, 2023; Ghana Investment Promotion Centre, 2020). Key policy interventions, including the State Housing Corporation and the Land Title Registration System, have shaped the industry, facilitating both residential and commercial development (Locus Estate, 2023). By 2019, the construction sector accounted for 9.1% of Ghana's GDP, contributing to economic growth while addressing a housing deficit of approximately two million units (Ghana Investment Promotion Centre, 2020). The sector's high return on investment has made it a lucrative avenue for both domestic and foreign investors (Eden Heights, 2024; Evans *et al.*, 2018). Environmental sustainability in Ghana's construction industry has gained increasing attention since the early 2000s, influenced by global sustainability trends and rising concerns over resource depletion, waste management, and climate change. The establishment of the Ghana Green Building Council (GHGBC) in 2003 marked a significant milestone, as it championed green building practices through certification programs, renewable energy promotion, and sustainable construction material advocacy (Ghana Green Building Council, n.d.). Government policies, such as the 2007 National Environmental Sanitation Policy and the 2012 Ghana Energy Efficiency and Conservation Policy, have reinforced commitments to reducing the environmental impact of construction activities, focusing on pollution control, energy conservation, and waste management (Ghana Energy Commission, 2012; Ministry of Local Government and Rural Development, 2007). Despite these initiatives, significant barriers to sustainability persist. Limited stakeholder awareness, weak enforcement of environmental regulations, and inadequate financial incentives continue to impede progress. Studies indicate that gaps exist in the implementation and effectiveness of environmental sustainability frameworks, with regulatory inefficiencies and financing constraints slowing the adoption of green building practices. The absence of strong economic incentives, such as tax breaks and subsidies, further discourages developers from integrating sustainability into mainstream construction (Kineber *et al.*,2022).

Government institutions and professional bodies have played crucial roles in addressing these challenges. The Ministry of Environment, Science, Technology, and Innovation (MESTI) and the Energy Commission have spearheaded policies such as the Renewable Energy Act (2011) and the Green Building Guidelines (2014), aimed at promoting energy-efficient construction and

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renewable energy adoption. Professional organisations, including the Ghana Institution of Engineering (GhIE), Institution of Engineering and Technology (IET), Architects Registration Council (ARC), and Ghana Real Estate Developers Association (GREDA), have also contributed through advocacy, training, and stakeholder engagement. This study provides a quantitative assessment of the environmental challenges facing Ghana's construction sector and examines their implications for sustainable development. By identifying key barriers and their systemic interrelations, this research aims to propose effective strategies to align the sector with global sustainability goals, ensuring that environmental management principles are fully integrated into construction practices in Ghana.

2. Literature Review

Environmental sustainability in the construction industry is vital for mitigating the sector's environmental impact. However, barriers to sustainable construction persist, particularly in developing economies where regulatory, financial, and technical constraints are prevalent. This review synthesises key challenges affecting environmental sustainability in Ghana, drawing on global insights to position the study within a broader sustainability discourse.

2.1. Theoretical Framework: Institutional and Resource-Based Perspectives

This study is framed within Institutional Theory and the Resource-Based View (RBV). Institutional Theory suggests that regulatory, normative, and cultural-cognitive forces shape firms' environmental practices (Scott, 2014). In the Ghanaian construction sector, weak regulatory enforcement and cultural inertia hinder the adoption of sustainability. Meanwhile, RBV posits that firms gain a competitive advantage by leveraging unique internal resources (Barney, 2022). The lack of financial, technical, and knowledge-based resources constrains firms' ability to implement sustainable construction practices. By integrating these perspectives, this study explains why environmental sustainability remains underdeveloped in Ghana's construction industry despite global pressure for green practices.

2.2. Awareness and Knowledge Gaps

Limited awareness among developers, contractors, and clients impedes the adoption of sustainability. Agyekum *et al.,* (2025) found that developers in emerging markets often underestimate the long-term benefits of energy-efficient buildings, reducing demand for green construction. In Ghana, Asiedu *et al.* (2024) observed that real estate firms fail to incorporate sustainability due to a lack of client awareness. Knowledge gaps perpetuate unsustainable practices such as inefficient waste management and reliance on non-renewable energy sources (Ayarkwa *et al.,* 2017). Addressing these gaps through capacity-building programs is crucial.

2.3. Financial Barriers and Investment Constraints

High upfront costs and limited access to financing remain significant obstacles to sustainability adoption (Unegbu and Yawas,, 2023). Developers in Ghana cite high capital costs of green technologies—such as solar panels and energy-efficient HVAC systems—as key deterrents (Anzagira *et al.,* 2024). In Nigeria, weak currency valuation exacerbates this issue, making green building materials unaffordable (Ekung *et al.,* 2022). Furthermore, statutory taxes and limited green financing mechanisms restrict developers' ability to invest in environmental solutions. Policy-driven financial incentives, such as tax credits for green construction, are needed to bridge this gap.

2.4. Regulatory Deficiencies and Compliance Gaps

Weak environmental policies and poor enforcement mechanisms significantly hinder EMP adoption (Ramaswami *et al*., 2016). Ghana's Environmental Protection Agency (EPA) has established environmental regulations, but enforcement remains lax, enabling non-compliance (Darko & Chan, 2018). In contrast, South Africa's Green Building Council has successfully enforced sustainability regulations, increasing LEED-certified buildings by 35% over five years (Chan *et al.*, 2018). Strengthening Ghana's regulatory framework through mandatory compliance measures and public-private partnerships is essential for progress.

2.5. Infrastructure and Resource Limitations

Access to green technologies and infrastructure is insufficient in Ghana's construction sector (Ahenkan *et al.,* 2022). Developers struggle with limited solar energy adoption, poor waste recycling infrastructure, and high material import costs. Similarly, construction firms demonstrate minimal engagement with material reuse or recycling, largely due to limited infrastructure (Baidoo, 2021). Empirical findings show that integrating green procurement practices such as mandatory waste management and sustainability clauses in contracts can significantly advance the circular economy in Ghana's construction sector (Kwasafo *et al.,* 2024).

2.6. Lack of Standardised Environmental Management Systems (EMS)

Environmental management systems (EMS) remain underdeveloped in Ghana, leading to inconsistent sustainability reporting (Osuizugbo *et al.*, 2020). Construction firms lack clear sustainability benchmarks, making it challenging to track carbon emissions, energy use, and waste disposal (Djokoto *et al,* 2014). In contrast, Nigeria's Sustainable Building Certification Framework provides standardised

reporting guidelines, driving higher sustainability compliance (Abdulsalam *et al.*, 2024). Ghana must adopt standardised EMS frameworks to promote accountability and facilitate sustainability monitoring (Ampratwum *et al.*, 2019).

2.7. Limited Technical Expertise

The Ghanaian construction sector lacks skilled professionals capable of implementing sustainable building practices (Agyekum *et al.*, 2025). Anzagira *et al.* (2024) found that in developing countries, sustainable design expertise remains scarce, leading to suboptimal implementation of eco-friendly solutions. In Ghana, few tertiary institutions offer specialised training in green construction, further exacerbating the skill gap. Capacity-building initiatives, industry collaborations, and professional training programs are needed to develop local expertise (Owusu-Agyeman & Aryeh-Adjei, 2023).

2.8. Insufficient Market Incentives for Sustainable Development

Incentives for sustainable real estate development remain weak, discouraging firms from integrating environmental management plans. Xu *et al.* (2023) found that preferential financing for green projects significantly boosts adoption rates. However, in Ghana, developers receive no financial incentives for green building certification, making sustainability a low-priority investment (Darko & Chan, 2018). To stimulate adoption, the government must introduce tax incentives, subsidies, and green finance schemes for sustainable construction projects.

3. Research Methodology

This study adopts a quantitative research design through a cross-sectional survey to assess environmental challenges in Ghana's construction sector. A structured questionnaire was administered to 275 stakeholders, including developers, lenders, environmental managers, government agencies, and estate agents. The questionnaire employed a five-point Likert scale to capture respondents' perceptions of key sustainability challenges. To ensure a representative sample, a multi-stage sampling approach was employed. Purposive sampling was used to select industry experts, while stratified sampling ensured proportional representation of key stakeholder groups. Within each stratum, random sampling was applied to minimise selection bias and enhance generalizability.

The validity of the questionnaire was confirmed using the Content Validity Index (CVI) = 0.98, which exceeds the 0.80 threshold (Polit & Beck, 2006), indicating a high level of clarity and relevance in measuring the intended constructs. Composite Reliability (CR) and Cronbach's Alpha were used to assess internal consistency, with both exceeding 0.90, demonstrating strong measurement reliability (Hair et al., 2021). The key constructs analysed included economic barriers (CR = 0.982), regulatory challenges (CR = 0.987), knowledge gaps (CR = 0.997), and infrastructure and material constraints (CR = 0.991). Data analysis involved descriptive statistics, correlation analysis, and exploratory factor analysis (EFA) to identify key environmental challenge constructs.

Descriptive statistics were used to summarise the severity of the identified challenges through mean scores and standard deviations. To assess the relationships between different challenges, Spearman's rank correlation analysis was applied. Spearman's method was chosen over Pearson's correlation due to the ordinal nature of Likert-scale data and its suitability for non-parametric relationships. This approach enabled the identification of the strength and direction of associations between key challenge factors. To further explore underlying challenge constructs, Exploratory Factor Analysis (EFA) was conducted using Principal Component Analysis (PCA) with Varimax rotation. EFA was preferred over Confirmatory Factor Analysis (CFA) as the study sought to explore latent structures rather than confirm pre-existing factor models. The suitability of the dataset for factor analysis was verified using the Kaiser-Meyer-Olkin (KMO) measure of sampling adequacy, which scored 0.84, indicating strong suitability, and Bartlett's Test of Sphericity ($\chi^2 = 2135.76$, $p < 0.001$), which confirmed significant correlations among variables. Factors with eigenvalues greater than 1.0 were retained to ensure statistical rigour in dimensionality reduction. Ethical approval was obtained prior to data collection, and all participants provided informed consent. Confidentiality was strictly maintained throughout the study. Despite its contributions, this study has some limitations. First, its cross-sectional design captures industry perceptions at a single point in time. Future research should consider a longitudinal approach to assess changes in environmental challenges over time. Additionally, since the study relies on self-reported data, there is potential for response bias. Future studies should triangulate findings using qualitative insights from expert interviews or case studies. Lastly, while the findings are relevant to Ghana, comparative studies across other African economies would enhance the study's generalizability and provide broader insights into environmental challenges in developing construction industries.

4. Findings and Discussion

Multiple challenges hinder the adoption of environmental sustainability practices in Ghana's construction sector. Table 1 (see Appendix 1) above provides insights into these challenges, with mean scores and standard deviations summarising responses from 275 participants.

The findings indicate that financial barriers, regulatory challenges, knowledge gaps, and infrastructure

limitations are the most pressing constraints. The high cost of sustainability practices (mean = 4.5, SD = 0.5) was the most significant concern, reinforcing the need for government incentives and subsidies to encourage adoption. Similarly, the lack of regulatory support (mean = 4.5, SD = 0.5) highlights gaps in policy enforcement, which limits compliance with environmental standards.

4.1. Correlation Analysis of Key Environmental Challenges

A Spearman's correlation analysis was conducted to examine relationships among key challenge constructs. Table 2 presents the correlation matrix. The results show strong correlations between financial barriers and regulatory issues ($r = 0.70$, $p < 0.01$), suggesting that weak enforcement of environmental policies limits financial investments in sustainable projects. Similarly, knowledge gaps correlate with regulatory issues ($r = 0.65$, $p < 0.01$), indicating that a lack of technical expertise and awareness reduces compliance with green construction standards.

4.3. Discussion of Findings

The findings highlight the systemic challenges hindering environmental sustainability in Ghana's construction sector. This section discusses how these challenges compare with prior studies and whether they confirm or challenge existing theoretical frameworks.

4.3.1. Financial Barriers: High Costs & Limited Incentives

Financial constraints remain the most significant deterrent to sustainability adoption, with a strong correlation ($r = 0.70$) between financial barriers and regulatory challenges, suggesting that weak policy frameworks limit financial investments. High statutory fees, lack of government incentives, and limited access to green financing discourage industry players from adopting eco-friendly construction technologies. These findings align with global studies emphasising the need for financial incentives, such as tax breaks, green bonds, and public-private partnerships, to support sustainability adoption (Darko & Chan, 2018). Comparatively, countries like South Africa and Nigeria have implemented green finance initiatives that have boosted sustainability adoption in their construction sectors (Osuizugbo *et al.,* 2020). Ghana's industry can benefit from similar government-led funding programs, tax credits, and sustainability-linked loans to reduce financial barriers and enhance investment in green construction.

Table 2: Correlation Matrix of Key Environmental Challenges
(Spearman's correlation coefficients, N = 275)

Variables	Financial Barriers	Regulatory Issues	Knowledge & Awareness Gaps	Infrastructure & Materials
Financial Barriers	1.000	0.70**	0.55**	0.58**
Regulatory Issues	0.70**	1.000	0.65**	0.62**
Knowledge & Awareness Gaps	0.55**	0.65**	1.000	0.57**
Infrastructure & Materials	0.58**	0.62**	0.57**	1.000

Table 3: Factor Analysis – Key Challenge Constructs

Factor Construct	Factor Loading (≥ 0.50)	Key Challenges Identified
Financial Barriers	0.72	High costs, lack of incentives, and limited financing
Regulatory Issues	0.78	Weak enforcement, absence of industry standards
Knowledge & Awareness Gaps	0.65	Lack of training, limited public awareness
Infrastructure & Materials	0.69	Limited access to sustainable materials, high costs

Method Used: Principal Component Analysis (PCA), Varimax Rotation

4.2. Factor Analysis – Key Challenge Constructs

To further analyse the underlying structure of these challenges, Exploratory Factor Analysis (EFA) was conducted using Principal Component Analysis (PCA) with Varimax Rotation. The results, presented in Table 3, confirm four key constructs. The factor analysis confirms that these four constructs account for most of the challenges faced in environmental sustainability within Ghana's construction sector. The highest loading factor (0.78) on regulatory issues suggests that policy enforcement remains a dominant challenge in sustainability adoption.

4.3.2. Regulatory Issues: Weak Policy Enforcement and Compliance Gaps

The results reveal a strong correlation ($r = 0.65$ - 0.75) between weak enforcement mechanisms and sustainability challenges. Despite the existence of environmental policies, gaps in enforcement hinder compliance. Developers frequently bypass

environmental regulations due to inconsistent policy implementation and the absence of financial penalties. This finding aligns with studies in other developing economies, where policy inconsistencies and weak enforcement mechanisms have been identified as significant challenges to sustainable construction (Ramaswami *et al.,* 2016). However, unlike Ghana, countries like Malaysia and Singapore have implemented strict regulatory enforcement mechanisms that incentivise developers to comply with green building regulations (Low *et al.*, 2014). The findings suggest that Ghana needs policy reforms, sustainability codes, and compliance monitoring to drive environmental responsibility in the construction sector.

4.3.3. Knowledge & Awareness Gaps: Limited Technical Expertise

A notable challenge is the limited knowledge and expertise (r = 0.57) among construction professionals, which significantly hinders the adoption of green construction. Many industry players lack specialised training in sustainable building practices, leading to inefficient implementation of eco-friendly designs. Additionally, public awareness about green technologies remains low, further reducing the demand for sustainable housing. These findings are consistent with global research highlighting the role of education and capacity-building programs in promoting sustainability (Ojo & Ogunsemi, 2019). In contrast, countries like China and Germany have integrated sustainability education into construction training programs, resulting in higher adoption rates of green technologies (Djokoto *et al.*, 2014). To bridge this gap, Ghana's construction industry must integrate sustainability education into its curricula and professional training programs, alongside public awareness campaigns to promote demand for green housing.

4.3.4. Infrastructure & Materials: Accessibility Challenges

Infrastructure limitations exacerbate sustainability challenges, particularly limited recycling infrastructure and the high costs of green materials. The correlation between high material costs and infrastructure challenges (r = 0.52) indicates that limited supply chains force developers to rely on costly imports. This challenge confirms prior studies that have identified inadequate local supply chains as a major barrier to sustainability in developing economies (Anzagira *et al.,* 2024). However, while countries like India and Brazil have invested in local green material production, Ghana remains heavily dependent on imported materials, increasing costs and project timelines (Eštoková *et al.*, 2023). The findings suggest that developing local sustainable material markets, improving waste management systems, and offering subsidies can reduce reliance on costly imports and enhance sustainability adoption.

These findings align with Institutional Theory, which emphasises the role of regulatory pressures, financial incentives, and stakeholder engagement in influencing environmental sustainability practices. The results also support the Resource-Based View (RBV), which highlights that firms with access to financial resources, technical expertise, and infrastructure are better positioned to adopt sustainable practices. However, the findings challenge previous studies that assume regulatory frameworks alone are sufficient to drive sustainability, highlighting the need for a holistic approach that integrates financial incentives, technical training, and infrastructure development.

5. Conclusion and Recommendations

This study identifies key environmental challenges hindering sustainable construction in Ghana, emphasising financial barriers, regulatory deficiencies, knowledge gaps, and infrastructure constraints. High costs and limited financing remain the most significant obstacles, necessitating government interventions such as tax relief programs, green loans, and public-private partnerships. Weak regulatory enforcement and fragmented policies further exacerbate sustainability challenges, highlighting the need for stricter compliance measures and standardised sustainability benchmarks. A lack of technical expertise also hinders green construction adoption, underscoring the urgency for structured training programs and integrating sustainability education into engineering and real estate curricula.

Additionally, the scarcity of sustainable building materials and inadequate waste management systems necessitate investment in local material production and recycling infrastructure to enhance long-term environmental sustainability. Achieving sustainability in Ghana's construction sector requires a convergence of financial incentives, policy enforcement, capacity-building, and infrastructure development. Future research should evaluate the effectiveness of policy interventions, employ Structural Equation Modelling (SEM) to explore causal relationships among challenge constructs, and conduct comparative studies to benchmark Ghana's sustainability efforts globally. Addressing these challenges through multi-stakeholder collaboration will facilitate a transition toward a more resilient, environmentally responsible construction industry.

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Appendix 1

Table 1: Descriptive Statistics on the Key Challenges to Effectively Adopt Environmental Management and Sustainability Practices in the Construction Sector

Statements	Mean	Standard Deviation	N
There is a lack of awareness and understanding of environmental sustainability practices among the construction stakeholders in Ghana.	4.3	0.6	275
The high cost of incorporating environmentally friendly practices is a barrier in the construction industry in Ghana.	4.5	0.5	275
The enforcement of environmental regulations is inadequate in the construction industry in Ghana.	4.2	0.6	275
The lack of standardisation in environmental sustainability practices hinders its adoption in the construction industry in Ghana.	4.4	0.5	275
Inadequate infrastructure limits the implementation of environmentally friendly practices in the construction industry in Ghana.	4.3	0.6	275
Limited access to financing impedes the adoption of environmental sustainability practices in the construction industry.	4.5	0.5	275
There is a lack of technical expertise to implement environmental sustainability practices in the construction industry effectively.	4.2	0.6	275
Most construction professionals lack awareness and understanding of sustainability issues within the construction industry and development.	4.4	0.5	275
The lack of financial incentives discourages the adoption of sustainable construction practices in the Ghanaian construction industry.	4.3	0.6	275
The absence of regulatory support hampers the development of sustainable construction in Ghana.	4.5	0.5	275
There is a lack of incentives for developers to adopt environmentally friendly practices in the Ghanaian construction industry.	4.2	0.6	275
Limited funding and slow policy reforms are challenges towards implementing environmental sustainability in Ghana's real estate.	4.4	0.5	275
The construction industry faces difficulties in acquiring developable land in urban areas in Ghana.	4.3	0.6	275
The lack of clear land titles poses a challenge to environmental sustainability.	4.4	0.5	275
The limited access to long-term and low-cost funding channels.	4.3	0.6	275
There are liquidity issues and piling debt affecting environmental sustainability practices in the Ghana construction industry.	4.4	0.5	275
Higher rates of statutory fees and taxes pose challenges to environmental sustainability in the Ghana construction industry.	4.5	0.5	275
The lack of environmental regulations in the industry contributes to unsustainable practices.	4.2	0.6	275
There is a lack of environmental awareness among stakeholders in the construction industry in Ghana.	4.3	0.6	275
Inefficient building management results in high environmental impact and costs.	4.4	0.5	275
The lack of sustainable building materials hinders environmental sustainability practices.	4.5	0.5	275
The lack of data on energy consumption, water usage, and waste management is a challenge towards achieving environmental sustainability in the construction industry.	4.2	0.6	275
The lack of standardised environmental management systems affects the construction industry in Ghana.	4.3	0.6	275
Construction professionals lack awareness and expertise in environmental sustainability issues.	4.4	0.5	275
The adoption of green building practices is limited in the construction industry in Ghana.	4.5	0.5	275
The Ghana construction industry lacks effective environmental policies and regulations.	4.3	0.6	275
Overall	**4.35**	**0.55**	**275**

Min = 1, Max = 5
Source: Authors's computations, SPSS, 22.

Min =1, Max = 5
Source: Author's computations, SPSS 22.

Sustainable Construction Policy Constraints in Nigeria: Stakeholders' Perspective

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Abstract

This study aimed to understand the policy challenges stakeholders face in implementing sustainable construction practices in the Nigerian construction industry. The research aim was achieved through the literature review and semi-structured interviews conducted among eleven built environment professionals in both Lagos and Abuja cities. Thematic analysis was done using NVivo 14, which resulted in seven themes. The findings reveal that there is a need for improved regulatory policy for sustainable construction with strict implementation. Adequate awareness before the enforcement of this policy is stressed. Results also advise that to obtain the maximum result in the application, the government, policymakers and professionals should effectively synergise on innovation and improved policy adaptation mechanisms for the industry. The study is of value to researchers within the built environment as it provides insights into the Nigerian construction industry's policy formation and implementation challenges, especially in relation to sustainable construction practice.

Keywords: Policy implementation, professionals, stakeholders, sustainable construction.

1. Introduction

Policy emerges from decision-making activities and serves as a framework for achieving societal goals. Public policies are designed to guide decision-making through a structured system of principles and plans to attain intended outcomes (Babalola et al, 2024). As a strategic roadmap for action, governance bodies typically adopt policies to prevent adverse effects or drive improvements. The effectiveness of policymaking is crucial to the strength of government authority and the overall stability of a nation (Isang, 2023).

Monetary and non-monetary costs can be significant when policies fail or remain unimplemented. In the construction sector, policies consist of regulations established at the national level to ensure proper governance and implementation within the industry (Hudson, Hunter, & Peckham, 2019). These regulations, enshrined in legal documents, serve to standardise construction practices, enhance industry performance, and safeguard public well-being by setting precise requirements for practitioners and stakeholders (Akadiri, Chinyio, & Olomolaiye, 2012). Governments have the overall responsibility to kick-start expected changes and developmental moves with the formulation and development of action plans, legal frameworks or strategies to encourage the application of appropriate standards and procedures upon which implementation and performance can subsequently be measured (Babalola et al, 2024). It is believed that unless pressured, the construction industry will not upgrade and implement required changes, as it has been adjudged as one with a low response rate to change and innovation (Babalola et al, 2024). Construction professionals and the public must understand and realise the advantages and benefits inherent in an improved built environment.

The Nigerian construction industry, although robust, shows signs of malaise. This is evident in its poor construction output, incidents of building collapse and the low implementation of sustainable construction initiatives (Babalola et al, 2024). This study aimed to understand the policy challenges stakeholders face in implementing sustainable construction practices in the Nigerian construction industry. Policies compel professionals and stakeholders to practice sustainable construction as a standard instead of relying on individual knowledge bases.

2. Literature Review

2.1. Sustainable Construction in Nigeria

The Federal Republic of Nigeria is a West African country with about 923,770 square kilometres, and about 1.4% of its land is water. Nigeria has a population density of 1,442 per square kilometre. Nigeria has a federating unit, thirty-six states and 774 local government headquarters (Federal Republic of Nigeria, 2006). This large size poses a problem of adequate coordination; as such, clear policies and clear policy implementation strategies should be a priority.

The Nigerian construction industry policy development initiatives are still at a very early stage and are just evolving compared with other developed nations (Oyewobi & Jimoh, 2022; Onuoha et al., 2017). It was noted that while ample literature exists on green building, the focus is not on developing green building policies and skills in Nigeria, as the effective

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underlying policies are lacking. Onuoha et al. (2017) realised that the perceived inadequacies in the Nigerian young green building industry are challenges to formulating and implementing policies and programmes for sustainable construction in Nigeria.

The government sets the environmental rules for every trade, and the lack of legislation and policy is an extreme barrier to the implementation of sustainable construction practices, specifically in the Nigerian property development industry (Oyewobi & Jimoh, 2022). The government's silent encouragement of old practices through a lack of innovative trends in the industry and the non-usage of sustainable practices in government offices and on government projects are amongst other barriers that have far-reaching consequences (Oribuyaku, 2015).

Davies and Davies (2017) and Oyewobi and Jimoh (2022) caution that there are gaps in all aspects of construction practice regarding sustainable construction, advocating that it should be brought into the industry through training and academics. Government policies should generally favour sustainable construction and energy savings, knowing the impacts of both construction and living on the citizenry's quality of life (Isang, 2023). Usually, if implemented, these policies should help the built environment become safer to work in, more efficient due to the frameworks and desired strategy, and sustainable in terms of efficient service delivery to its clients (Akadiri et al., 2012).

Presently, there are no such policies, regulations, professional councils, or bodies to enhance knowledge in the sustainable construction domain and generally promote socio-economic and environmental sustainability (Isang, 2023). Despite several efforts to address the gap policies pose, such as the Global Environmental Forum (GEF) in 2011 (Atanda & Olukoya, 2019) and the Building Energy Efficiency Codes (BEEC) in 2018 (Geissler, Österreicher and Macharm, 2018), not much has been achieved within the Nigerian construction industry.

With regards to extant laws on environmental protection and the need for newer laws, Nwokoro and Onukwube (2015) noted that the advancement and fortification of municipal bye-laws for some major critical urban communities in Nigeria ought to be supported and energised because of their vital level of development. While Governments are responsible for nurturing the economy, they must drive corporate sustainability through legislation and benefits/penalties (Isang, 2023).

Teething problems associated with implementing new initiatives in an existing industry, such as the need to improve technical know-how and skills on sustainable construction, low awareness and insistence on sustainable construction techniques on sites and during construction processes by clients and enlightened professionals and lack of adequate expertise are perceived as barriers to adequate implementation of sustainable construction from the industry stakeholders' perspective (Bungwon et al., 2018), these can be controlled with adequate policies being implemented as argued by (Goh et al., 2020). Most of these barriers are believed to be adequately overcome by adequate policies.

Policies, regulations and professional guidelines on sustainable construction and development should be taken very seriously by the government, as the consequences of not being proactive in this regard are dire (Davies & Davies, 2017). In Nigeria, the lack of sustainability in construction projects is visible, as there are still apparent deviations from ideal sustainability dictates and principles. Infusing these principles is vital to improving the construction environment in Nigeria to avoid further building collapses and enhance capital and economic growth (Isang, 2023).

2.2. Status of the Nigerian Building Code

Building codes establish the fundamental regulations for construction quality, with area-specific bylaws strengthening requirements in urban centres. Such codes are the foundation for all construction policies in developed nations like the United Kingdom (Gibbs & O'Neill, 2015) and Denmark (Drysdale, Mathiesen, & Paardekooper, 2019). However, the building code in Nigeria lacks regulatory backing and is rarely implemented in practice (Geissler et al., 2018).

There is an urgent need to revise and strengthen the Nigerian Building Code to support sustainable construction. Critics argue that the code lacks enforcement power and has low implementation rates (Ogunbiyi, 2014). While the code sets minimum standards for construction, its application begins at the local government level through the Building Code Advisory Committee (BCAC) (Federal Republic of Nigeria, 2006). Some scholars propose that sustainable construction should be driven at the municipal level (Babalola et al, 2024). However, the Nigerian building code has not been adequately empowered to establish minimum infrastructure requirements. Moreover, inconsistent professional adoption has led to uneven implementation across the industry (Isang, 2023).

Nigeria was registered as a prospective World Green Building Council member in 2014 (WGBC, 2018). There is no active green building council to further these interests and advise the construction clients appropriately on sustainable construction (Babalola et al, 2024). This lack of an active green building council has adversely affected the growth of sustainable construction practices in the Nigerian construction environment. Nigeria currently does not have a construction strategy/ agenda. Firms and professional

institutions only work according to client requirements and organisational preferences.

3. Research Methodology

This study adopted an interpretive approach, utilising semi-structured interviews with construction industry professionals. The target sample included architects, quantity surveyors, builders, civil engineers, and urban planners in Nigeria. Participants were selected to ensure diverse representation, as each profession brings unique perspectives on sustainable construction. Achieving this diversity was essential for capturing a comprehensive view of the industry's challenges and opportunities.

To ensure validity, professionals were chosen based on their years of practice and depth of experience in sustainable construction. Experience was a key criterion, given the study's focus on policymakers and senior industry personnel. A purposive list of fifteen participants was initially identified in Abuja and Lagos, with invitations sent via email and phone calls. Ultimately, eleven professionals agreed to participate, and eleven interviews were conducted. This sample size was deemed sufficient, aligning with Tracy's (2012) recommendation of 10 to 12 interviews for qualitative research. Due to the small sample size, the findings of this study cannot be generalised.

Abuja and Lagos were selected due to their status as the country's administrative and commercial capitals and their high concentration of construction professionals due to urbanisation. Interviews were conducted in the office and open spaces during work hours, with each session averaging forty-five minutes. The interviewee profiles are summarised in Table 1.

4. Findings and Discussion

Results obtained were multi-coded using NVivo 14. Responses were transcribed and coded under likely themes. Seven themes emerged, namely: the perception of professionals on sustainable construction practice in their location and the country generally, the significant challenges observed to the complete uptake of sustainable construction in the Nigerian construction industry, the interviewee's perception of the usage of the Nigerian building code, their ideas on improving sustainable construction practice through a policy, the need for strict policies and implementation mechanisms, stakeholder's inputs to improve sustainable construction practice and the possibility and capacity of the local government in the implementation and enforcement of sustainable construction policy. These are discussed below:

4.1. Perception of sustainable construction practice

Respondents agreed that the practice of sustainable construction is low in the locations (Abuja and Lagos) and practically non-existent in other parts of the country. "*Being a new concept, the level of practice is very low; in Lagos, for example, you can count the number of houses built with sustainable materials"* Participant 10. This non-existence was occasioned by the fact that there are no existing policies to control the actions of stakeholders in the construction industry. "*More needs to be done about sustainable construction on the level of policies and adequate implementation*", Participant 2. Respondents believed that the political will to affect the existing environmental laws was lacking. "*The level of sustainable construction practice is very low even in Lagos, which hosts most construction activities in the country,*" Participant 8. In the cities where there is some evidence of sustainable construction, it is due to these areas' population and Urbanisation rate and the level of challenges these have posed to residents. This is in line with the literature, wherein Ogunbiyi (2014) and Onuoha et al. (2017) identified the level of sustainable construction practice as low.

4.2. Major challenges to the complete uptake of sustainable construction

Respondents were then requested to assist with perceived significant challenges in implementing sustainable construction in the Nigerian construction industry, especially in their location. Results were generated into four sub-themes, as discussed below.

Bungwon et al. (2018) identified a lack of awareness and adequate training as part of cultural enshrinements expected to improve knowledge of sustainable construction within the industry. The lack of adequate awareness was also confirmed in this study. Sensitisation and training were advocated to introduce people within and outside the industry to the basic knowledge and benefits of sustainable construction practices.

Lack of policy enforcement and educational issues were highlighted by Davies and Davies (2017) in the literature as a key challenge. Participant 7 indicated that the absence of a government-laid-down plan or strategy

Table 1: The demographic details of the participants

Interviewee	Profession	Age	Gender	Qualification	Years of Experience	Place of work
Participant 1	Architect	>50	Male	Masters, PMP, FNIA	30	Federal Govt. Agency, Abuja
Participant 2	Architect	>50	Male	Masters, MBA, FNIA	25	Private Practice, Abuja
Participant 3	Civil Engineer	45 -50	Male	MSc, MNSE	30	Govt. Agency
Participant 4	Builder	45- 50	Male	MSc, FNIOB	30	Building Control Agency, Abuja
Participant 5	Quantity Surveyor	40-45	Male	MSc, FNIQS	20	Govt Agency, Abuja
Participant 6	Quantity Surveyor	40-45	Male	MSc, MNIQS	15	Private Practice, Abuja
Participant 7	Builder	35-40	Male	MSc, MNIOB	13	Private Practice, Lagos
Participant 8	Civil Engineer	45-50	Male	BSc, MNSE,	20	Private Practice, Lagos
Participant 9	Urban Planner	35-40	Female	BSc, MNITP	15	Local Govt. Municipal office in Lagos
Participant 10	Quantity Surveyor & Lecturer	50-55	Male	PhD, MNIQS	21	Private Practice & Academic
Participant 11	Quantity Surveyor	45-50	Female	MSc, MNIQS, PMP	24	Project Mgt Firm

Key: FNIA - Fellow of the Nigerian Institute of Architects
MNIQS – Member, Nigerian Institute of Quantity Surveyors for the quantity surveyors
MNITP – Member, Nigerian Society of Urban (town) planners
MNIOB - Member, Nigerian Institute of Building
MNSE – Member, Nigerian Society of Engineers

for stakeholders to follow is challenging. The Nigerian construction industry lacks strategic short-term and long-term goals concerning sustainable construction. Hence, there is a gap as knowledge of sustainable construction is not even taught to incoming professionals.

The incoming professionals need to start learning experientially as it relates to the organisational ethos of the individual companies they work with; this is not ideal. The lack of current policy enforcement was a typical comment by participants 2, 5 and 11, and it is a key barrier. It was noted that although the enforcement mechanism of the industry is currently non-existent, no practising professional wants to be seen as being on the wrong side of the law, so if the policy is actively put in place with necessary enforcement mechanisms, the likelihood of success is high.

The lack of adequate and sustainable building codes emerged as a challenge. There are problems with enforcing the existing building code, as stated by Participant 1, and formulating a new sustainable building code is not exactly forthcoming unless underlying issues with the non-performing building code are resolved (Participant 10). These underlying issues include the lack of teamwork and harmony among professional institutions in the country, the lack of a coordinating agency/board for all professional institutions, and the lack of monitoring and regulatory agencies for contractors and subcontractors within the industry. Oribuyaku (2015) and Ogunbiyi (2014) mentioned the lack of enforcement of the code in the literature.

Lack of 'Political will' by the government. The general perception of the lack of political will from the government to get things done within the industry and economy at large was not distinctly identified in the literature. However, it is identified from the field interview. Participant 2 stated that ''*it is the lack of political will to get things done that encourages corruption and a lukewarm attitude within the industry*.'' Participant 6 responded, ''If the government wants something implemented, it gets implemented and 'political will' is essential to implementing *policies in a democracy"*.

4.3. Status of the building code

The building code was generally accepted not to be in full active use except in cities where it was minimally

utilised. This comatose state of the building code agrees with the views and concerns raised by Ogunbiyi (2014).

Various reasons were highlighted for its non-performing status, including its status as a regulation versus an enforceable law, as offenders of the building code generally go unpunished. "*There may be building codes in Nigeria, but implementation is limited only to major projects and urban developments*," Participant 8. Participant 4 stated, "*Not adhered to, because it is not a law. Resistance even from other relevant bodies within the industry (Planners and Architects)*." "*The code is good, but theoretical without the ability to act. Also, personal and professional interests hinder the implementation*," Participant 5. Participant 11 expressed frustration by stating, "As *of now, the building code has many lapses. Some professionals (especially engineers) in the construction industry refused to adopt it because they felt they did not contribute to its content*."

4.4. Improving sustainability in the Nigerian construction practice

Outcomes from this theme were coded into professional and government inputs to capture the efforts needed to ensure sustainable construction.

Government inputs: The government's focus on sustainable construction must be clear and not change with a change of power. Also, policies on tax subsidies, reducing costs, and discouraging importation are primarily in the purview of the government. "*Subsidies and reduced costs, discouraging importation and allowing local research and production to grow, Research aimed at commercial production by the Government.*" Participant 1. The government must also allow local research and production to grow through commercial production and embrace cultural sustainability, which requires a serious and consistent approach. Awareness, training and retraining of policy implementers within the industry and a general orientation are also needed on the part of the government to ensure sustainability is 'homegrown' within the industry. "*We need to make sustainability a way of life, culturally, and teach it in schools. It requires a lot of seriousness and consistency,*" stated Participant 2.

Professionals' inputs: For the professionals and the professional institutes, improvements through awareness, training, upholding professional standards, artisanal training, and inputting sustainable construction deliverables from the design stage are envisaged. Local research on adaptation and enhancing the use and development of alternative building materials is also key, as noted by Bungwon, Dabo, and Ishaya (2018). "*Research and Development on improved and enhanced alternative building materials and development generally"*, Participant 1.

4.5. The need for strict regulations and policies for SC practice

Outcomes from this theme were unanimous in specifying that strict regulations are essential for the Nigerian construction industry. Strict policies and consistent regulations on sustainable construction and punitive measures for defaulters were stressed by almost all the respondents in the interview sessions. "Y*es, People must know there are consequences for their actions and inactions. People do things because they know they will get away with it. We need to be consistently strict*," Participant 2. Construction processes generally must be improved within the Nigerian construction industry. All the participants agreed that unlawful actions must have consequences in line with the government's plans for the industry. People tend to fear the law and ordinarily do not want to obstruct laid-down principles, as they know the consequences of doing so.

However, adequate training and orientation of the general public must be carried out before the regulations come into full force. This is to ease the implementation phase and achieve some policy legitimacy when the policies are being applied.

4.6. Input of stakeholders to drive sustainability

The contributions expected from stakeholders to drive sustainability in the Nigerian construction industry are as follows:

Professional Institutes and Professionals

Professionals must uphold high standards in their practices and provide well-informed advice to clients. Additionally, interdisciplinary research within the industry and firmer collaboration among professionals are encouraged. Professional institutes must take greater responsibility by engaging in research, increasing public awareness, and fostering synergy among fellow professional bodies.

Government as a Stakeholder

The government plays a critical role in policy creation for the industry, as emphasised in the literature (Akadiri et al., 2012; Ojo et al., 2014). Raising awareness and increasing publicity efforts are essential, as contractors and other industry practitioners look to the government for guidance and patronage. Furthermore, investment in research and development is necessary to ensure effective policy adaptation. As noted *by Participant 4, this will prevent situations where "policies are not just lifted from Europe and other developed nations*" without proper consideration for Nigeria's unique context.

Clients and End-Users

Clients must be made aware of the benefits of sustainable construction, particularly how it impacts their quality of life and overall comfort. Greater

awareness is expected to influence client demands, which, in turn, will shape construction outputs.

Other Stakeholders
Actors such as developers must comply with the industry's minimum standards, ensuring adherence to regulations throughout all stages of construction. Coordination among all industry players is crucial to achieving sustainability goals. However, as Participant 6 observed, "*Developers in the Nigerian construction industry are mostly profit-driven and, as such, have reserved regard for quality delivery*."

4.7. Implementation of Sustainable construction through the municipality

Local government is best suited as the starting point for implementing sustainable construction (Davies & Davies, 2017), as local governments are closer to the people and spatially cover the whole country. However, the current capacity of the local government to handle the implementation of sustainable construction, given its inadequate staffing and ineffectiveness, was doubted, as they have not been active. "*Yes, if the local level can be active, it will greatly reduce the negative effects at the federal level, but it is currently the weakest unit of government*." Participant 2. "*Local government is best suited, but the capacity could be a challenge right now*'' Participant 1. Also, the fact that they can be easily compromised was raised because they are easily exposed to bribery and corruption. "T*hey are corrupt; they compromise easily. They are also not adequately motivated to carry out the enforcement. They are poorly remunerated, so they are exposed to the temptation of bribery and corruption*, according to Participant 11. To successfully implement sustainable construction through this route, adequate measures should be implemented to face the concerns raised.

5. Conclusion and Further Research

This study investigated the policy challenges stakeholders face in implementing sustainable construction practices in the Nigerian construction industry. The findings emphasise the need for active regulatory policies, an improved building code with enforcement mechanisms, and stronger stakeholder collaboration, which is currently lacking.

The study stressed that the government's political will is crucial, including professional involvement in policy discussions. While sustainable construction exists at individual levels, a clear regulatory framework hinders widespread adoption. Strict policies are necessary, but should be implemented with adequate stakeholder training. Local government involvement offers potential but is limited by a lack of trained professionals. Capacity building is essential for effective policy execution.

Addressing these challenges will require a coordinated effort among government agencies, industry professionals, and other stakeholders to create a sustainable construction framework that is both practical and enforceable. Without decisive action, the Nigerian construction industry risks lagging in global sustainability efforts, impacting environmental and economic progress.

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Barriers to Effective Construction Waste Reduction: A Study of Contractors in The Eastern Cape Province, South Africa

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Abstract

In the Eastern Cape Province, construction projects generate massive amounts of solid waste that pose a threat to environmental sustainability and resource efficiency. This study aims to identify the obstacles Eastern Cape Province contractors have in effectively cutting construction waste. The study employed a quantitative research approach, and a questionnaire survey was used to examine the challenges of minimising construction waste. Descriptive and inferential statistics were applied in data analysis. Principal factor analysis indicated that there are seven significant factors with eigenvalues greater than one that affect contractors' capacity to minimise waste: insufficient communication for waste reduction, poor access to recycling facilities, inappropriate on-site reusing of materials, no zero-waste philosophy, failure to identify near-on-site recycling facilities, inadequate waste management equipment, and inability to trace on-site-produced waste. The findings offer valuable insights into the challenges faced by contractors in the Eastern Cape in reducing construction waste. These findings will help industry professionals, policymakers, and contractors develop targeted solutions, design effective training programmes, and adopt best practices to promote sustainable construction, reduce waste, and lower costs. The primary aim of this research is to span the knowledge gap in understanding the waste minimisation problems faced by contractors in the Eastern Cape, a province with unique socioeconomic and infrastructure challenges.

Keywords: Construction waste, Waste reduction plans, Recycling facilities, Waste management, Sustainable procurement strategies.

1. Introduction

Construction has a significant detrimental impact on the environment due to building waste, despite being a significant contributor to economic expansion (Purchase *et al*., 2021). Das *et al*. (2019) state that waste reduction in the construction industry has become a critical concern as attention shifts globally to sustainability. However, even with increased awareness and improved eco-friendly building practices, contractors face numerous challenges in controlling and reducing waste (Udawatta *et al*., 2015). These barriers include insufficient facilities for accessing recyclables, financial matters, poorly implemented waste management systems, and inadequate training on sustainable practices for employees (Al-Otaibi *et al*., 2022). In addition, inconsistent rules, variable recycling service charges, and client requests for cost reductions all make it more challenging to implement effective waste reduction plans (AlJaber *et al*., 2023).

The problem, therefore, persists in that contractors face continuous barriers in reducing construction waste that is harmful not only to the environment but also to increased project costs and reduced opportunities for material recovery and recycling (Ajayi & Oyedele, 2018). Lack of awareness, inadequate infrastructure, and the need to weigh the long-term advantages of waste reduction against the immediate cost savings all contribute to this problem (Hasmori *et al*., 2020). It is for this reason that this study seeks to address the following research question:

What are the key barriers faced by contractors in the Eastern Cape Province in implementing effective construction waste reduction practices?

This study aims to fill a gap in the existing methods of waste management by determining the major barriers that contractors face in trying to minimise construction waste and by offering practical solutions to overcome such challenges. While sustainable building practices have been researched in the past, very little attention has been paid to the specific barriers contractors face in the full implementation of waste reduction measures (Adetooto *et al*., 2024; Masia *et al*., 2020). The study's analysis of these issues and identification of areas in urgent need of growth contribute to the growing body of research on sustainable construction techniques. The following sections include a literature review relevant to the study, the research methodology used in the study to meet the study objectives, the analysis and discussion of results, and the conclusions and recommendations.

2. Literature review

2.1. Construction waste management

Construction waste management is essential for promoting sustainable practices in the construction

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industry, focusing on minimising waste generation and maximising resource recovery. Key strategies include waste reduction, reuse, recycling, and proper disposal to mitigate environmental impact (Dosumu & Aigbavboa, 2019). According to Ajayi and Oyedele (2018), effective waste management not only reduces environmental harm but also lowers project costs by improving overall efficiency. However, Nyika *et al*. (2019) highlight that poor planning and insufficient stakeholder awareness exacerbate waste-related issues in South Africa's construction industry. These challenges underline the need for theoretical frameworks that guide more efficient and sustainable waste management practices.

2.2. Underpinning theories

To address the challenges of construction waste management, theoretical approaches such as lean construction and the circular economy offer valuable insights. The circular economy promotes the reuse and recycling of resources, creating closed-loop systems that minimise waste and maximise resource efficiency (Geissdoerfer *et al*., 2017). In contrast, lean construction focuses on reducing material waste and optimising processes to enhance overall project efficiency (Al-Otaibi *et al*., 2022). By integrating these theories, contractors can better understand how inefficiencies in the construction process and linear waste management strategies contribute to waste generation. These theoretical foundations provide a basis for improving design, material selection, and construction procedures, ultimately helping to reduce waste and promote more sustainable practices (Mbote *et al*., 2016).

2.3. Barriers to construction waste reduction

The main challenges that Eastern Cape Province is facing in achieving effective reduction of construction wastes are a lack of clear goals about waste reduction, a lack of appropriate training, and a scarcity of recycling facilities (Godfrey & Oelofse, 2017). Major logistical issues which contractors often face in managing wastes include an inadequate infrastructure for segregating and recycling wastes and an inadequate storage area on site (Oelofse & Nahman, 2013). According to Wilson *et al*. (2017), financial obstacles also make it challenging to embrace waste reduction strategies, such as waste management systems and the purchase of sustainable materials, which are expensive endeavours. Godfrey and Oelofse (2017) add that effective waste management adoption is also hindered by behavioural and cultural factors such as disinformation and resistance to change.

2.4. Policy and legislative context

Construction waste management in South Africa is governed by the National Environmental Management Waste Act, No. 59 of 2008. This act emphasises minimisation, reusing, and recycling. It provides the basis for effective, sustainable waste management and empowers the local authorities to enforce such in respect of waste management. However, most policies are not fully effective due to enforcement issues, lack of resources, and uncoordinated players (Nyika *et al*., 2019). Nahman (2021) suggests incorporating clear guidelines for contractors, giving financial and technical support, and providing incentives for compliance.

2.5. Contractors' role in waste management

Contractors play a crucial role in waste management at construction sites since they are responsible for implementing waste reduction strategies at the sites. Ong and Pheng (2021) note that contractors contribute a great deal to waste generation and waste disposal in their decision-making on the procurement of materials, waste segregation, and optimisation of processes. Liu *et al*. (2020) emphasise that those contractors applying sustainable practices, including materials recycling and optimisation of construction methods, significantly contribute to waste reduction efforts. Alazmi *et al*. (2025) indicated that most of these strategies are limited in their real-world effectiveness by information gaps, competing priorities, and financial constraints. Kabirifar *et al* (2020) demonstrated that contractors could be offered clear rules, financial incentives, and training to increase the sustainability of effective measures against waste management.

3. Research Methodology

3.1. Research design

This study employs a **quantitative research approach** using a structured survey questionnaire to examine barriers to construction waste reduction among contractors in the **Eastern Cape Province, South Africa**. The questionnaire was designed on a **five-point Likert scale** to capture contractor perceptions. **Descriptive statistics** and **Principal Factor Analysis (PFA)** were used to identify and categorise key barriers (Ravid, 2024; Sürücü *et al*., 2022).

3.2. Population and sample size

The study targeted **cidb Grades 5–9 contractors** registered in the Eastern Cape, giving a total population of **228 contractors. Purposive sampling** was applied to select **201 key professionals, including project managers, quantity surveyors, construction managers, site agents, health and safety managers, and site technicians** directly involved in construction waste management.

A **95% confidence level** and **50% assumed population proportion** yielded a required sample size of **144 respondents**, as per (Mutisya *et al.,* 2017). A total of **105 completed responses** were received, representing a **52.2% response rate**, which is deemed acceptable for survey-based research (Ong et al., 2020).

3.3. Data collection

The survey questionnaires were email-administered between 15 October 2023 and 24 November 2023, accompanied by a consent letter ensuring confidentiality and voluntary participation. The questionnaire comprised Section A, which collected demographic details such as age, gender, qualifications, profession, experience, and cidb grade, and Section B, which addressed construction waste reduction challenges. Section B was measured on a five-point Likert scale, with responses ranging from 1 (Unsure) to 5 (Strongly Agree).

3.4. Data analysis

Data was analysed using SPSS Version 29, incorporating descriptive statistics for respondent profiles, including frequencies and percentages. Mean ranking was used to determine the relative importance of barriers (Pallant, 2020), while standard deviation assessed response variability (Creswell & Creswell, 2017). Cronbach's alpha was applied to test reliability, with a threshold set at 0.70. Principal Component Analysis (PCA) was conducted to consolidate key barriers, retaining components with eigenvalues greater than 1 (Pallant, 2020).

4. Findings and Discussion

4.1. Demographic profile of the respondents

The survey included 229 respondents, with 53.3% being men. The majority of respondents (69.5%) were between the ages of 26 and 39. The highest proportion of respondents held a bachelor's degree (46.7%). The largest group of respondents were quantity surveyors (58.1%). Most respondents (81.9%) had 0 to 5 years of relevant experience. In terms of cidb grading, the highest proportion of contractors was in Grade 5 (46.7%).

4.2. Ranking construction waste reduction barriers experienced by contractors

Table 1 (Appendix 1) presents the results on the barriers to construction waste reduction faced by contractors. The highest-ranked barrier was the lack of waste reduction plans (MV=4.26), with 81.9% of respondents agreeing that this is a significant challenge. A moderate level of agreement was shown by 12.4%, while 2.8% were unsure and 2.9% disagreed. The second-highest ranking barrier was the lack of education on waste reduction (MV=4.24), with 81% of respondents agreeing, and 16.2% showing a moderate position. In contrast, 2% disagreed, and only 0.8% were unsure. The lowest-ranked barrier was 'Fear of project delays due to waste reduction initiatives' (MV=3.82), with 69.5% agreeing that it is a concern. However, 14.3% were moderate, 10.5% disagreed, and 5.7% were unsure. Since all the mean values are greater than 3.00, the mean value of 4.08 suggests a high degree of agreement or relevance in the evaluated elements. The difficulties that have been identified are typically deemed significant by the respondents.

4.3. Underlying barriers experienced by contractors

This study adopts factor analysis to identify barriers experienced by contractors related to the reduction of construction waste in construction sites. Evidence from Table 2 (Appendix 1) shows that a total of 30 barriers experienced by contractors were examined to identify key barriers. The sample was judged suitable for factor analysis since its Kaiser-Meyer-Olkin (KMO) value of sampling adequacy was 0.834, which is more than 0.60. Furthermore, the chi-square value of 1631.370 and the significance level of 0.001 of the Bartlett's test of sphericity verify that the correlations between the variables are sufficiently high to support component analysis. Factor analysis is acceptable when the variables are connected, as indicated by a statistically significant Bartlett's test ($p < 0.05$) (Pallant, 2020). Seven (7) meaningful components with eigenvalues greater than 1.0 were revealed by principal components analysis factor extraction with varimax rotation, after examining 30 construction waste reduction. These components account for a cumulative variance of approximately 72.37%. Specifically, factor one explains 45.97% of the variance; factor two, 5.80%; factor three, 4.59%; factor four, 4.39%; factor five, 4.11%; factor six, 3.88%; and factor seven, 3.63%. Except for a few suppressed variables with values less than 0.30, multiple strong loadings on the component matrix are displayed. Field (2013) suggests that factor loadings below 0.30 should be suppressed, since such low values indicate that the factor accounts for less than 10% of the variance in the observed variable, rendering them less meaningful for interpretation.

Table 2 presents variables that are appropriate for components; this is indicated by a positive relationship between seven (7) components. The variable that are enclosed on Component 1 signifies "*ineffective communication regarding waste reduction*", Component 2 signifies *"limited access to recycling facilities"*, Component 3 signifies *"improper reuse of materials on-site"*, Component 4 signifies *"there is no zero-waste culture in the construction worksite"*, Component 5 signifies *"identification of nearby recycling facilities"*, Component 6 signifies *"the use of Inadequate equipment"* and Component 7 signifies *"facing difficulties in tracking waste on site"*.

5. Discussions of principal factor analysis findings

Component 1: Ineffective communication regarding waste reduction comprises several factors that highlight key barriers to efficient waste management. The first two factors are **ineffective communication regarding waste reduction (0.800)** and **lack of contractors' integrated waste management systems (0.799).**

Effective communication is key for aligning project goals with waste reduction practices (Udawatta *et al*., 2015). Without integrated systems, contractors struggle to implement waste reduction strategies consistently (Ajayi & Oyedele, 2018).

Component 2: Comprises the following barriers. The first two factors are **limited access to recycling facilities (0.527)** and **lack of clear waste reduction goals and targets (0.447).** According to Darko *et al*. (2017), the inaccessibility of recycling facilities discourages contractors from making an effort toward recycling in their operations. The other important barrier is the lack of clear and specific targets regarding waste reduction. Durdyev *et al*. (2018) note that clear and measurable targets guide contractors in waste reduction, while Ajayi and Oyedele (2018) indicate that less frequent monitoring and insufficient enforcement of such goals result in further delays.

Component 3: Includes the following barriers. The first two factors are **improper reuse of materials on-site (0.415)** and **consideration of deconstruction when appropriate (0.397).** Tam *et al*. (2018) observed that inappropriate reuse of materials on-site can be linked to a lack of understanding of appropriate repurposing procedures. Due to the lack of information about successful repurposing, improper reuse often happens. Darko *et al*. (2017) further establish this connection, suggesting that comprehensive waste reduction strategies incorporating material reuse techniques are necessary for proper on-site waste management. Consideration of deconstruction when appropriate is also very important. According to Bao and Lu (2021), deconstruction can reduce waste by increasing on-site material reuse compared to conventional destruction methods. However, Liu *et al*. (2020) caution that deconstruction can be more costly and time-consuming.

Component 4: Comprises the following factors. The first two are **that there is no zero-waste culture on the construction worksite (0.508)** and **choosing material without thorough thinking (0.352).** The absence of a zero-waste culture on construction sites poses a significant challenge to sustainable waste management practices. Zaman and Lehmann (2011) assert that establishing a zero-waste culture requires comprehensive strategies and commitment from all stakeholders, including clear policies and top-down leadership. However, the development of such a culture is often hindered by a lack of awareness and education regarding the importance of waste reduction (Ajayi *et al*., 2015). The selection of materials without proper consideration contributes to waste generation. According to Purchase *et al*. (2021), most contractors select materials based on cost and availability rather than sustainability, often choosing materials that are not easily recyclable or reusable. Durdyev *et al*. (2018) indicated that this lack of awareness of alternatives leads to inefficient material selection.

Component 5: Comprises the identification of nearby recycling facilities (0.454) and the fear of project delays due to waste reduction initiatives (0.334). Access to recycling facilities is important for contractors to recycle materials rather than dispose of them improperly. Gharfalkar *et al*. (2015) noted that this ensures that construction waste is recycled in a timely and inexpensive manner. According to Portny and Portny (2022), source separation on crowded building sites is difficult due to a lack of space and a shortage of bins. Contractors may be concerned that waste management practices such as separation and on-site recycling of materials will delay operations or increase workload. These issues, as stated by Zaman and Lehmann (2011), are compounded by the absence of effective waste reduction procedures that further discourage contractors from practising sustainability. Ajayi *et al*. (2015) have stressed that such delays can be avoided and efficiency ensured without compromising on environmental goals by training the employees and integrating waste management into the project process.

Component 6: Includes the following factors. The first two are the **use of inadequate equipment (0.468)** and **disregard for sustainability practices (0.330).** Using inadequate equipment in construction projects leads to inefficient waste handling and processing, increasing waste volumes and project costs (Ali *et al*., 2010). Galvez-Martos *et al*. (2018) argue that when equipment not designed for effective waste management is used, it worsens the environmental impact, particularly when sustainability practices are disregarded. Kabirifar *et al*. (2020) further emphasise that promoting the use of sustainable equipment and practices would help reduce waste and preserve the environment.

Component 7: Comprises the following factors. The first two are **obstacles of waste tracking at the site level (0.502)** and **inadequate waste tracking and reporting systems (0.371).** Tam *et al*. (2018) illustrated that the incompetence of waste monitoring systems has made on-site waste tracking complicated for contractors, which is a core factor in reducing waste and enhancing recycling operations. These inadequate methods limit the identification of areas for improvement, as they generate inexact data regarding creation and disposal, constraining practical projects for waste reduction implementation (Nawaz *et al*., 2023).

6. Conclusion and Further Research

The study identified the significant barriers to the effective reduction of waste included poor communication about waste reduction, lack of access to recycling facilities, ineffective on-site material reuse, having no zero-waste culture available, difficulty finding appropriate recycling options within proximity,

not having good machinery in order to manage waste, and not being able to track on-site generated waste effectively. These add significantly to the woes of contractors in reducing construction waste and have a direct impact on environmental sustainability and resource efficiency. The study has highlighted that clearly stated goals regarding waste reduction, along with a proper tracking system and education and training for contractors, would improve the management of waste at the construction site.

While this study has contributed to the present pool of knowledge, there are many further lines of investigation. Subsequent studies could examine specific waste management policies and strategies that have been implemented at national or regional levels in South Africa to assess their effectiveness. Research might also be directed at the way technology can support better waste management: the use of digital tools for waste tracking, mobile recycling solutions, and real-time reporting systems.

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Appendix 1

Table 1: Barriers experienced by contractors

Barriers experienced by contractors ***N……..105***	**Unsure**	**Strongly Disagree**	**Disagree**	**Moderate**	**Agree**	**Strongly Agree**	**Mean**	**Std.**	**Rank**
Absence of waste reduction plans	2.8	1.0	1.9	12.4	37.1	44.8	4.26	.832	1
Lack of education about waste reduction	0.8	1.0	1.0	16.2	36.2	44.8	4.24	.830	2
Lack of a comprehensive waste management plan	3.9	0.0	1.9	11.4	45.7	37.1	4.23	.733	3
Lack of awareness about waste reduction	2.7	1.0	1.0	14.3	40.0	41.0	4.23	.807	3
Lack of sustainable procurement strategies	9.5	0.0	1.9	12.4	41.9	34.3	4.20	.752	4
Lack of on-site recycling facilities	1.9	0.0	5.7	8.6	43.8	40.0	4.20	.833	4
Improper waste segregation	8.6	0.0	1.9	14.3	41.9	33.3	4.17	.763	5
Ineffective communication regarding waste reduction	3.9	0.0	3.8	11.4	47.6	33.3	4.15	.780	6
Contractors focus on production rather than waste reduction	2.9	1.9	3.8	10.5	43.8	37.1	4.14	.901	7
Implementation of lean construction principles	8.6	0.0	1.9	16.2	41.9	31.4	4.13	.771	8
Limited space for on-site waste sorting and storage	4.8	1.0	4.8	15.2	35.2	39.0	4.12	.924	9
Lack of clear waste reduction goals and targets	4.7	1.0	2.9	14.3	43.8	33.3	4.11	.840	10
Ineffective systems for waste tracking and reporting	2.8	1.0	3.8	12.4	46.7	33.3	4.11	.843	10
Lack of training for contractors and workers	0.0	0.0	4.8	16.2	41.9	37.1	4.11	.847	10
Inadequate waste audits to assess types and quantities	4.8	1.9	2.9	11.4	47.6	31.4	4.09	.866	11
Source separation of waste	3.8	1.9	2.9	16.2	40.0	35.2	4.08	.913	12
Contractors face cost-related hurdles when implementing waste reduction measures	2.8	1.0	0.0	18.1	50.5	27.6	4.07	.748	13
Disregard for sustainability practices	9.5	1.9	1.0	13.3	47.6	26.7	4.06	.823	14
Facing difficulties in tracking waste on-site	2.7	1.0	6.7	12.4	42.9	34.3	4.06	.921	14
Limited space for waste storage	1.9	3.8	2.9	12.4	43.8	35.2	4.06	.978	14

Identification of nearby recycling facilities	3.7	1.0	1.0	18.1	48.6	27.6	4.05	.779	15
Lack of a contractor's integrated waste management system	5.7	1.0	1.9	19.0	42.9	29.5	4.04	.832	16
Improper reuse of materials on-site	1.9	1.0	4.8	13.3	51.4	27.6	4.02	.840	17
Unclear responsibilities for waste management at the construction work site	2.9	1.0	3.8	17.1	49.5	25.7	3.98	.832	18
The use of inadequate equipment	4.8	0.0	7.6	15.2	43.8	28.6	3.98	.887	18
Choosing material without thorough thinking	1.9	1.0	7.6	18.1	37.1	34.3	3.98	.970	18
Limited access to recycling facilities	2.9	1.9	6.7	15.2	43.8	29.5	3.95	.958	19
Consideration of deconstruction when appropriate	10.4	1.0	8.6	13.3	41.9	24.8	3.90	.951	20
There is no zero-waste culture in the construction worksite	2.7	4.8	6.7	14.3	41.0	30.5	3.88	1.084	21
Fear of project delays due to waste reduction initiatives	5.7	3.8	6.7	14.3	47.6	21.9	3.82	1.004	22
Average							**4.08**		

Table 2: Component Matrix on barriers experienced by contractors

Barriers experienced by contractors	**Component**						
	1	**2**	**3**	**4**	**5**	**6**	**7**
C1 Ineffective communication regarding waste reduction	.800						
Lack of a contractor's integrated waste management system	.799						
Contractors focus on production rather than waste reduction	.766						
Limited space for on-site waste sorting and storage	.763						
Contractors face cost-related hurdles when implementing waste reduction measures	.759						
Implementation of lean construction principles	.747						
Lack of education about waste reduction	.735						
Lack of a comprehensive waste management plan	.734						
Inadequate waste audits to assess types and quantities	.671						
C2 Limited access to recycling facilities		.527					
Lack of clear waste reduction goals and targets		.447					
Limited space for waste storage		.436					
Unclear responsibilities for waste management at the construction work site		.377					
Improper waste segregation		.301					

C3 Improper reuse of materials on-site			.415				
Consideration of deconstruction when appropriate			.397				
Absence of waste reduction plans			.348				
Source separation of waste			.306				
C4 There is no zero-waste culture in the construction worksite.				.508			
Choosing material without thorough thinking				.352			
Lack of awareness about waste reduction				.301			
C5 Identification of nearby recycling facilities					.454		
Fear of project delays due to waste reduction initiatives					.334		
C6 The use of inadequate equipment						.468	
Disregard for sustainability practices						.330	
Lack of sustainable procurement strategies						.312	
C7 facing difficulties in tracking waste on site.							.502
Ineffective systems for waste tracking and reporting							.371
Lack of on-site recycling facilities							.303
Lack of training for contractors and workers							.303
Eigen value	13.791	1.739	1.378	1.316	1.232	1.165	1.091
Proportion of variance (%)	45.972	5.795	4.594	4.388	4.108	3.882	3.635
Cumulative variance (%)	45.972	51.767	56.360	60.749	64.857	68.739	72.374
Extraction Method: Principal Component Analysis.							
[a]7 components extracted.							

Nature-Based Solutions and Materials Promoting Net-Zero Construction in South Africa: Trends and Insights from a Bibliometric Review

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Abstract

Buildings contribute 40% of global greenhouse gas emissions, with materials like cement, steel, and aluminium significantly adding to the carbon footprint. The worldwide goal to achieve net-zero emissions from the built environment can be achieved through Nature-based Solutions. NbS leverage ecosystems and their innate services to tackle pressing sustainability challenges, including climate change, energy consumption, energy poverty, and decarbonisation. This study examines the role of NbS and sustainable materials in advancing net-zero construction, emphasising their potential to reshape the industry's traditional approach to environmental and societal challenges. This bibliometric study, conducted using Elsevier Scopus, retrieved 51 documents and later filtered to 30 relevant studies, using the keywords "nature OR based AND solutions AND materials AND net AND zero AND construction." VOS viewer text-mining tool was employed to analyse the data, through cluster analysis identified key themes such as "Innovative Strategies for Decarbonisation and Circular Economy," "Sustainable Building Materials and Carbon Management," "Energy Efficiency and Decision-Making in Sustainable Architectural Design," "Zero-Carbon Strategies in Construction and Housing," and "Embodied Carbon and Sustainability in Construction Supply Chains." The analysis revealed the critical role of nature-based solutions in reducing carbon emissions, optimising supply chains, and enhancing energy efficiency. However, gaps persist in integrating life cycle analysis with nature-based materials and addressing regional disparities in adoption. Limitations include reliance on the Scopus database and quantitative data, excluding qualitative insights for a comprehensive research perspective. This study provides a foundation for advancing sustainable practices and contributes to the growing discourse on environmentally conscious construction strategies.

Keywords: Carbon Footprint, Nature-based Solutions (NbS), Net-Zero Construction, Sustainable Materials, Sustainability.

1. Introduction

Current trends of rapid population increase bring with them an alarming rate of energy demands. The construction industry significantly contributes to global greenhouse gas emissions, accounting for nearly 40% of energy-related emissions worldwide (Mathur *et al.*, 2021). As the most prevalent greenhouse gas (GHG), carbon dioxide (CO2) emissions have become a growing concern for governments worldwide. In recent years, major carbon-emitting nations have formulated strategies and roadmaps to reduce their CO2 emissions, aiming to achieve a carbon-neutral future (Xiao *et al.*, 2023). The construction industry also recognises the need to shift from a traditional linear economy to a circular economy, which offers a more sustainable and restorative approach (Otasowie *et al.*, 2024). This reality has driven researchers and practitioners to explore innovative pathways toward achieving net-zero construction (Frota De Albuquerque Landi *et al.*, 2023; Matthews, 2024; Päätalo *et al.*, 2024). Central to this effort is the integration of nature-based solutions (NbS) and sustainable materials, which promise to revolutionise building practices by reducing carbon footprints and promoting circular economies (Labaran *et al.*, 2024; Saint *et al.*, 2023). This study employs a bibliometric analysis to investigate the role of nature-based solutions in advancing net-zero construction and using Elsevier Scopus as the primary database. VOS viewer text-mining software (version 16) was employed to identify and classify the emerging themes from sequencing cluster analysis in research, including innovative decarbonisation strategies, sustainable material use, energy efficiency, zero-carbon construction methods, and the role of embodied carbon in supply chains. The contribution of this study that sets it apart is its bibliometric approach to uncovering gaps and opportunities within the current body of knowledge. While prior studies have explored aspects of sustainable construction and net-zero targets (Archila *et al.*, 2023; Labaran *et al.*, 2024), this work uniquely highlights the interplay between nature-based solutions and net-zero buildings. The originality of this study lies in its focus on synthesising diverse themes into a coherent framework that underpins net-zero construction efforts. This study further contributes to the growing discourse on sustainable construction practices, underscoring the critical importance of aligning innovative, nature-based solutions with global decarbonisation goals, offering actionable insights for stakeholders aiming to transform the built environment into a more sustainable and resilient industry.

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2. Literature Review

Nature-based solutions (NbS) are sustainable design strategies that leverage natural processes to address environmental, social, and economic challenges, including climate change mitigation and adaptation (Cohen-Shacham *et al*., 2016). In the context of net-zero carbon buildings, NbS incorporates green infrastructure, passive design strategies, biophilic architecture, and ecosystem-based approaches to enhance energy efficiency, carbon sequestration, and climate resilience (Raymond *et al.*, 2017). Nature-based Solutions (NbS) have gained recognition in environmental sciences and construction, offering sustainable strategies to achieve net-zero emission goals. By leveraging natural processes and ecosystems, NbS promotes the development of sustainable infrastructure, enhancing energy efficiency, reducing resource consumption, and mitigating climate impacts. (Chen *et al.*, 2024).

Net-zero energy buildings provide a propitious approach to decarbonisation by reducing energy consumption and enhancing renewable energy integration (Hadba *et al*., 2024; Matthews, 2024). As net-zero targets become more stringent, NbS provides a cost-effective and regenerative pathway to achieving sustainability goals in the construction industry (Seddon *et al.*, 2020). Examples include green roofs, fog harvesting, and renewable materials like clay, timber and cypress, which not only improve air quality and reduce urban heat but also support renewable energy integration (Hadba *et al.*, 2024; Matthews, 2024; Perera *et al.*, 2022; Saint *et al.*, 2023). Net-zero energy buildings, defined as structures with zero net energy or carbon consumption, exemplify how NbS can transform the construction industry by reducing environmental footprints and aligning with decarbonisation goals (Ahmed *et al.*, 2022).

Recent studies reveal that NbS have gathered enough momentum using other related terms such as “biomimicry”, “biophilic”, and “nature-inspired” (AlAli *et al.*, 2023; Moreira Da Silva *et al.*, 2024). Oguntona and Aigbavboa (2023) highlighted the substantial role of nature-inspired solutions in combating climate change. Incorporating features such as green roofs and walls enhances cities' capacity for carbon sequestration, effectively reducing greenhouse gas emissions. Similarly, Singh and Ru (2022) demonstrated that these solutions align with clean energy goals by improving energy efficiency in buildings, decreasing energy consumption, and reducing reliance on non-renewable energy sources. Moreover, urban green initiatives promote sustainable consumption patterns and help minimise the ecological footprint of urban areas.

Additionally, Azari *et al.* (2024) reveal that building envelopes adapt to environmental changes and are also essential for managing heat, air, and moisture exchange between a structure's interior and exterior. Their efficient design and implementation can significantly reduce energy use and carbon emissions over the building's lifecycle. In regions like South Africa, where construction significantly contributes to greenhouse gas emissions (23 per cent) (Simpeh & Smallwood, 2021), adopting NbS is crucial for mitigating environmental impacts and addressing energy poverty.(Dosumu and Aigbavboa, 2021). A systematic review of current literature on NbS and net-zero construction can thus inform innovative frameworks and strategies, advancing the development of resilient, sustainable urban environments.

3. Research Methodology

The primary objective of this study was to explore the role of NbS and sustainable materials in advancing net-zero construction. This was accomplished using a bibliometric approach to identify and map core knowledge domains and co-occurring keywords, uncovering research trends and gaps. Bibliometric analysis employs science mapping tools to visualise the physical aspects of scientific research and domains while elucidating the structural composition of their disciplines (Waltman *et al.*, 2010). As highlighted by Akinlolu *et al.* (2022), bibliometric analysis provides a quantitative and comprehensive approach for examining existing literature, surpassing the limitations of manual reviews. For this research, the bibliometric analysis followed a four-step process outlined by Aliu and Aigbavboa (2023). The data for this study were sourced from the Scopus database, renowned for its extensive coverage and high-quality literature resources. As one of the largest abstract and citation databases, Scopus provides a vast collection of peer-reviewed books, book chapters, journals, and conference proceedings, surpassing other databases like Clarivate Web of Science and Google Scholar in scope and reliability (Aghimien *et al.*, 2019; Aliu & Aigbavboa, 2023). In the Scopus database catalogue, the following retrieval schema was entered: "nature OR based AND solutions AND materials AND net AND zero AND construction." "TITLE-ABS-KEY" indicated either a conference paper or journal article title, abstract, and keywords.

The period for this study search was 2014-2024, and using the above keywords, 51 documents were retrieved. The review period for this bibliometric study was limited to 2014–2024 to ensure the inclusion of contemporary and high-impact research on Nature-Based Solutions (NbS) in achieving net-zero carbon buildings. Accordingly, academic publications on NBS and net-zero buildings gained momentum from 2014 onward, driven by advancements in green infrastructure, biophilic design, and regenerative materials. In contrast, earlier studies lacked a strong focus on net-zero carbon buildings due to their recent

emergence in policy frameworks, certification standards (e.g., LEED Zero, EDGE Zero Carbon), and research funding priorities (Frantzeskaki *et al*., 2019; Lützkendorf *et al.*, 2015; Seddon *et al*., 2020). Also, bibliometric analysis benefits from a well-defined time frame that captures relevant trends and emerging themes while ensuring data consistency (Donthu *et al.*, 2021). Therefore, by setting the review period from 2014 onwards, this study ensures the inclusion of recent and high-quality literature that reflects the latest technological advancements, policy shifts, and industry adoption of NbS in net-zero construction. The research design employed for the bibliometric analysis is shown in Figure 1.

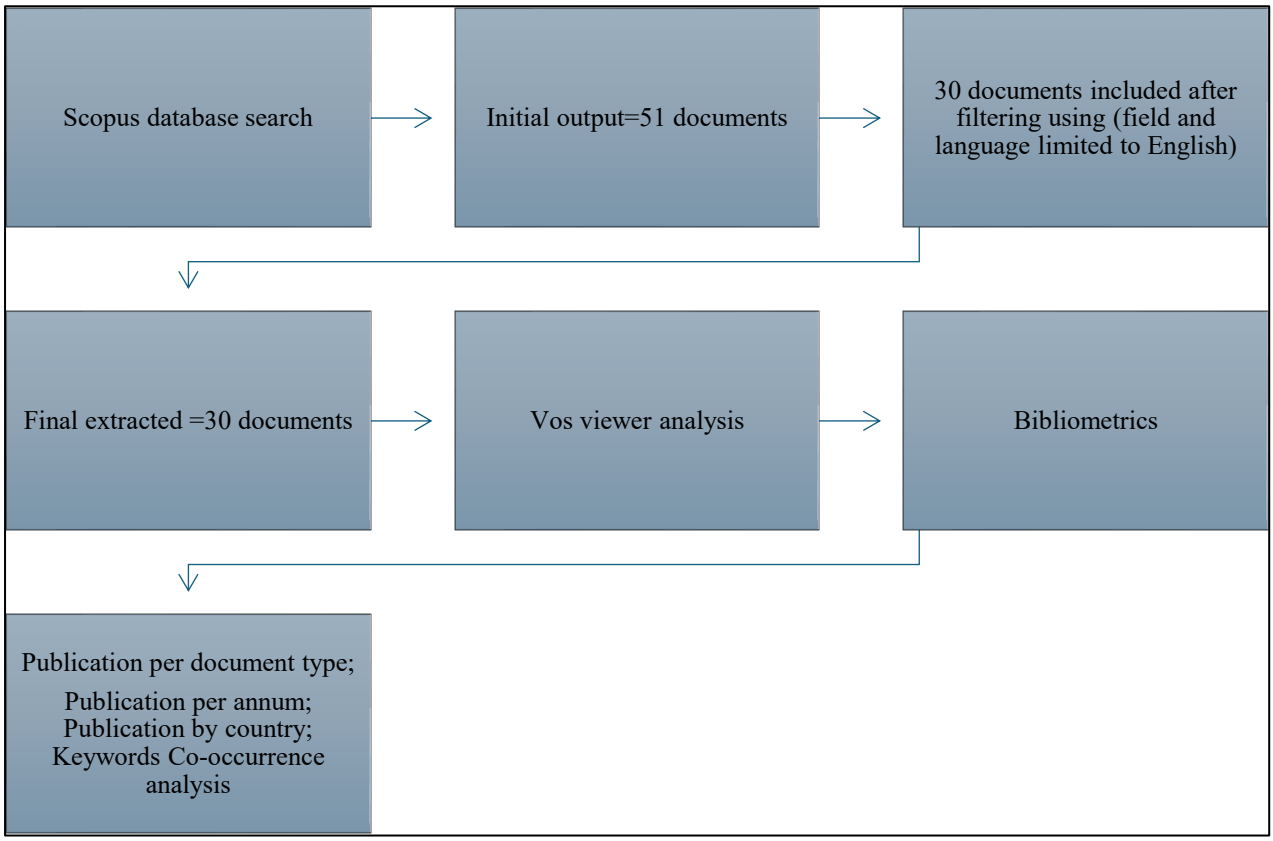


Figure 3: Research design Methodology

The results were refined using two parameters: field (Engineering, Energy, Materials Science, and Environmental Science) and language (English). This filtering process initially identified 31 documents. Following a manual screening, one document was excluded, resulting in a final set of 30 relevant documents for review. Visualisation tools such as CiteSpace, HiteSpace, VOSviewer, Gephi, and BibExcel are frequently used in bibliometric studies (Moral-Munoz *et al.*, 2019). This study utilised VOSviewer software to analyse statistical data from the source and generate a keyword co-occurrence map (Van Eck & Waltman, 2014). VOSviewer is widely adopted in construction literature reviews (Aghimien *et al.*, 2019; Akinlolu *et al*., 2022; Aliu & Aigbavboa, 2023). Vosviewer analysed bibliometric networks based on several key metrics. These included: (1) the number of publications per document type, (2) publications by country, (3) publications by year, and (4) the co-occurrence of keywords. A final cluster analysis was done after the co-occurrence of keywords network map was generated. This structured methodology ensured a systematic and in-depth exploration of the literature on Nature-based Solutions and Sustainable materials in the built environment.

4. Findings and Discussion

4.1. Publications per annum and Document type

Results illustrate the annual publication trends on NbS and their influence on net-zero buildings from 2014 to 2024. Before 2014, no publications were recorded in this area. Between 2014 and 2019, research activity was minimal, with only four publications by 2019, reflecting slow initial growth. A decline occurred in 2021, with only one publication, but interest rallied in 2022. A notable surge followed in 2023, with the number of publications rising to seven, three more than

the previous year. By 2024, research momentum had significantly increased, culminating in 12 publications to date. This upward trend aligns with the growing recognition of NbS as a vital strategy for promoting efficient energy use and innovative approaches to climate action.

Previous studies anticipate continued expansion in this field as researchers increasingly focus on leveraging NbS to address environmental challenges and support sustainable construction practices (Hadba et al., 2024; Labaran et al., 2024; Matthews, 2024; Päätalo et al., 2024). A total of 30 documents were analysed, comprising 15 journal articles, seven conference papers, five review papers, and three book chapters. The relatively low number of journal articles may be attributed to the rigorous peer-review process required for publication, which can limit the volume of accepted articles. Similarly, the number of conference papers is modest, despite their quicker publication timelines and higher volumes, often influenced by the relevance of conference themes. African countries could capitalise on conference platforms to boost research output in this area. Figure 2 illustrates the findings.

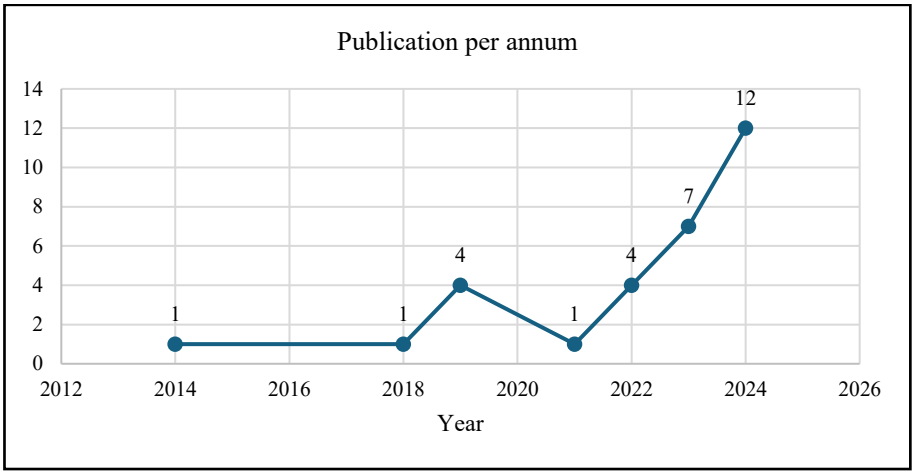


Figure 4: Publication per annum

4.2. Publication by Country

These findings highlight the global distribution of publications on Nature-based Solutions (NbS) in net-zero buildings, showcasing the number of documents and citations by country. Data, analysed using a VOS viewer with a minimum threshold of two publications per country, reveal 14 countries (depicted in the world map, Figure 3 in Appendix 1) with research outputs. The United Kingdom leads with 10 publications and 33 citations. Australia follows with five publications and 12 citations, while the United States and Finland each have four publications, accumulating 70 and 75 citations, respectively. Italy and India also recorded four publications, 75 and three citations, respectively. South Africa, by contrast, had only one publication, cited three times and did not meet the set threshold. This analysis reveals the uneven global research output, with certain countries significantly contributing to the literature, particularly in Europe and North America. At the same time, regions like Africa remain underrepresented despite the growing importance of NbS in addressing climate challenges and net-zero construction. Table 1 (see Appendix 1) provides the results of the top 5 countries discussed (Figure 3).

4.3. Analysis of Co-occurring Keywords and Cluster Themes

Keywords are meaningful in describing research content and concepts, particularly in studies on sustainable construction strategies. Using Scopus data and VOS viewer, a visualisation map was generated to reveal co-occurring keywords and research topic networks, where keyword proximity and similarity indicate the degree of co-occurrence (Van Eck & Waltman, 2014). A keyword co-occurrence analysis was thus achieved to uncover the core structure and thematic clusters within research on the impact of Nature-based Solutions (NbS) on net-zero construction. Utilising VOS viewer software, a network was generated from 395 keywords, with 55 keywords meeting the threshold of at least two co-occurrences. It was realised that some keywords repeated, emphasising their importance across multiple thematic clusters in literature. This analysis identified six prominent keyword clusters, as visualised in the network map presented in Figure 4.

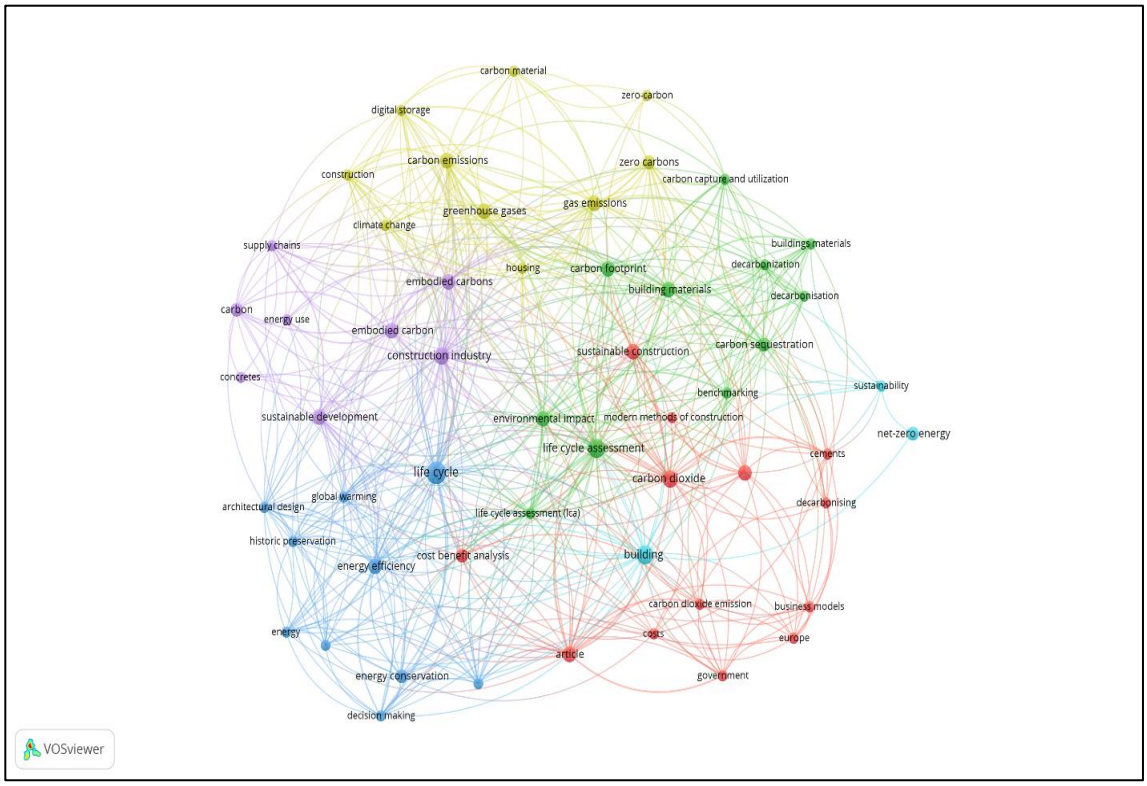


Figure 5: Network visualisation of Co-occurring Keywords

Cluster 1: Innovative Strategies for Decarbonisation and Circular Economy in Net-Zero Construction. The first cluster contains 13 keywords, and it makes up the red region of the map. The keywords were: article, business models, carbon dioxide, carbon dioxide emissions, cement, circular economy, cost-benefit analysis, decarbonising, costs, modern methods of construction, sustainability and sustainable construction. This theme underscores research on the role of nature-based solutions in reducing carbon dioxide emissions and integrating circular economy principles into construction(Archila *et al.*, 2023; Chakraborty, 2023; Perera *et al.*, 2022). Materials like low-carbon cement and modern construction methods can help achieve decarbonisation while addressing cost-benefit analysis concerns(Ahmadi *et al*., 2024; Frota De Albuquerque Landi *et al*., 2023; Khalid *et al*., 2023). Furthermore, these studies highlight that exploring business models aligned with sustainable development ensures cost-effective and environmentally conscious practices towards Net-Zero Construction.

Cluster 2: Sustainable Building Materials and Carbon Management in Construction. Cluster 2, represented by green in the visualisation, comprises 11 keywords, which are benchmarking, building materials, carbon capture and utilisation, carbon footprint, carbon sequestration, decarbonisation, environmental impacts, and life cycle assessment. Research works by (Ekanayake *et al.*, 2024; Hu, 2019; Saint *et al.*, 2023) indicate that life cycle assessment and carbon footprint analysis are critical in understanding the environmental impact of building materials. Carbon capture, utilisation, and sequestration technologies can be leveraged to enhance material sustainability (Archila *et al.*, 2023; Gallego Dávila & Aagesen, 2024). Integrating nature-based materials into construction processes supports decarbonisation and reduces long-term environmental impacts.

Cluster 3: Energy Efficiency and Decision-Making in Sustainable Architectural Design. The third cluster is made up of the blue region with 10 keywords: architectural design, decision making, energy, energy conservation, energy efficiency, feasibility study, global warming, historic preservation, life cycle, and life cycle analysis. Energy conservation and efficiency are integral to achieving net-zero construction goals, as highlighted in several studies (Azari *et al.*, 2024; Ehsan & Maryam, 2022). Nature-based solutions in architectural design, such as passive solar design and green roofs, can reduce energy use (Hu, 2019; Labaran *et al.*, 2024). Additionally, decision-making informed by feasibility studies and life cycle analysis ensures that design choices align with global warming mitigation and historic preservation (Frischknecht *et al.*, 2019).

Cluster 4: Cluster 4 highlights the theme "Zero-Carbon Strategies in Construction and Housing" with 10 keywords in the yellow region on the map. The keywords include carbon emissions, carbon material, climate change, construction, digital storage, gas emissions, greenhouse gases, housing, zero carbon, and

zero-carbon. This theme reveals studies that have focused on the reduction of greenhouse gas emissions through innovative materials and digital storage solutions in construction (Matthews, 2024; Pisini *et al.*, 2024; Saint *et al.*, 2023). Nature-based housing materials and designs can minimise energy use and promote zero-carbon living and the well-being of inhabitants. Sustainable strategies in construction align with climate change goals and support global net-zero initiatives through strategies such as NbS.

Cluster 5: The fifth cluster, representing the purple section of the map, has eight keywords: carbon, concretes, construction industry, embodied carbon, supply chains, sustainable development, and is themed "Embodied Carbon and Sustainability in Construction Supply Chains." Embodied carbon in construction materials is a significant contributor to overall emissions. Using sustainable materials and optimising supply chains can reduce the environmental footprint(Ahmadi *et al.*, 2024; Azari *et al.*, 2024; Weber *et al.*, 2022). Nature-based solutions provide alternatives that prioritise energy efficiency and sustainable development within the construction industry(McGarry *et al.*, 2022).

Cluster 6: Net-Zero Energy Buildings for Sustainability. The last cluster is represented by the turquoise region with three keywords: buildings, net-zero energy and sustainability. The theme highlights research conducted on revealing the importance of integrating nature-based solutions in building designs to achieve net-zero energy performance (Byrne et al., 2019; Villarruz, 2019). Technologies like energy-efficient materials and renewable energy systems ensure sustainability, as indicated in studies by Ahmadi et al. (2024) and Azari et al. (2024). Nature-based solutions and strategies not only reduce carbon emissions but also enhance long-term resilience and environmental harmony towards achieving a Net-Zero Construction industry.

5. Conclusion and Further Research

This study demonstrates the growing prominence of Nature-based Solutions (NbS) in achieving net-zero construction, particularly within Europe and North America. Research has demonstrated that incorporating nature-inspired strategies significantly contributes to reducing energy consumption, carbon emissions, and resource depletion while enhancing resilience to climate change. The analysis highlights NbS as a critical approach for reducing carbon emissions, optimising supply chains, and enhancing energy efficiency.

A keyword co-occurrence analysis identified six key research themes emerging in this field from 2014 to the present. However, the review also revealed significant gaps, including lower conference paper publications, the limited integration of life cycle analysis with nature-based materials and pronounced regional disparities in research output and adoption, particularly in Africa, where only South Africa featured in the results. Addressing these disparities through policy support, localised research and capacity building is critical to advancing net-zero buildings and broader sustainability goals. This indicates that research in this area remains nascent in many developing regions. The study's reliance on the Scopus database and its focus on quantitative literature analysis present limitations, which may overlook relevant work in other databases or non-English publications. Future research should prioritise exploring the practical applications of NbS in diverse contexts, assessing their scalability in achieving net-zero construction, and addressing the gaps in underrepresented regions. Expanding the scope to include multiple databases and multilingual sources will provide a more comprehensive understanding of this evolving field.

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Appendix 1

Table 1: Publication by Country (Top 5 countries)

Country	Number of documents	Citations
United Kingdom	10	33
Australia	5	12
United States of America	4	70
Finland	4	75
Italy	3	75
India	3	7

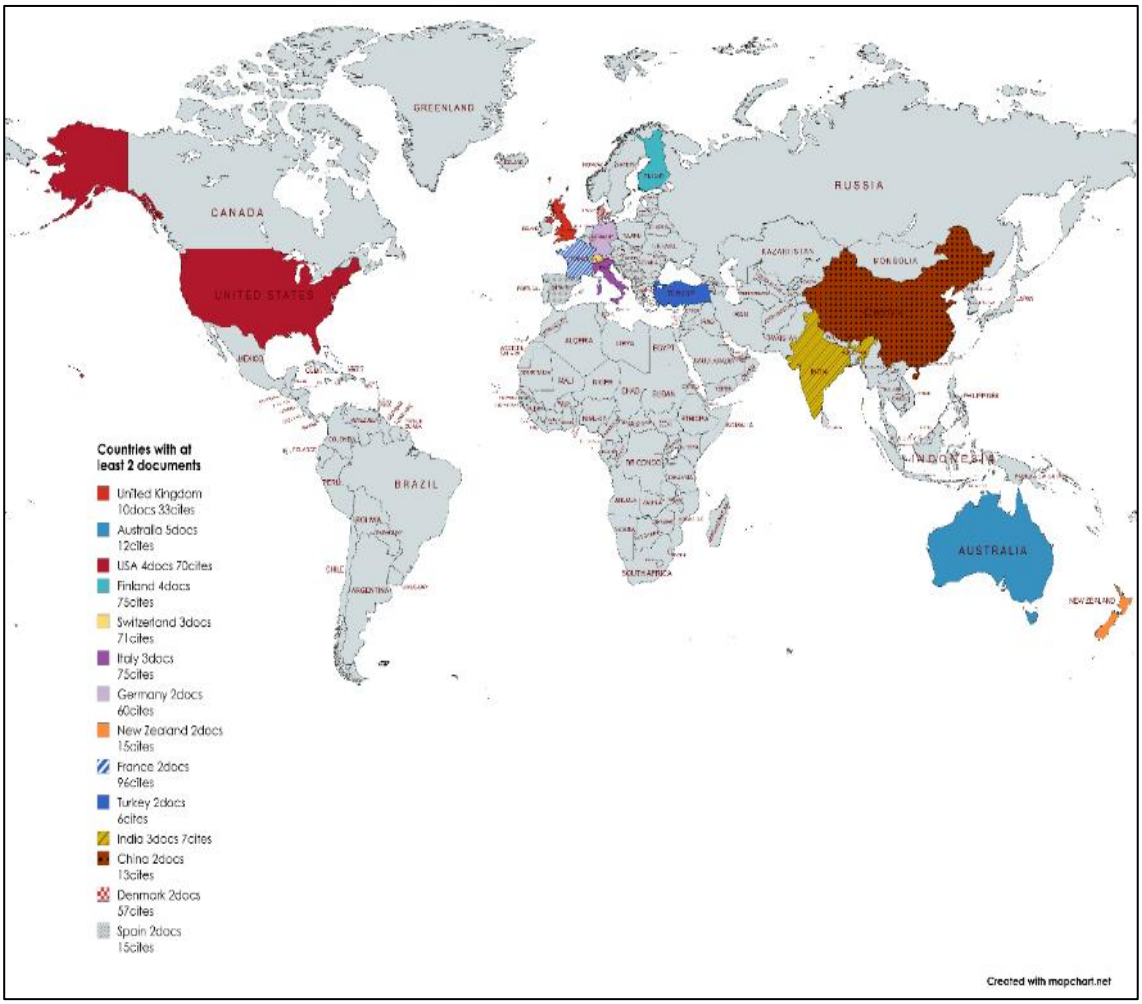


Figure 6: Map showing the number of publications per country

ACADEMIC PAPERS: THEME 4 - STRATEGIC MANAGEMENT AND LEADERSHIP IN CONSTRUCTION

Developing an Inclusive Leadership-Psychological Safety Relationship Framework to Foster Creative Performance in the Nigerian Built Environment

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Abstract

Construction employees over the years have been exposed to risky, complex and uncertain workplace environment due to the multitasking nature of construction works. Thus, innovative ideas are needed in a leader-member relationship on construction projects, in order to improve productivity. However, managers are often faced with challenges of developing high level of inclusiveness and how to incorporate members' creative ideas, which could eventually jeopardize psychological safety, with consequent low productivity at workplace. In light of this, this paper attempts to develop an inclusive leadership-psychological safety relationship framework to enhance creative behavior in the built environment. Using a conceptual approach, the study reviewed literature on inclusive leadership, psychological safety, and the attributes of inclusive leadership-psychological safety relationship in promoting employee creative behavior. By reviewing 39 articles and citing 18 secondary sources, the key features/elements of inclusive leadership and psychological safety relationship were extracted to developed the framework. The study established that key elements of inclusive leadership-psychological safety such as inclusion, openness, commitment to diversity, awareness to bias, learning culture, supportive feedback, trust and respect among others are essential in achieving belongingness, and supportive climate in the construction workplace. This framework provides direction in fostering creative behavior within construction workforce, thereby improving organizational productivity.

Keywords: Construction, Creativity, Inclusive Leadership, Nigeria, Psychological Safety.

1. Introduction

An organization workforce is best described through the nature of its workplace environment. In essence, the workplace is essential to facilitate and promote the objectives of an organization and its workforce. The workplace environment refers to the physical settings, situations, culture, job profile, market conditions and the environment in which people work (Briner, 2000; Tripathi, 2014 & Oludeyi, 2015). It defines an environment in which individuals undertake their designated tasks and responsibilities within an organization. In the construction industry, the workplace is quite unique and distinct due to the complexity and risky nature of construction works, coupled with the existence of separate disciplines and separate work environments in the construction industry. Hence, leadership is essential in the built environment to give directions both in construction projects implementation and in administrative procedures. According to Vidya (2011) and Rani *et al*, (2022), certain critical factors such as motivation, psychological safety/well-being, and leadership among others are required to effectively manage complex workplace environment such as construction industry. An organization leadership style is identified as one of the key factors to either enhance or retard the interest, behaviors, commitment of employees in an organization (Veliu *et al,* 2017). In recent times, inclusive leadership is found useful in promoting organization productivity and employee creative behavior. According to Carmeli; *et al* (2010), Randel *et al* (2017) and Qi *et al* (2019), inclusive leadership is found to exhibits vital attributes such as inclusion, availability, accessibility, openness, uniqueness, valuing diverse perspectives, equity, belongingness and support for creativity, that are needed to promote employee creative behavior and psychological safety. It creates a positive and psychologically safe workplace environment where employees feel valued, respected and included (Ferdman, 2014; Zeng *et al;* 2020). Which in turn affirms the relationship between inclusive leadership and psychological safety in managing complex and multifaceted workplace environment, such as the construction industry. The inclusive leadership concept is beneficial in workplace climate, to groom innovative leaders for the sustainable development and implementation of construction projects. The absence of framework to promote and foster inclusiveness, psychological safety and creative behavior in leader-member relationship at workplace in the built environment has necessitated the study. It is acknowledged that the leadership style in workplace environment is significant to influence creative behavior in an organization workforce. This study therefore develops a framework to foster construction employee creative behavior.

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2. Literature Review

2.1. Inclusive Leadership

In management field, effective management requires a set of skills like planning, communication, organization and leadership style, in order to attain improve performance at workplace environment (Jennifer, 2023). Different forms of leadership dimensions have been studied such as transformational leadership, shared leadership, benevolent leadership, moral leadership, humble leadership, transactional leadership and relational/inclusive leadership (Carneli *et al.,*2010, Sun *et al*.,2016; Wang & Chang, 2010; Wang *et al.,*2018 & Naqvi *et al.*,2017). These forms of leadership are evolving in response to actual situations in most organizations, with varying degree of outcomes. According to Carneli *et al.,* (2010), Uhl-Bien, (2006) and Fletcher, (2004) inclusive leadership is described as one of the emerging concepts in the study of leadership. Inclusive leadership is distinct from other mode of leadership in the sense that it creates an avenue for followers to air their views and opinions in creative manner provided the leaders demonstrate high level of inclusiveness. It emphasizes the values of diversity and active involvement of all team members in promoting creativity in teams (Nembhand & Edmondson, 2016). Construction activities are characterized by urgency to deliver construction projects before deadline dates. Timelines are set for each task which in turn put immense pressure on construction workers, particularly the construction managers. In this regard, there is tendency for toxic work environment which could result in low level inclusiveness and lack of psychological safety among construction workers. Nevertheless, psychological safety through inclusive leadership is still critical because people are allowed to speak up about their concerns, provide feedbacks about their operations and reduce potential errors (Newman *et al*., 2017). Primarily, inclusive leadership style is concepted to produce inclusive leaders with peculiar attributes and impacts that are needed to lead actively. The inclusive leader attributes are significant to demonstrate inclusion, belongingness, and uniqueness, with consequent impacts on employee/subordinates' creative behavior and psychological safety in the workplace. As highlighted in Fagan *et al,* (2022), inclusive leaders are expected to demonstrate certain attributes such as "authentic leadership, change maker, collaborative, commitment to diversity and cultural competency, ideals, offer followers support and openness". These in turn increased psychological safety, follower well-being, creativity, increased follower productivity, performance and work engagement, increased trustworthiness in leader-follower relationship, together with follower motivation to get involved and produce results (Fagan *et al*, 2022). In Nigeria, a study of inclusive leadership and employee work engagement in hospital setting by Babaita *et al*., (2023) revealed the significance of inclusive leadership key elements such as accessibility and openness in fostering open discussion and enabling inclusive workplace environment within work teams, regardless of diverse background.

2.2. Psychological Safety (P.S)

The concept of psychological safety is beginning to gain wider interest in the construction industry. P. S is a common factor that drives employee creativity in an organization (Gong *et a*l., 2012 & Liu *et al.,* 2020). The applicability of the concept of psychological safety in the construction industry is still an on-going development (Gomez *et al.,*2019), while its usefulness and outcomes have been studied in different sectors such as education, healthcare, manufacturing and information technology (Kessel *et al*.,2012; Turner & Harder 2018; Lee *et al.,*2011 & Bergmann & Schaeppi, 2016). According to Edmondson (2018), psychological safety is the belief or perception by an employee that he or she will not be punished or humiliated in a workplace when different creative ideas, questions or concerns are being shared. In attaining organizational success, P.S encourages openness, making use of creative chances by working together, thereby leading to improved productivity and problem-solving abilities within the workforce (Khalid & Saqali, 2023). By reviewing the antecedents and outcomes of psychology safety, Newman *et al.,* (2017) highlighted the factors that influences the way employee perceived psychological safety to include leader inclusiveness, support, trustworthiness (trust in the leader), openness, and behavioral integrity. These perceptions of psychological safety are noticeable both at individual and team levels. Psychological safety was identified as the topmost characteristic of an impactful work teams by reducing team member's error, and enhancing safety (Nembhard & Edmondson, 2011; Leroy *et al*, 2012; Bergmann & Schaeppi, 2016). According to Hallam *et al* (2023), a psychologically safe workplace is achieved through certain key elements such as effective communication, organizational culture, leadership practices, performance feedback mechanisms, respect among colleagues, staff development opportunities, teamwork and trust. The impact and significance of psychological safety in the construction workplace are crucial to denote employee creative behaviour in a risky workplace environment. The psychological safety climate in the construction industry has been examined through four dimensions, which are management support, management priority, organizational communication, and organizational participation (Xie et al. 2020). The comparison of the level of psychological safety both in megaprojects and ordinary projects showed a higher level of psychological safety climate in megaprojects when compared to ordinary projects (Xie et al. 2020). Similarly, the impact of psychological safety is positively reflected in lean construction when compared to traditional construction projects (Demirkesen et al., 2021).

2.3. Inclusive Leadership - Psychological Safety Relationship

Studies have shown the significance of inclusive leadership to sustain the value of diversity, the active involvement of all team members, and to positively influence team creativity (Leung *et al.,* 2015; Roberson, 2016; Nembhard & Edmondson, 2016; European Commission, 2017 & Bakkes, 2023). Inclusive leaders are known to exhibit certain traits such as thriving in a diverse new world, cognizance, curiosity, cultural intelligence, collaboration, commitment, and courage (Bourke & Dillon, 2016). Other noticeable inclusive leadership traits include humility, respect, authenticity, openness, tolerance for ambiguity, vulnerability, and integrity (Ferdman, 2014; Moore *et al.,* 2020 & Wasserman, 2020). In essence, inclusive leadership promotes a sense of psychological safety, encourages diverse perspectives and facilitates open communication (Bakkes, 2023). The psychological safety (PS) of an employee is important to ascertain the degree at which they can make contributions at workplace environment. P.S could impact the state of wellbeing of an employee. A psychological safe employee has the tendency to display better wellbeing, unlike an employee facing poor psychological safety. According to llies *et al*., (2010) "not being able to speak up can lead to work-related stress, which can incubate this problem and lead to more significant health problems farther down the line". Inclusive leadership-psychological safety relationship is essential to curb workplace challenges. The relationship is characterized by supportive climate, openness, accessibility and availability, courage to speak up, with creative ideas and novel put, openness to experience and motivation, conducive and nontoxic workplace environment, an atmosphere of trust and open communication, among others (Carmeli *et al.,* 2010; Carmeli *et al.,* 2013 & Mavrokordatos, 2015). As revealed by Bourke and Espedido (2020), in inclusive leadership – psychological safety relationship, 70% of an inclusive leader actions make the difference in determining whether an individual reports feeling included in an organization. It is noted that the inclusive leader influence is aided by certain inclusive leadership key traits such as visible commitment to valuing diversity, humility, awareness of bias (main key to inclusiveness), curiosity about others, cultural intelligence and effective collaboration (Bourke & Espedido (2020).

2.4. Leadership style in the construction industry

Leadership in the construction industry has been assessed through different perspectives. It is an emerging issue in the built environment that has been subjected to intense debate in recent time (CIOB, 2008). In construction, leadership is about people, places and events (Chan, 2008). According to Ali *et al;* (2020) leadership styles are required due to the complex nature of construction projects, to promote creative performance and attaining project success. In particular, the effective leadership style enables the workforce to achieve project goals through novel and creative idea (Wu *et al;* 2018 & Li *et al;* 2020). It is noted that the lack of leadership and /or inadequate essential leadership style by construction managers in project- based organizations decelerated the growth and sustainability of the built environment (CIOB, 2008; Ismail & Fathi, 2018). In attaining construction project success, the construction manager leadership style is found critical (Goleman, 2002). Most especially when construction managers deploy suitable leader style in a given situation (Liphadzi *et al* 2015). Studies such as Giritli and Oraz (2004), Akhila (2018), Ismail and Fathi (2018), Emere *et al* (2018), Kalambay *et al*., (2021) and Liphadzi, (2015) among others have found the impact, and the common leadership styles in the construction industry across different countries. To mention a few, the following are the common leadership styles in the construction industry: laissez-Faire and transformational leadership (India), authoritative (Turkey), democratic, transformational and transactional leadership (South Africa), strategic, democratic, charismatic and transformational (United Kingdom), transformational and transactional leadership style (China and Ghana). Some similar leadership styles are also manifesting in the Nigerian built environment. Notably among them are autocratic (Oke, 2013), goal oriented, relationship, technical, team style and task/autocratic (Odediran & Babalola, 2015), democractic and autocratic leadership style (Ayangade *et al*; (2017), transformational, transactional and Laissez-Faire leadership style (Oyetunji *et al;* 2019), and democratic, strategic, transformational, peace setting and facilitative leadership styles (Mesoma, 2022) among others. Similar to the findings of Liphadzi (2015) in South Africa and Akhila (2018) in India, the Laissaez-Faire leadership style is negatively correlated with construction worker performance in Nigeria (Oyetunji *et al*; 2019), while the autocratic leadership style is described as the predominant, and mostly not preferred leadership style in the Nigerian built environment (Oke 2013 & Mesoma, 2022). Broaden views on leadership styles in the built environment have identified inclusive leadership as an important leadership style. Inclusive leadership is identified to have positive impacts on project success (Rehman, 2020 and khan *et al*., 2020).

3. Methodology

This study reviewed published literature on inclusive leadership and psychological safety to established their relationship. Data collection was done by reviewing related literature sourced from the internet and online databases such as Google Scholar, ResearchGate, ScienceDirect, Emerald and Academia, by using the research topic keywords such as inclusive leadership, psychological safety, and creativity with no year limitation. 56 (fifty-six) academic resources were

initially downloaded, out of which 39 academic resources were considered for review, based on the relevance of their core contents. Additional, 18 secondary sources were also referenced from the identified academic resources. The academic resources include journal articles, conference proceedings, book chapters, and research thesis. These resources are basically in English language. The review considered the findings of studies on inclusive leadership and psychological safety in the workplace, in different sectors such as construction, health, tourism, education among others. The selected academic resources were read, classified, and analyzed using content analysis to quantify the occurrence of key features/elements of inclusive leadership-psychological safety relationship in fostering creative behavior in the workplace. The findings of the impact of inclusive leadership on workplace environment both in Nigeria and overseas were considered in developing the framework.

4. Results and Discussion

The review of literature on inclusive leadership revealed key features that are essential in fostering employee creativity and psychological safety in the built environment. These key features of inclusive leadership include openness/availability/accessibility, inclusion, commitment to diversity, awareness of bias, and cultural intelligence. These findings formed the basis for facilitating inclusion within a diverse workplace. A psychologically safe workplace is evident where learning culture, open communication, supportive feedback, supportive interpersonal relationships, trust, and respect are noticeable. In the construction industry, the risky nature of tasks requires an enabling environment where inclusiveness acts as the main driving force in fostering creative behavior and ensuring psychological safety. Having a psychologically safe workplace in the construction industry is essential to improve productivity and reduce occupational health and safety risks (Demirkesen *et al*., 2021). According to Howell *et al*. (2017) and Edmondson (2018), there exists a positive impact of open communication, mutual respect, and trust in promoting psychological safety and creativity in construction projects. These findings suggest a high-quality relationship between inclusive leadership and psychological safety in fostering employee creative behavior in the construction industry.

4.1. Framework to Foster Construction Employee Creative Behavior

In relation to the aim of this study, a framework was developed to foster creative behavior in the construction workplace environment. The key features of inclusive leadership-psychological safety relationship were instrumental in the development of the framework (figure 1). In inclusive leadership style, certain features such as inclusion, availability, awareness of bias, commitment to diversity provides the leverage to attaining learning culture, effective communication, trust and respect, which are embedded in a psychologically safe workplace environment. The effectiveness of the inclusive leadership-psychological safety relationship is manifested through supportive climate, belongingness, conducive and nontoxic working environment. More importantly, the key features of inclusive leadership greatly influenced construction managers to lead by example, while the subordinates value individual differences and practice inclusion by working together. The resultant features of these relationships enhanced construction employee creative behavior in the workplace environment.

As depicted in figure 1, both the inclusive leadership and psychology safety are in interactive relationship through their respective elements, such as inclusion, openness, availability, accessibly, commitment to diversity, a learning culture, open communication, supportive feedback etc., which in turn produce resultant features such as supportive climate, belongingness, courage to speak up with creative ideas and novel input etc. The framework also depicts the role of inclusive leadership in influencing construction managers to lead by example, by champing inclusion in the workplace, commitment to workforce diversity in the organization and openness to ideas. The inclusive construction manager is positioned to influence the subordinates/members to value individual differences, take personal responsibility, and practice inclusion by working together. The leader-follower inclusive practices contribute to the overall resultant features, which in turn lead to enhanced construction employee creative behavior in the workplace environment.

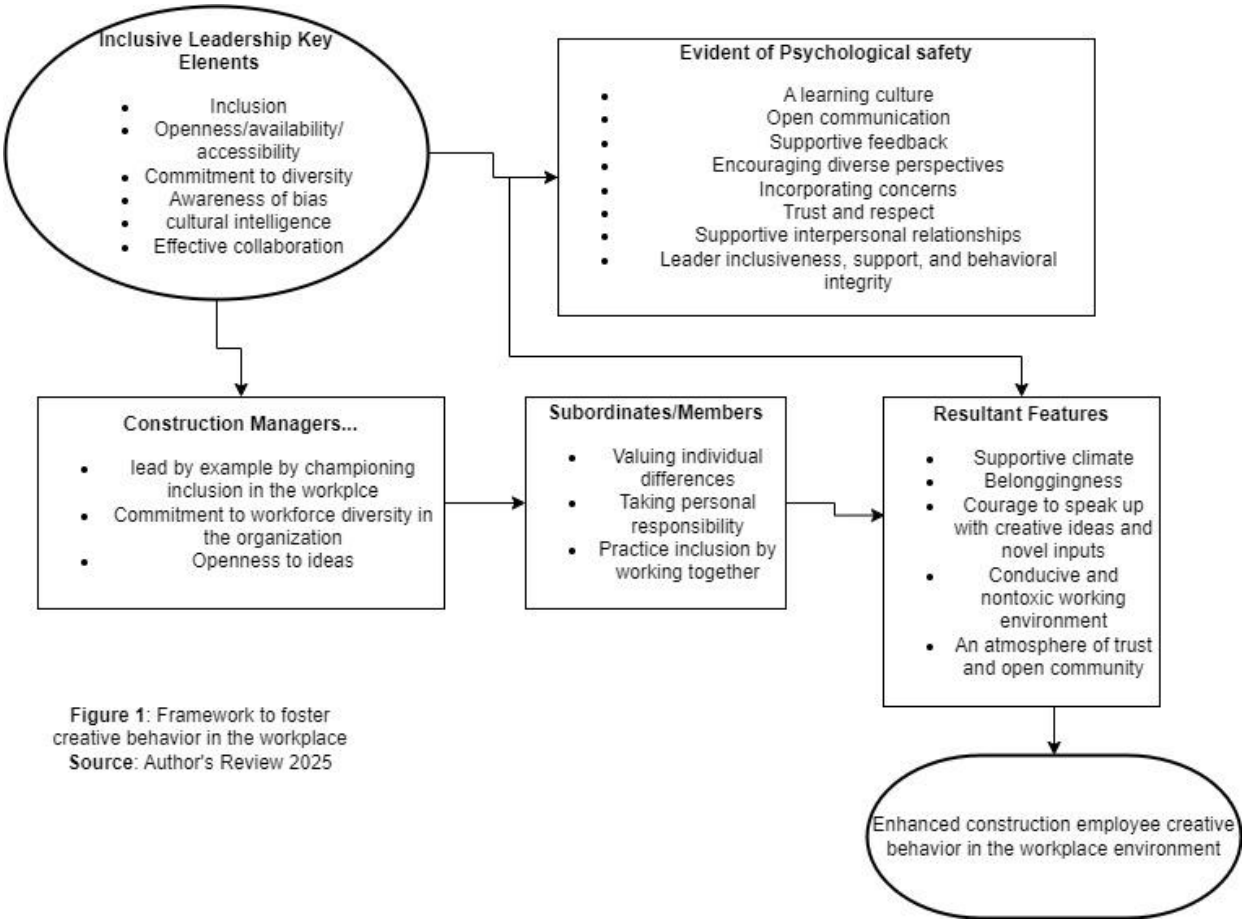


Figure 1: Framework to foster creative behavior in the workplace
Source: Author's Review 2025

Figure 1: Framework to Foster Creative Behaviour in the Workplace
Source: Author's Review 2025

5. Conclusions

This study develops an inclusive leadership - psychological safety relationship framework through literature review. The study explored the interactive relationship of inclusive leadership and psychological safety in obtaining key resultant features of inclusive workplace environment. The framework demonstrates the expected outcomes when construction manager exhibits key inclusive leadership elements, which are fundamental in influencing employee/subordinate creative behavior in the construction workplace environment, and attaining organizational productivity. This present study only attempts to develop an inclusive leadership – psychology safety relationship framework through desktop analysis, which could limit the framework verification. Empirical studies are needed in developing a well-structured inclusive leadership-psychological safety relationship framework, to enhance employee creative behavior in the Nigerian built environ.

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Unveiling the Key Drivers of Successful Operations Management in Construction Subcontracting

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Abstract

A significant portion of construction work is executed through subcontracting (SC). If not managed properly, SC can contribute to poor project performance. Failures in subcontracting can arise in various phases, including subcontractor selection, operations, and monitoring. This study aimed to identify and prioritize the key drivers of successful operations management in construction subcontracting. A systematic literature review (SLR) was conducted to examine the available scholarly literature from Scopus, Web of Science, and ProQuest databases on the focus area of the study. From the databases, 31 studies were screened for further detailed review. A thematic content analysis, done with ATLAS.ti25, was done to identify eleven drivers of successful operations management in construction subcontracting. The findings ranked mutual trust and fairness; long-term partnership; adherence to quality standards and specifications; coordination of subcontractors; and timely payment as the top five critical drivers.

Keywords: Construction industry; drivers; operations; systematic literature review; subcontracting

1. Introduction

Subcontracting (SC) is a business strategy that main contractors employ to address construction market uncertainties and transfer risks, such as completion risks, financial risks, and employee responsibility (Schaufelberger & Holm, 2017). Subcontracting (SC) in construction has become increasingly prevalent in recent decades (Zubair et al., 2016; Mbachu et al., 2022) due to the growing complexity of construction projects, the scarcity of skilled labor, the drive to maximize profits, and the need to reduce risk, Studies indicate that in Zambia more than 50%, and in some specific sectors up to 90% of projects involve subcontracting (Mudzvokorwa, Mwiya & Mwanaumo, 2020). In South Africa, around 70% of building and 30% of civil construction project works are performed through subcontracting (cidb, 2013); while in Nigeria, a minimum of 70% of the projects rely on subcontracting (Okunlola, 2015).

Subcontracting (SC) enhances project performance if properly managed (RICS, 2021). On the contrary, poor SC has been identified as a potential risk for project performance. Previous studies have identified poor SC as one of the reasons for project delays and cost overruns (Osama, El & Wefki, 2023; Daoor et al., 2020). Olanrewaju et al. (2022) also underscored poor SC as one of the reasons for poor quality, delay, and project disputes. The subcontracting supply chain has been highlighted as problematic because of antagonistic relationships between the main contractor and subcontractor, poor communication, blame culture, a lack of focus on serving the ultimate end user, and other reasons (Rompoti, Madas & Kitsios, 2020). These factors impact project performance and highlight the need for a structured evaluation of subcontracting success factors.

While studies have been conducted on individual SC major activities including subcontractor selection (Karaman, 2022); the contractor-subcontractor relationships (Tan et al., 2017); conflicts and disputes in SC (Magazi & Kikwasi 2022); payment issues (Daoor et al., 2020), and others. There is a knowledge gap regarding the key drivers of successful operations management in construction subcontracting. This study aims to bridge this gap by systematically identifying and ranking these key drivers to enhance subcontracting performance and project success. The findings will offer valuable insights for construction industry stakeholders to optimize subcontracting operations, enhance project performance, and minimize risks associated with poor subcontracting operations.

2. Literature Review

The construction industry is characterized by complexity and time-constrained projects. High complexity, uniqueness of activities, and the number of required technologies urged construction firms to consider outsourcing strategies, including SC (Fridkin & Kordova,2022). Subcontracting (SC) is a well-established practice in the construction industry (Daoor et al., 2020). It is subletting the obligations of the main contractor stipulated in a separate main contract with the project owner. In some cases, a project owner directly nominates the subcontractor to carry out part of the main contract works (RICS, 2021).
The main contractor can lower its operational costs and improve competitiveness with SC. Subcontracting (SC) is also an efficient and economical means of accessing

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resources (Daoor et al., 2020). Subcontracting (SC) is invaluable for construction projects as it allows specialization and creates market access to local subcontractors. Due to the mentioned and other benefits of SC, the reliance of the construction industry on SC has increased (Magazi & Kikwasi 2022). However, rather than contributing to better project performance, SC could exacerbate project outcomes (Koshe & Jha, 2016). According to Osama, El & Wefki (2023), one of the primary reasons for the delay of construction projects is poor SC performance. If SC is not managed properly, it could result in project cost overrun and poor quality of work.

Construction project owners demand their projects to be delivered on time, on budget, free from defects, right the first time, and safely by the construction firms involved (Mbachu et al., 2022). The dependence of main contractors on subcontractors to execute the major portion of their work makes construction projects' success highly dependent on SC performance. However, it is not only the subcontractor who is the responsible party for SC performance. The other major project stakeholders, including the contractor and project owner, also contribute their share to the success or failure of SC in a project (Chamara et al., 2015).

Contracting is widespread in construction project management (Schaufelberger & Holm,2017). The execution of construction projects involves contracting (to formally hire) an external organization. This external organization itself might involve other different organizations allied by numerous contractual agreements. Initially, the project user or owner contracts with the main contractor are sometimes mentioned as the systems development organization (SDO) responsible for the overall project.

In turn, the main contractor enters contracts with secondary parties—such as subcontractors, consultants, material suppliers, and to carry out specific portions of a construction project. These secondary parties, in turn, may establish contracts with tertiary parties, further extending the subcontracting network (Schaufelberger & Holm, 2017). The main contractor is hired by the project user or owner to manage the overall construction project. From a market point of view, where the contractor operates primarily as the buyer, it is responsible for buying materials, equipment, and services necessary for project execution. This position entails evaluating the state of the market, negotiating contracts with suppliers, and making sure the products and services acquired adhere to project requirements, quality standards, and financial limitations(Nwaguru et al., 2022). Project budgets, schedules, and success are all impacted by the contractor's capacity to handle procurement.

Conversely, from an engineering- contract perspective, the contractor assumes the role of the seller. In this case, it will be accountable for delivering specified services, products, or completed projects to the project owner or client(Plessis & Oosthuizen, 2019). This includes adhering to regulatory requirements, contractual agreements, and industry standards throughout the project lifecycle. Subcontracting (SC) makes it possible to handle market uncertainties in the construction industry and to transfer risks, including completion and financial risks. It lowers direct costs as well as overhead, enabling the main contractor to work with firms that have reduced overhead and a better understanding of the market dynamics, practices, and processes (Daoor et al., 2020). Additionally, SC makes it easier to complete high-quality work, utilizing specialized subcontractors who possess the required expertise in particular trades. The non-adoption of SC could request a great amount of manpower and equipment that would be, at some moment, sub-used (cidb, 2013).

Operations management in subcontracting plays a crucial role in ensuring project efficiency, cost-effectiveness, and quality outcomes. It involves coordinating resources, schedules, and stakeholder relationships to optimize subcontractor performance. Effective management enhances workflow continuity, minimizes disputes, and fosters collaboration between contractors and subcontractors (Magazi & Kikwasi 2022; Tan et al., 2017).

Previous studies have identified a range of factors influencing subcontracting operations. Specifically, the effectiveness of construction subcontracting work is shaped by subcontractor-related factors (Ali et al., 2024), subcontractor-contractor interactions (Debelo & Weldegebriel, 2022), and contractor-related factors (RICS, 2021). This study seeks to systematically identify and rank the key drivers within these three categories that impact the operations of subcontracting works.

3. Research Methodology

In this study, a Systematic Literature Review (SLR) was employed to explore the existing research on the key drivers of successful operations management in construction subcontracting. The SLR focused on peer-reviewed articles and conference proceedings to explore different drivers of successful operations management. A systematic literature review (SLR) was initially adopted to examine the existing scholarly publications on the key drivers of successful operations management in construction SC. A systematic literature review (SLR) involves comprehensive searches of relevant studies on the subject of study (Saunders, Lewis & Thornhill, 2016; Mase, 2020). The researchers followed the preferred reporting items for systematic reviews and meta-analyses (PRISMA) (2020) to conduct the SLR (Matthew et al., 2021). The data were acquired from Scopus, Web of Science, and

ProQuest databases. The query strings and keywords used for the search were: ("subcontracting"), ("construction"). Regarding the exclusion criteria, the authors discarded: duplicate articles; and articles written in other than English language. Book chapters and book reviews were also excluded. Studies conducted from 2000-2024 were included. The procedures followed for the article selection are presented in Figure 1.

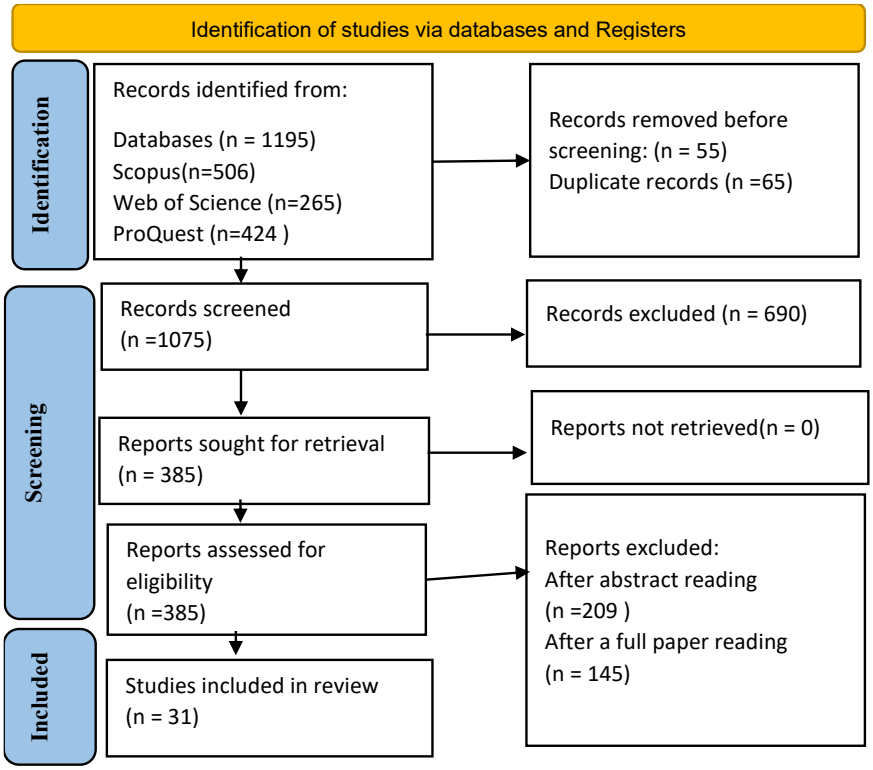


Figure 1: PRISMA 2020 flow diagram for identification of studies for synthesis

Then the screened 31 studies were reviewed to identify what has been studied regarding the key drivers of successful operations management in construction SC.

4. Results

The thematic analysis of the screened articles was done using ATLAS.ti25 software to explore the drivers of successful operations management in construction SC. The identified drivers were grouped into three categories: Contractor-related, Subcontractor-related, and Contractor-Subcontractor collaboration in the analysis. Table 1 is a summary of the drivers identified for successful operations management in SC, corresponding reference authors, and their ranks. The code-document analysis table output of ATLAS.ti25 is the input for Table 1.

5. Discussions

In the pursuit of operational excellence in subcontracting works, the three discussed interrelated categories in the previous section: contractor-subcontractor collaboration, contractor-related drivers, and subcontractor-related drivers serve as essential drivers that significantly enhance project performance and efficiency.

Different key drivers that enhance efficiency and performance influence successful operations management in construction subcontracting were identified in the previous section. These drivers could create a collaborative and productive working environment between contractors and subcontractors ensuring effective operation in subcontracting. By working on these drivers, construction projects can achieve improved outcomes, timely completion, and higher-quality deliverables. Next, the top five key drivers identified through the Systematic Literature Review (SLR) will be discussed.

Table 1: Drivers of successful operations management in construction subcontracting

Overall Rank	Driver	Frequency	Authors
Contractor-Subcontractor Collaboration			
1	Mutual Trust and Fairness	5	(Kadan et al., 2024; Omotayo et al., 2023; White & Marasini, 2014; Wu et al., 2023; Zhang et al., 2016)
2	Long-term Partnership	4	(Cao & Wang, 2014; Omotayo et al., 2023, Lee et al., 2009)
6	Effective Communication	3	(Fridkin & Kordova, 2022; Eom et al., 2015; Lew et al., 2020)
7	Lean Construction Practice	3	(Eom et al., 2015; Kadan et al., 2024; Maturana et al., 2007)
9	Power Symmetry/Balance	2	(Deep et al., 2022; Wu et al., 2023)
Subcontractor-Related Drivers			
3	Adherence to Quality Standards and Specifications	4	(Fridkin & Kordova, 2022; Lew et al., 2012; Ng et al., 2010; White & Marasini, 2014)
8	Availing Manpower and Other Resources	3	(Eom et al., 2015; Lew et al., 2020; Yin et al., 2014)
10	Meeting Milestones/Execution Capability/	2	(Maturana et al., 2007; Shi et al., 2023)
Contractor-Related Drivers			
4	Coordination of Subcontractors	4	(Lee et al., 2009; Tan et al., 2017; White & Marasini, 2014)
5	Timely Payments	4	(Lew et al., 2020; Yin et al., 2014; Rostiyanti et al., 2020; Youssef et al., 2023)
11	Planning and Budgeting	2	(Fridkin & Kordova, 2022; Yin et al., 2014)

Source: ATLAS.ti25 Code-Document Analysis Output

5.1. Mutual Trust and Fairness

Mutual trust and fairness are essential elements in the relationship between the main contractor and subcontractors within the construction industry. Trust is cultivated through the expectation that both parties will act in a manner that is equitable and beneficial, even amidst the inherent risks and uncertainties of construction projects. This trust fosters collaboration and minimizes conflicts, as it encourages open communication and a willingness to share vital information (Wu et al., 2023). When subcontractors perceive fairness in their dealings-such as equitable distribution of rewards, transparent decision-making, and respectful interactions, they are more likely to engage positively and commit their resources to the project. This perception of fairness significantly enhances relationship stability and project success, as it reduces the likelihood of opportunistic behavior and promotes a cooperative environment (Kadan et al., 2024). Furthermore, mutual trust and fairness not only facilitate smoother project execution but also contribute to the development of long-term partnerships that benefit both parties. The psychological aspects of trust, including goodwill and competence, highlight the importance of these factors in ensuring that subcontractors feel valued and respected. This, in turn, influences their commitment to the project and the overall success of the construction endeavor (Omotayo et al., 2023; Zhang et al., 2016).

5.2. Long-term Partnership

Long-term partnerships in construction subcontracting are characterized by ongoing collaboration between general contractors and subcontractors, extending beyond individual projects to encompass multiple engagements over time. This strategic approach contrasts with traditional, project-based relationships that often prioritize short-term gains. Long-term partnerships foster a cooperative environment where both parties can invest in each other's growth, leading to improved performance and efficiency. For instance,

general contractors may provide training and managerial support to subcontractors, enhancing their capabilities and ensuring that they can meet project demands effectively (Cao & Wang, 2014).

The benefits of such partnerships are manifold. They facilitate cross-project learning, allowing subcontractors to refine their skills and processes over time, which can lead to cost reductions and higher-quality outputs (Lee et al., 2009). Additionally, long-term relationships can mitigate the risks associated with opportunistic behavior, as both parties develop a vested interest in each other's success (Eom et al., 2015). However, establishing and maintaining these partnerships requires a commitment to mutual goals, open communication, and a willingness to share resources. As noted by Omotayo et al. (2023), the construction industry has increasingly recognized the importance of these long-term relationships in enhancing project outcomes and fostering innovation.

5.3. Adherence to Quality Standards and Specifications

In the construction industry, the success of a project heavily relies on the subcontractor's commitment to adhering to quality standards and specifications. Subcontractors are tasked with executing specialized components of a project, and their ability to meet established quality benchmarks is crucial for ensuring the overall integrity and performance of the construction work (Fridkin & Kordova, 2022; Ng et al., 2010).

Non-compliance with these standards can lead to significant repercussions, including project delays, increased costs due to rework, and potential legal disputes. Implementing a centralized subcontractor appraisal system can enhance quality assurance by providing a structured framework for evaluating subcontractor performance based on critical criteria such as workmanship, safety, and resource management. Such an approach not only identifies capable subcontractors but also promotes a culture of quality within the subcontracting community, ultimately contributing to the successful delivery of construction projects (Fridkin & Kordova, 2022; White & Marasini, 2014).

5.4. Coordination of Subcontractors

Coordination of subcontractors is essential for successful operations management in construction subcontracting, particularly concerning resource allocation and spatial organization. Effective coordination ensures that all subcontractors are aligned with project goals and timelines, which is crucial for optimizing the use of resources. When subcontractors are well-coordinated, it minimizes the risk of resource conflicts and ensures that materials, labor, and equipment are allocated efficiently. This alignment is particularly important in complex construction environments where multiple subcontractors may be working simultaneously on different aspects of a project. By establishing clear communication channels and regular coordination meetings, main contractors can facilitate better resource management and prevent delays caused by misallocation(Tan et al., 2017).

In addition to resource allocation, effective coordination also plays a vital role in managing spatial constraints on construction sites. Construction projects often involve limited space, and the simultaneous activities of various subcontractors can lead to congestion and inefficiencies if not properly managed. Main contractors must ensure that subcontractors are aware of their designated work areas and the timing of their activities to avoid overlaps and conflicts. This involves providing timely information, resources, and support to ensure subcontractors perform their tasks effectively (White & Marasini, 2014). By implementing standardized processes and utilizing technology for better communication and information sharing, the main contractors can improve coordination efforts and reduce the likelihood of delays and conflicts.

5.5. Timely payments

Timely payments are critical in the construction subcontracting landscape, significantly influencing the operational efficiency and financial stability of subcontractors. Rostiyanti et al. (2020) emphasize that subcontract agreements must include clear payment provisions to mitigate disputes arising from late payments, which can further complicate project execution. The reliance on prompt payments is particularly pronounced among smaller subcontracting firms, which often operate on tight cash flows. Payment delays can lead to severe repercussions, including project delays, strained supplier relationships, and even bankruptcy (Youssef et al., 2023).

The operational dynamics between the main contractors and subcontractors are heavily influenced by payment practices. Conditional payment clauses, such as "pay when paid" or "pay if paid," can exacerbate cash flow issues for subcontractors, leading to a cycle of financial instability. Research indicates that a significant percentage of disputes between main contractors and subcontractors stem from payment delays, highlighting the need for clear and fair payment terms (Lew et al., 2020). By establishing transparent payment processes and adhering to timely payment schedules, construction firms can improve collaboration, reduce conflicts, and ultimately enhance project outcomes.

6. Conclusions

Using a Systematic Literature Review (SLR)-Analytical Hierarchy Process (AHP) methodology, this

study identified and prioritized the key drivers of effective operations management in construction subcontracting. The SLR provided a thorough basis for analysis by methodically extracting important drivers from the body of current literature.

The findings provided valuable insights for contractors, subcontractors, project owners, consultants, and other stakeholders to understand their gaps, and design and implement corresponding strategies to boost operational performances at projects. The study also contributed to the existing body of knowledge on construction subcontracting where operational challenges are more pronounced. Further empirical study is recommended on the identified drivers of effective operations management in construction subcontracting.

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The Effectiveness of Supply Chain Management in Enhancing Project Management Outcomes

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Abstract

Supply Chain Management (SCM) plays a critical role in improving the efficiency and effectiveness of project management across various industries. This paper explores the effectiveness of SCM on project management outcomes in local municipalities, focusing on key performance indicators such as cost reduction, time management, risk mitigation, and quality control. Effective SCM integration within project management frameworks minimizes delays, optimizes resource allocation, and improves overall project performance. The research highlights how the SCM strategies such as just-in-time (JIT) delivery, and risk mitigation contribute to enhanced project execution. By streamlining supply chain processes, organizations can mitigate uncertainties, minimize waste, and improve collaboration among stakeholders. This paper also examines case studies where efficient SCM has led to successful project completion and identifies challenges such as supply chain disruptions, vendor management issues, and compliance risks. The findings suggest that companies that prioritize robust SCM practices achieve better project outcomes in terms of cost efficiency, quality assurance, and stakeholder satisfaction. Additionally, integrating SCM principles into project management enhances operational efficiency and resilience, making it a vital component for achieving strategic project goals. Future research should explore advanced digital technologies and sustainable SCM practices to further optimize project success. A mixed method approach has been adopted, grounded in a pragmatic research philosophy. Data was analyzed by employing SPSS version 29.2. The findings suggest that integrating SCM principles into project management not only streamline processes but also increases the likelihood of meeting project goals, particularly in large-scale and complex projects.

Keywords: supply chain management, project management, key performance indicators, resource allocation, quality

1. Introduction

Infrastructure development projects in local municipalities face multiple challenges ranging from insufficient funds, budget constraints, political interference, maladministration and poor governance (Durdyev and Hosseini 2020). Latent conditions impede the municipality's ability to deliver projects effectively. The reasons for delays in public sector project delivery, according to the assessment of Thusi and Selepe (2023), are labor shortages, unqualified workers, owner delays in evaluating and approving design papers, and project owner delays in progress payments. Nee, Beatrice and Yong (2022) reviewed the construction time performance of Malaysian public projects. Rather than project characteristic characteristics, the study discovered that delays are caused by variables related to excusable delays. With the use of factor analysis, Mahajan and Narkhede (2024) investigated the reasons for delays in construction projects and discovered poor site management, scope revisions, late payments to suppliers and contractors, and inadequate project planning. Gurgun, Koc and Kunkcu (2024) found that poor site management, inadequate planning, and a lack of materials were hindrances that deter attaining effective project management delivery. The aim of the study is to explore the effectiveness of the integration between supply chain and project management. With a focus on how effective resource allocation, supplier management, procurement, and logistics all contribute to project success, this study explores the integration of SCM practices within project management frameworks, emphasizing how efficient procurement, logistics, supplier management, and resource allocation contribute to the success of projects. Key findings from the research reveal that THLM lacks effective supply chain management procedures. The study's findings indicate that late payments to contractors and suppliers are the most significant cause that instigate project delays

2. Literature Review

2.1. Background

From a corporate point of view, successful Project management is described by achieving a continuous stream of project objectives with consideration of time, cost, quality, at a desired performance level, while deploying resources efficiently and effectively, providing value to stakeholders (Kerzner, 2025). In the field of project management, Chen (2023) asserts that the supply chain is essential to the project's successful completion. A project's cost, schedule, and quality results can all be greatly impacted by how well its supply chain works. In implementing service delivery

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across the nation, municipalities are essential. According to Widjaja (2024), infrastructure projects are known to stimulate economic growth and social well-being. The Local Government: Municipal System Act 32 of 2000, mandates municipalities with the implementation of service delivery and developmental projects to improve the quality of life of residents and contribute to economic development (Mbedzi 2023). Nevertheless, implementing such projects does not come without challenges. It is against this backdrop that measures are sought to streamline operations to deliver quality output.

2.2. Supply Chain Management Challenges in Local Municipalities

In South African local municipalities, supply chain management (SCM) faces many obstacles that affect governance, financial efficiency, and service delivery. Sibanda, Zindi and Maramura (2020) pointed out several challenges in local municipalities which include insufficient planning and forecasting, bureaucratic and inefficient processes, fraud and corruption. Other constraints highlighted by Maramura and Ruwanika (2023) are supplier's challenges, poor governance and budget restraints, the effect of which often leads to the inability to meet developmental goals and compromised service delivery.

2.3. Project Management Challenges in Local Municipalities

Project management in local municipalities in South Africa faces several unique challenges due to socio-economic, political, and operational factors. Notable key challenges encountered are shortage of skilled personnel, political interference, corruption and mismanagement of funds, legislative and regulatory bottlenecks, poor monitoring and evaluation (Munzhedzi and Phago 2020; Van der Waldt and Fourie 2022).

2.4. Mitigating factors to enhance SCM effectiveness in Project Management

It is often known that supply chain management (SCM) and project management (PM) are closely related fields that, when properly coordinated, can greatly improve organizational effectiveness and produce superior results. Common features in both fields include planning, execution, monitoring, and controlling processes to achieve specific objectives (Tang 2021). Whereas SCM focuses on the flow of goods, information, and resources across a network to meet customer demand, PM is primarily concerned with the execution of temporary, goal-specific initiatives within defined constraints of time, cost, and scope. To maximize the contribution of the two disciplines, there should be careful planning and effective utilization of resources to optimize performance (Elisa, Nabella and Sari 2022). Both SCM and PM accentuate strategic planning and effective utilization of resources.

The integration of SCM into PM enhances resource allocation, visibility and control. Consequently, linking supply chain management and project management is essential for operational synergy. It is widely accepted that this integration enhances efficiency, mitigates risks, supports innovation, and ultimately ensures successful project delivery in competitive and dynamic business environments. Strategic advantage can be achieved significantly by organizations that invest in bridging these two domains. The built industry, encompassing sectors like construction, architecture, engineering, and urban planning, is a cornerstone of economic development and societal progress. It involves the design, construction, and maintenance of infrastructure such as buildings, roads, bridges, and public spaces. The industry is highly dynamic, influenced by factors such as technological advancements, economic conditions, environmental sustainability, regulatory frameworks, and evolving customer needs. Diagram 2.1 below illustrates the Supply chain-project management value chain.

3. Research Methodology

This paper adopted a mixed-methods approach, grounded in a pragmatic research philosophy. Biesta (2021) asserts that the pragmatism research philosophy suggests that research questions should be central, and the choice of methods should be guided by their usefulness in addressing these questions. This approach allows for a comprehensive understanding of the complex relationship between SCM and project management outcomes by integrating both qualitative data and quantitative data. Whereas quantitative data will provide a statistical overview of the phenomenon, qualitative data, on the other hand, will offer in-depth insights into the experiences and perspectives of stakeholders. Thembisile Hani Local Municipality is one of the municipalities under eNkangala District Municipality which controls six local municipalities including THLM.

3.1. Population and Sample

The population of interest comprises all professionals within the eNkangala District Municipality involved in project management and supply chain management. This includes, but not limited to, project managers, procurement officers, finance officials, senior management, and other relevant stakeholders. A purposive sampling technique was utilized to select a representative sample, considering various factors such as size, geographic location and historical project performance. Primary data was collected from sample of 78 participants within the district. The technique guaranteed that the study captures a diverse range of experiences and contexts.

3.2. Sample strategy

For quantitative methodology, the paper adopted a stratified random sampling technique within each selected municipality to ensure proportional representation of different professional categories. A sufficient sample size was determined using a power analysis to ensure adequate statistical power for detecting significant relationships. For qualitative methodology, a purposive sampling technique was employed to select interview participants based on their experience and involvement in project management and supply chain processes. This ensured the inclusion of individuals with diverse perspectives and in-depth knowledge. The sample size was guided by data saturation, until no new significant information emerged.

3.3. Data Collection Instruments

For quantitative methodology, a structured questionnaire was developed based on a thorough review of the literature on SCM and project management effectiveness. The questionnaire included key elements such as: demographic information, Project performance, SCM implementation and overall project success. A (1-5) Likert scale was utilized to measure outcomes. The questionnaire was pilot-tested with a small group of professionals to ensure clarity, validity, and ease of completion before final distribution. The questionnaire was administered online using Google Forms to facilitate data collection and analysis. For qualitative methodology, a semi-structured interview guide was developed to guide the semi-structured interviews. The interview guide included open-ended questions designed to explore the following:

i. Perceptions of the role of SCM in project management;
ii. Challenges and barriers to effective SCM implementation in the municipality;
iii. Examples of successful and unsuccessful projects and the role of SCM in their outcomes;
iv. Suggestions for improving SCM practices to enhance project management outcomes, and
v. Impact of SCM on specific project aspects such as time, cost, quality, stakeholder satisfaction.

With the help of current technology, interviews were conducted via a video conferencing, considering logistical considerations. All interviews were audio-recorded with the participant's prior consent and transcribed verbatim for analysis.

3.4. Data Analysis Techniques

Quantitative data was examined using the Statistical Package for the Social Sciences (SPSS) version 29.2. The analysis in this study primarily focused on descriptive statistics. Thematic analysis was utilized to analyze the qualitative data collected from the semi-structured interviews. The analysis included Transcription and Familiarization, Coding, Theme development, Interpretation and Reporting.

4. Findings and Discussion

Results from the study reveal that THLM lacks effective supply chain management procedures. Key findings from the research reveal that SCM significantly impacts on time, project cost, schedule, and quality. The study's findings indicated that late payments to contractors and suppliers were the most significant cause of instigating project delays. There is a need for effective collaboration between SCM and PM teams for success. The main reason for project delivery delays, according to Shivambu and Thwala (2019), is suppliers' late payments. These results are consistent with those of a study on Kenyan local administrations by (Barsemoi, Mwangagi and Asienyo 2014). The study of Hoque (2022) establishes that one of the main issues affecting service delivery in South African municipalities is the lack of necessary supply chain skills and capabilities. Another significant discovery is that ineffective execution of some management tasks and responsibilities causes project completion delays, which impacts the municipality's ability to provide services. Findings reveal a greater need for technological improvements in the current systems in order to streamline supply chain processes and improve project success. The public sector in its current form faces a unique challenge in implementing SCM and PM due to regulatory constraints and bureaucratic processes. Results point to the municipality's capacity to complete projects on schedule due to critical factors, such as clear scope definition, effective communication, employee training, investing in emerging technology, allocating sufficient resources, and work plan.

4.1. Descriptive Statistics of the respondents

Table 1 displays the descriptive statistics of the study participants. Over half (66.1%) of the participants were women, while 33.9% were men. Many participants were general workers (35.7%), followed by supervisors (16.1%), artisans (17.9%), technicians (16.1%), and others (15.1%). Regarding educational qualifications, 48.2% of participants held a certificate as their highest level of education, 32.1% had a diploma, 16.1% had a degree, and just 3.6% had a master's degree. Additionally, the study found that 26.8% of participants had less than six years of work experience, 33.9% had 6 to 10 years, and 39.3% had 11 to 15 years of experience.

Table 1: Descriptive statistics of the respondents

Variable		n (%)
Gender	Male	19 (33.9)
	Female	37 (66.1)
Job title	General workers	20 (35.7)
	Supervisors	9 (16.1)
	Artisans	10 (17.9)
	Technicians	9 (16.1)
	Other	8 (15.1)
Academic qualification	Certificate	27 (48.2)
	Diploma	18 (32.1)
	Degree	9 (16.1)
	Masters	2 (3.6)
	PhD	-
Length of service (years)	1 - 5	15 (26.8)
	6 - 10	19 (33.9)
	11 - 15	22 (39.3)
	16+	-

- n (%) = number (percentage)

To assess the reliability of the items, the researchers employed Cronbach's alpha coefficient (α). Reliability refers to the internal consistency of the construct(s) and their stability (Nunnally & Bernstein, 1994). The Cronbach's alpha value ranges from 0 to 1, and according to Bagozzi and Yi (1998), an α value greater than 0.6 indicates data consistency and reliability for analysis. In this study, the value of α was greater than 0.7 in each section, indicating that all the items agreed on each other (Table 2).

Table 2: Reliability Statistics

Section	Items	Cronbach's alpha
Deliberate practices that delay project delivery in THLM	5	0.725
Impact of late payments on project delivery	5	0.809
Impact of late payments on project delivery	4	0.891
Management practices that delay project delivery in THLM	5	0.774
OVERALL	**14**	**0.882**

4.2. Deliberate practices that delay project delivery in THLM

Table 3 presents the level of agreement or disagreement among respondents regarding the idea that THLM employs strategies to implement the MFMA Act of 2003, despite intentional activities that lead to delays in the municipality's project delivery. A Likert scale ranging from 1 (strongly disagree) to 5 (strongly agree) was used to assess responses, with a mean score (MS) between 1.00 and 5.00. The result reveals that respondents generally agree that intentional actions, such as delayed payments to contractors and suppliers, contribute to project delivery delays in THLM (MS = 3.95). On the other hand, respondents were neutral about statements such as "THLM complies with the MFMA of 2003 in implementing projects" (MS = 3.38), "THLM has effective supply chain management practices" (MS = 2.98), and "Payments to suppliers are made within 30 days" (MS = 2.92). Additionally, respondents strongly disagreed with the statement that workers possess adequate supply chain management skills and competencies (MS = 2.28).

4.3. Impact of late payments on project delivery

Table 4 demonstrates that the mean scores (MS) for all items assessing the impact of late payments on project delivery exceeded 3.5. This suggests that the majority of respondents agreed that late payments result in several negative effects on project completion,

including causing workers to strike (MS = 4.07), prolonging the construction timeline (MS = 4.01), leading to the departure of expert personnel from the project (MS = 3.78), contributing to time and budget overruns (MS = 3.82), and causing contractors to run out of working capital, leading to cash flow problems (MS = 3.68).

Table 3: Deliberate practices that delay project delivery in THLM

Contributor	Response in percentage (%)					MS
	1	2	3	4	5	
Late payments to contractors and suppliers contribute to project delays	-	12.5	-	44.6	42.9	3.95
THLM complies with the MFMA of 2003 in implementing projects	8.9	16.1	23.2	23.2	28.6	3.38
THLM has an effective supply chain management practices	1.8	35.7	28.6	32.1	1.8	2.98
Payments to suppliers are made within 30 days	1.8	39.3	28.6	28.6	1.8	2.92
Employees have an adequate supply chain management skills and competencies	35.7	33.9	17.9	10.7	1.8	2.28

Source: Author's construction

Table 4: Impact of late payments on project delivery

Outcome	Response in percentage (%)					MS
	1	2	3	4	5	
Workers strike on project site	0.0	0.0	14.3	39.3	46.4	4.07
The construction program is prolonged	0.0	0.0	16.7	42.9	41.1	4.01
Skilled employees leave the project	5.4	3.6	12.5	46.4	32.1	3.78
Projects experience cost and time overruns	3.6	3.6	14.3	44.6	33.9	3.82
Contractor runs out of working capital (cash flow problems)	0.0	12.5	23.2	32.1	32.1	3.68

4.4. Measures for improving the performance of the supply chain management unit

Table 5 reveals that the mean scores (MS) for 75% of the items related to enhancing supply chain management performance to improve project delivery in THLM fall between 3.5 and 4.0. This suggests that most respondents believe the following actions could boost THLM's project delivery: increasing staff numbers (MS = 3.77), providing training for current staff (MS = 3.88), and adopting the latest and most effective supply chain management procurement system (MS = 3.58). On the other hand, 25% of the items had an MS close to 3, indicating that respondents were neutral about the idea that improving project delivery in THLM could be achieved by utilizing current employees combined with better planning and communication strategies.

4.5. Management responsibilities

4.5.1. Management practices that delay project delivery in THLM.

Table 6 below illustrates the respondents' level of agreement or disagreement with management practices that may contribute to delays in project delivery at THLM. Forty percent of the items (1 and 2) show mean scores (MS) greater than 3.5, indicating that the respondents agree that certain management practices lead to delays, such as delayed approvals (MS = 3.94) and late payments to suppliers and contractors (MS = 3.90). Additionally, respondents were either neutral or disagreed with the statement that senior management is consistently available when needed, with an MS of 2.71, suggesting that this is not a significant factor in causing project delays. Furthermore, 40% of the items (4 and 5) had MS values below 2.5, indicating that respondents disagreed with the notion that senior management follows effective procedures to improve project delivery, including approving projects within

Table 5: Impact of late payments on project delivery

Measures/action	Response in percentage (%)					MS
	1	2	3	4	5	
Propose training of the existing staff members	0.0	7.1	16.1	37.5	39.3	3.88
Increase the number of staff members	0.0	10.7	17.9	37.5	33.9	3.77
Introducing the latest most and efficient supply chain management procurement system	0.0	10.7	30.4	35.7	23.2	3.58
Utilize the existing staff members but strengthen proper planning and communication	12.5	30.4	17.9	35.7	3.6	2.91

Source: Author's construction

Table 6: Impact of late payments on project delivery

Contributor	Response in percentage (%)					MS
	1	2	3	4	5	
Late approvals contribute to project delays	0.0	3.6	14.3	44.6	37.5	3.94
Late payments are made to contractors and suppliers	1.8	1.8	17.9	41.1	37.5	3.90
Senior management is always available when required	21.4	25.0	32.1	12.5	8.9	2.71
Changes in scope are approved within a reasonable time frame	33.9	30.4	21.4	7.1	7.1	2.39
Projects are approved within a reasonable time frame	39.3	39.3	19.6	1.8	0.0	2.08

Source: Author's construction

appropriate time frames (MS = 2.08) and granting revisions to project scopes in a timely manner (MS = 2.39).

5. Conclusion and further research

The paper has revealed that effective SCM is crucial for enhancing project management outcomes in the Thembisile Hani Local Municipality. By properly implementing strategic SCM practices, municipalities can successfully address resource constraints, thereby reducing costs, with improved stakeholder satisfaction, and ultimately enhance the successful delivery of projects. This research paper contributes to the body of knowledge by providing a comprehensive framework for understanding how SCM and PM are interconnected in the municipal context, highlighting the potential for improved project performance, and identifying key strategies for effective SCM implementation. Future studies should focus on conducting empirical studies to validate the framework and explore the impact of specific SCM practices on project outcomes in differently graded municipalities.

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Adapting Marketing Strategies in a Post-Pandemic Digital Landscape: Insights from Project Managers

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Abstract

The COVID-19 pandemic has significantly transformed business operations, particularly in marketing and consumer engagement strategies. As industries adapt to evolving market conditions, project managers play a crucial role in navigating these challenges. This study explores how project managers adapted their marketing approaches to maintain business resilience and consumer trust during and after the pandemic in KwaZulu-Natal, South Africa. The study aimed to investigate the impact of the COVID-19 crisis on project managers' marketing strategies, focusing on digital transformation, corporate social responsibility (CSR) initiatives, and consumer engagement tactics. A qualitative research approach was adopted, utilising semi-structured interviews with eight purposively selected project managers. Thematic analysis was conducted to identify key patterns and insights from the collected data. The findings reveal that project managers rapidly increased their digital marketing efforts, shifting towards online platforms, social media, and targeted digital advertising to sustain client engagement. Additionally, the need for agility and flexibility in marketing strategies was emphasised, as project managers continuously adjusted campaigns to align with shifting client behaviours and regulatory changes. Despite these adaptive efforts, challenges such as digital fatigue, budget constraints, and consumer scepticism toward CSR initiatives were identified. The study contributes to the growing body of knowledge on crisis-driven marketing adaptations, offering insights into how project managers can leverage digital tools and CSR to enhance resilience in volatile market conditions. These findings have practical implications for businesses seeking to develop robust marketing strategies that are responsive to future disruptions.

Keywords: consumer trust, corporate social responsibility, COVID-19, digital transformation, marketing strategies.

1. Introduction

The COVID-19 pandemic significantly disrupted global markets, forcing businesses to rethink and adapt their marketing strategies to navigate an unpredictable economic landscape. Lockdowns, supply chain disruptions, and shifting consumer behaviours accelerated the adoption of digital marketing and e-commerce, highlighting the need for agility and innovation in marketing practices (Sheth, 2021). Companies that embraced digital transformation and data-driven decision-making emerged more resilient, while traditional marketing approaches struggled to remain effective in a rapidly changing environment (Ceocea et al., 2022).

As the world transitions into the post-pandemic era, businesses must continue leveraging the lessons learned during the crisis to remain competitive. Consumer expectations have shifted, with greater emphasis on digital convenience, personalised experiences, and corporate social responsibility (Sawang, 2023). Additionally, advancements in artificial intelligence, automation, and omnichannel marketing are reshaping how brands engage with their audiences (Mushe, 2023; Sheth, 2021). Understanding these trends is crucial for project managers seeking to build sustainable and adaptive strategies.

This paper examines how marketing strategies have evolved in response to the pandemic, exploring key trends such as digital transformation, changing consumer behaviours, and technology used by project managers to shape their marketing strategy. By analysing post-pandemic marketing adaptations, project managers can develop more resilient and future-proof strategies to thrive in an increasingly digital economy.

2. Literature Review

Project managers in the construction and built environment sector operate in a distinct context compared to those in purely commercial industries. Their core responsibilities often encompass the strategic coordination of project lifecycles, stakeholder management, regulatory compliance, and value-driven delivery of infrastructure or building assets. Unlike commercial project managers who may directly engage in marketing or advertising, construction project managers align more closely with business strategies aimed at client retention, project continuity, and long-term partnerships (He & Harris, 2020; Hoekstra & Leeflang, 2020). Marketing efforts in this sector are therefore often integrated into broader business development strategies and client relationship management.

The COVID-19 pandemic disrupted traditional operations in the built environment sector, requiring project managers to respond with agile and innovative

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approaches to stakeholder communication, client engagement, and brand trust (He & Harris, 2020; Hoekstra & Leeflang, 2020). Project managers responsible for executing business initiatives have had to navigate an unprecedented shift in consumer behaviour, digital transformation, and corporate responsibility (Alshaketheep et al., 2020; Hanaysha, 2020). Understanding these changes is crucial for optimising marketing strategies that enhance brand resilience and consumer engagement.

Given these developments, this study examines the strategic marketing approaches project managers can adopt to enhance consumer engagement, build trust, and maintain flexibility in an evolving market. By understanding how project managers leverage digital marketing, CSR initiatives, and adaptive strategies, this research provides critical insights into the role of agile marketing practices in a post-pandemic world. The literature review explores the key themes of CSR, consumption patterns, marketing and advertising, consumer trust and engagement, and agility in marketing strategies, all of which contribute to a comprehensive understanding of project managers' evolving roles in modern business environments.

2.1. Corporate Social Responsibility

In the context of the COVID-19 pandemic, the importance of Corporate Social Responsibility (CSR) intensified across industries, including construction. He and Harris (2020) highlighted the renewed emphasis on stakeholder reliance, which pushed businesses to re-evaluate their long-term survival strategies. In the built environment sector, this translated into greater emphasis on ethical labour practices, community engagement around construction sites, and environmental stewardship (Asante Antwi et al., 2021; Hanaysha, 2020; Mahmud et al., 2021).

CSR, defined as a corporation's method of assessing and managing its social, environmental, and economic impact (Mahmud et al., 2021), is particularly relevant in construction where operations directly affect communities and urban landscapes. CSR in construction may include initiatives like using sustainable materials, engaging local labour, or supporting local COVID-19 recovery efforts. Asante Antwi et al. (2021) argue that CSR enhances brand image, competitiveness, and client trust, which aligns closely with business strategy objectives in the built environment.

Studies during the pandemic revealed that construction firms adopting proactive CSR—such as providing PPE to workers, supporting community health initiatives, and ensuring workforce safety—saw improved client retention and public approval (Ahmed et al., 2021; Zhai et al., 2022). Moreover, firms demonstrating CSR were more likely to access governmental subsidies, further supporting their operational resilience. Transparency in CSR disclosure correlated with enhanced client trust and project continuity (Mahmud et al., 2021; Popa et al., 2022).

Despite the advantages, some scholars caution against the misuse of CSR as a superficial marketing tool. Asante Antwi et al. (2021) warn that the pressure for survival may lead construction firms to adopt performative CSR, risking reputational damage. Popa et al. (2022) also note that CSR efforts perceived as insincere may generate distrust among both employees and clients. Billedeau et al. (2022) emphasizes the need for context-specific CSR models, particularly in complex and multi-stakeholder sectors like construction.

2.2. Shifting Consumption and Client Expectations in the Built Environment

Consumption patterns refer to the purchasing behaviour of consumers influenced by demand, technological advancements, and environmental regulations (Rutitis et al., 2022). These patterns encompass how and why consumers obtain products based on their needs, financial capacity, and situational factors such as economic stability, crisis events, and regulatory policies (He & Harris, 2020; Hoekstra & Leeflang, 2020).

The pandemic significantly altered client behaviours and expectations in the construction sector. Consumption patterns, traditionally driven by demand for office spaces, housing, and infrastructure, shifted in response to economic uncertainty and remote working trends (Dumitras et al., 2021; Rutitis et al., 2022). Clients began prioritising health-conscious designs, flexible usage of space, and environmental performance.

These behavioural shifts reflect broader consumer anxieties and the demand for projects that address post-pandemic realities (Hanaysha, 2020). In the built environment, this has led to increased interest in digital construction solutions (e.g., BIM, digital twinning), sustainable building certifications, and transparent communication from project teams about safety and progress (Dumitras et al., 2021).

2.3. Marketing and Business Strategy in Construction Project Management

Marketing communication in the construction sector is not about direct consumer sales but about building long-term client relationships, enhancing firm visibility, and securing new project opportunities (Alshaketheep et al., 2020; He and Harris, 2020; Hoekstra & Leeflang, 2020). Strategies include public relations, participation in industry events, digital presence through professional platforms, and submission of bids and tenders aligned with client expectations (Hanaysha, 2020; Hoekstra and Leeflang, 2020).

The pandemic forced construction project managers to adopt digital tools for client engagement and stakeholder updates. Virtual site visits, online proposal submissions, and webinars became essential components of business development strategies (Toubes et al., 2021). Purpose-driven messaging, aligned with CSR and health safety measures, further demonstrated a firm's reliability and adaptability (DiResta et al., 2020).

The digitalisation of communication and promotion allowed firms to stay connected with existing and prospective clients. Alshaketheep et al. (2020) note that online presence helped firms attract attention to their crisis management efforts, boosting brand trust. This is particularly important in construction where project managers act as both technical leads and brand ambassadors.

2.3.1. Building Client Trust and Engagement

Client trust in the construction industry hinges on clear communication, ethical practices, and demonstrated project performance. During the pandemic, firms that maintained transparency about project delays, health measures, and risk management earned client loyalty (Popa et al., 2022). Project managers played a pivotal role in delivering these communications, thereby reinforcing business relationships and brand equity.

Park et al. (2022) assert that authentic and empathetic communication—such as updates on worker safety and proactive project planning—helped reduce client uncertainty. Such actions aligned with traditional business strategies in construction, where trust and reliability are key to securing repeat business (Taylor, 2020).

2.3.2. Digitalisation

The biggest trend in marketing communications with respect to the global pandemic was digitalisation. In the wake of COVID-19, many companies used digitalisation as an innovative tool for retaining and expanding their consumer bases (He and Harris, 2020) since digital processes were mostly unaffected by the state of events (Taylor, 2020). Consumers themselves were found to embrace digitalisation, especially given the restrictions and uncertainties caused by the virus (Alshaketheep et al., 2020). Digitalisation is the process by which technological advances and online platforms are used to conduct business matters (Alshaketheep et al., 2020; Toubes et al., 2021); hence, with the appearance of the COVID-19 virus, digitalisation was not just an alternative but also a necessary medium for business survival. Several authors like Alshaketheep et al. (2020), He and Harris (2020), Hoekstra and Leeflang (2020), Sheth (2020) and Taylor (2020) have echoed these sentiments of new marketing operations and paradigm shifts due to changing consumer behaviours and the move towards digitalisation.

2.3.3. Agility and Flexibility in Construction Business Strategies

Agility and flexibility became critical to business survival in the built environment sector. Faced with material shortages, labour disruptions, and health regulations, construction project managers had to adapt quickly. These adjustments included rescheduling project timelines, incorporating modular construction techniques, and renegotiating supplier contracts (Alshaketheep et al., 2020; Hanaysha, 2020).

According to Sheth (2020) and Taylor (2020), agile strategies that prioritise adaptability, learning, and decentralised decision-making enabled firms to remain competitive during the pandemic. In construction, this agility translated into reconfigured workflows, digital project management platforms, and proactive stakeholder engagement. Project managers who embraced such changes contributed directly to business continuity and resilience.

The COVID-19 pandemic has reshaped expectations, practices, and strategies within the built environment sector. While marketing strategies are not a direct responsibility of construction project managers, their roles have evolved to include client engagement, CSR alignment, and digital communication which are core elements of business strategy. This literature review fills a notable gap by examining these themes through the lens of construction project management, offering a contextualised understanding of how industry professionals adapted during the crisis.

3. Research Methodology

This study adopted a qualitative research design underpinned by an interpretivist paradigm (Saunder, et al., 2019)to explore the adaptive marketing and business strategies employed by construction project managers in the post-pandemic context. The aim was to understand the lived experiences, practices, and perspectives of professionals operating within the built environment sector in South Africa.

A purposive sampling approach was used to identify participants via LinkedIn who are professionally registered with the South African Council for the Project and Construction Management Professions (SACPCMP). A total of eight participants were interviewed virtually via Zoom. Each interview lasted approximately 30 minutes, and responses were recorded and transcribed for analysis.

Although the sample size of eight participants appears limited given the extensive SACPCMP database, the qualitative nature of the study prioritised depth over breadth. The chosen sample size aligns with qualitative research norms where rich, detailed accounts from a smaller group provide valuable insights into context-

specific phenomena (Creswell, 2014). Furthermore, interviews were deemed appropriate due to the exploratory nature of the study, allowing for open-ended inquiry into sensitive and strategic professional experiences that may not be captured through surveys or quantitative tools.

This methodological approach ensured that the nuances of project managers' strategic decisions during a volatile period were adequately explored, providing valuable contributions to the understanding of business strategy adaptation in the construction industry post-pandemic.

A thematic analysis approach was used to identify common patterns and key insights across the interviews. The data was coded using Nvivo 14 to ensure accuracy and depth in the analysis. The themes emerging from the data were compared with existing literature to establish the consistency or divergence of findings, providing a well-rounded understanding of post-pandemic marketing adaptations.

4. Findings and Discussion

All participants in this study were male as indicated in Table 1. The researcher acknowledges the inherent gender bias in the sample; however, this was not intentional. The composition of the participant pool resulted from individuals' availability and willingness to participate at the time the interviews were conducted. It reflected the profile of those who were available and willing to participate at the time of data collection. Additionally, the participants had an average of 26 years of employment experience, and the highest academic qualification attained among them was a master's degree. Six of the participants were professionally registered with the SACPCMP, and two had their PMP registration.

Table 1: Participant Demographic Information

Participant	Age	Gender	Qualification	Years of Experience
P1	52	Male	Master's Degree	31
P2	45	Male	Honours Degree	23
P3	56	Male	Honours Degree	34
P4	40	Male	Post Grad Diploma	17
P5	49	Male	Honours Degree	28
P6	42	Male	Bachelor's Degree	20
P7	55	Male	Bachelor's Degree	32
P8	47	Male	Honours Degree	26

Four themes emerged from the data: increased digital marketing efforts, building consumer trust and engagement, agility and flexibility in marketing strategies and challenges in adapting marketing strategies, which are elaborated on further below.

4.1. Increased Digital Marketing Efforts

A notable finding from the interviews was the significant increase in digital marketing efforts by project managers during the COVID-19 pandemic. Many participants highlighted the shift towards online platforms as a means to maintain engagement with customers. Participant 2 noted, *"We had to completely rethink our marketing strategy. Traditional methods were no longer effective, so we increased our digital presence through social media and targeted advertising."*

Participant 5 emphasised the role of social media, stating, *"During the lockdown, our social media interactions doubled. We had to create more engaging content, collaborate with marketing experts, and use data-driven strategies to remain competitive."* This aligns with research by Ceocea, et al. (2022), which underscores digital marketing as a critical tool for business continuity.

Project managers also reported an increased reliance on data analytics. Participant 2 explained, *"We used data analytics extensively to track website traffic and tailored our campaigns accordingly. Understanding what our clients wanted in real-time was key to our success."*

However, some project managers acknowledged challenges in sustaining digital efforts. Participant 8 stated, *"The initial shift to digital marketing was necessary, but maintaining it requires constant innovation. Consumers are now bombarded with digital content, so standing out is becoming more difficult."* This highlights the need for businesses to balance digital marketing expansion with meaningful and personalised engagement strategies.

These insights reinforce the necessity for businesses to invest in digital marketing, not only as a short-term crisis response but as a long-term strategy for sustained

growth in an increasingly digital economy (Ceocea, et al., 2022).

4.2. Building Consumer Trust and Engagement

Project managers emphasised that building consumer trust and engagement was a critical strategy during and after the COVID-19 pandemic. Many businesses focused on transparency, customer-centric communication, and corporate social responsibility to foster stronger relationships with their customers. Participant 3 stated, *"During uncertain times, clients wanted reassurance. We made a conscious effort to be as transparent as possible about our service offerings, delivery times, and safety measures."* This aligns with Sawang et al. (2023), who stress that trust-building through clear communication enhances customer loyalty.

Another key strategy was personalisation. Participant 1 explained, *"We tried to deliver personalised experiences. Clients responded better when they felt our brand understood their unique needs and preferences."*

Corporate social responsibility (CSR) also played a significant role in strengthening consumer trust. Participant 4 highlighted, *"We supported local communities during the pandemic. Clients appreciated the effort, and it strengthened our brand loyalty."* This echoes the findings of DiResta, et al. (2020) and Sheth (2021), who emphasise that brands demonstrating social responsibility see greater long-term engagement.

However, challenges in maintaining engagement were noted. Participant 7 expressed concern, stating, *"Consumer expectations have evolved. They now demand authenticity and consistency across all touchpoints, which requires continuous effort and adaptation."* This highlights the need for businesses to sustain their trust-building efforts beyond the pandemic era.

Businesses successfully built consumer trust and engagement during the pandemic by focusing on transparency, personalisation, and corporate responsibility. These findings suggest that trust remains a key pillar of marketing strategies moving forward, requiring brands to maintain clear, authentic, and customer-focused communication.

4.3. Agility and Flexibility in Marketing Strategies

Project managers highlighted that agility and flexibility were crucial for business survival during the pandemic. Participant 6 noted, *"We had to make rapid adjustments to our marketing approach almost overnight. Consumer behaviours were changing daily, and only businesses that could quickly pivot were able to stay ahead."* This supports Sheth (2021), who emphasises that businesses that adopt real-time data-driven strategies are more resilient in times of crisis.

Participant 2 explained, *"Our supply chain was disrupted, and we had to rethink how we delivered products and services. Flexible marketing strategies allowed us to communicate these changes effectively to our customers, keeping them engaged and informed."* This aligns with the findings of Alshaketheep et al. (2020), who highlight the role of adaptive marketing in crisis management.

Participants also stressed the need for real-time responsiveness. One interviewee stated, *"We moved to a more agile decision-making process so that we could adapt quickly to clients' needs."* This reflects the argument by Sawang, et. al. (2023) and Sheth (2021) that marketing strategies must be iterative and responsive to changing customer expectations.

Agility and flexibility enabled businesses to respond effectively to unpredictable market shifts during the pandemic. These findings indicate that companies should continue embracing adaptive marketing approaches to remain competitive in an evolving business environment.

4.4. Challenges in Adapting Marketing Strategies

While many project managers successfully adapted their marketing strategies, they also faced significant challenges. One major issue was the rapid need for upskilling. As Participant 5 noted, *"We had to learn new digital tools almost overnight. The pressure to adapt was immense, and not everyone on the team was equipped to handle the transition."* This aligns with the findings of Sheth (2021), who noted that rapid digitalisation exposed skill gaps in many organisations.

Another challenge was resource allocation. Participant 2 explained, *"Our budget constraints made it difficult to implement all the changes we wanted. We had to prioritise digital initiatives that provided the most immediate impact."* This supports Mushe (2023) assertion that financial constraints often limit the extent of digital transformation efforts.

Additionally, digital fatigue among consumers was a growing concern. Participant 7 shared, *"People were overwhelmed with digital content. Engagement levels started high but began to drop as clients became more selective about what they paid attention to."* This echoes the concerns raised by Ceocea et al. (2022) regarding digital saturation and consumer burnout.

These challenges highlight the complexities of digital transformation and the need for businesses to adopt sustainable, well-planned marketing strategies that balance innovation with consumer needs.

5. Conclusion and Further Research

This study highlights the critical role of project managers in navigating marketing challenges during and after the COVID-19 pandemic. The findings demonstrate that digital transformation, corporate social responsibility (CSR), and consumer trust-building were pivotal in sustaining business resilience. Project managers leveraged digital marketing tools, social media engagement, and data-driven insights to maintain customer relationships while adapting to shifting client behaviours and market uncertainties.

Moreover, integrating CSR into marketing strategies enhanced consumer loyalty, provided that initiatives were perceived as authentic and aligned with broader societal concerns. Agility and flexibility emerged as essential competencies for project managers, as they continuously adjusted marketing strategies to respond to rapidly changing external conditions. However, challenges such as digital fatigue, budget constraints, and scepticism towards CSR initiatives indicate the need for a balanced approach to marketing adaptation.

The study contributes to the growing body of literature on crisis-driven marketing by emphasising the intersection of project management and marketing strategies. Future research could further explore industry-specific adaptations and long-term impacts of these strategies beyond the pandemic context. For businesses, the key takeaway is the importance of proactive and consumer-centric marketing approaches that integrate digital innovation, social responsibility, and strategic adaptability to ensure resilience in uncertain environments.

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Barriers to the Adoption of Emerging Technologies for Quality Management in Construction Projects in Nigeria

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Abstract

The aim of this study is to examine the barriers to the adoption of emerging technologies for quality management in construction projects. A questionnaire was designed to examine the barriers to the adoption of emerging technologies for quality management in construction projects. Questionnaires were distributed, and 127 valid responses were elicited. Thereafter, data were analysed using descriptive and inferential statistics. The study was limited to barriers to the adoption of emerging technologies in construction quality management in Nigeria utilising a quantitative research method. The study's findings can serve as a model for tackling similar barriers in other countries in the global south. The results from the study revealed that cost **(**high costs of software and hardware), resistance to change, and risk of technology obsolescence were the top most three barriers to the adoption of emerging technologies in construction quality management in Nigeria. From a practical viewpoint, overcoming these barriers to adoption of emerging technologies for quality management will lead to broader spread adoption of emerging technologies for quality management, enhancing project efficiency and outcomes.

Keywords: Adoption, Barriers, Construction projects, Emerging technologies, Quality management

1. Introduction

Construction industry plays a significant function in the economic and national growth of a country. However, the impact of this sector has been affected by productivity problems and poor performance of projects as reported by Osuizugbo and Alabi (2021). Factors responsible for the poor construction project performance have been identified by past studies to include industry complexity, poor quality, safety issues, low productivity, slow innovation, high costs, client dissatisfaction, and skill shortages among others (Osuizugbo & Ojelabi, 2020). Notably, poor-quality in construction project delivery has been reported as the most challenging and prevalent issue within the construction industry (Luo *et al.*, 2022). Meanwhile, the growth of the sector relatively depends on the quality of projects. Thus, effective management of construction projects' quality should be paramount to construction stakeholders. In other words, quality management is a key indicator which affects the value of construction projects.

More recent attention has focused on developing emerging technologies for enhancing construction quality management and inspection, which can improve the image of construction industry. Emerging technology in this study refers to innovative, cutting-edge advancements that are in the early phases of construction and have the possibility to extensively impact society, industries, and economies. Blockchain, Photogrammetry and laser scanning, Augmented Reality (AR), Building Information Modelling, Internet of Things (IoT), and Computer Vision (CV) among others are some of the emerging technologies employed in construction quality management (Luo *et al.*, 2022; Safa *et al.*, 2015; Wang, 2008). These emerging technologies are designed to provide remarkable benefits to safety on site, quality, and productivity improvement. Adopting these emerging technologies in construction projects help eliminate information barriers between design, prefabrication, and construction, enhance training, safety, and communication, reduce rework, enable process monitoring, preventive maintenance, site productivity assessment, real-time structural health tracking, and enhance defect detection and quality management (Luo *et al.*, 2019).

Despite many benefits that are linked with these digital tools, there are some challenges that hinder its adoption and application in the construction sector which includes resistance to change, security concerns, high costs of hardware and software, absence of standardised guidelines and practices, lack of financial need, lack of market data for technology incorporation, and low level of knowledge among others (Tam *et al.,* 2024; Chen *et al.*, 2023; Maqsoom *et al.*, 2023; Kamaruddeen *et al.*, 2022). According to Saka and Chan (2019), the construction industry has been accused for lagging behind in terms of technology implementations compared to other industries. The common approach to assessing new policies and their execution is studying the barriers/challenges they face, which typically requires identifying the root causes of resistance to change (Osuizugbo *et al.*, 2024). Using

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Nigeria as a representative case, these barriers are specifically important because of economic constraints, and poor-quality in construction project delivery. These barriers to emerging technologies are intensified by a shortage of technical expertise and insufficient commitment in research and development, hindering the application of advanced construction projects' quality management practices. Secondly, high costs of software and hardware, and low knowledge of digital tools formed additional barriers. These barriers overlap with economic and regulatory factors, where monetary limitations hinder way in to cutting-edge technologies, and regulatory guidelines might lack the necessary enforcement and encouragement methods to drive the adoption and application of emerging technologies in construction quality management. Addressing these interconnected barriers is vital for enhancing construction projects' quality in Nigeria and other nation in global south.

Over the course of time, several studies have been conducted on quality management. For instance, Keenan and Rostami (2019) examined the influence of quality management systems on construction performance. Wickramarachchi *et al.* (2018) studied total quality management execution in Sri Lankan construction industry. In contrasts, Wang and Wei (2020) investigated BIM-based technology implementation on quality management in construction engineering. Wang (2008) proposes Radio Frequency Identification (RFID)-based technology for enhancing construction quality inspection and management. The study by Safa *et al.* (2015) presented an automated approach to construction quality management, utilising advanced technologies to detect defects. Majority of these existing researches have largely domicile in global north. Moreover, not all African countries have derived the same benefit from emerging technologies, including digitalisation processes (Badaru & Mphahlele, 2023). Thus, study that addresses barriers to the adoption of emerging technologies for quality management in construction projects in Nigeria is scarce. This implies that, there is little or no understanding of factors that hinder the adoption of emerging technologies for quality management in construction projects in Nigeria. In addition, industry characteristics influence the adoption of emerging technologies for construction practices (Kamaruddeen *et al.*, 2022). This indicates that, the adoption and application of emerging technologies for quality management practices may vary from one country to another. Hence, to tackle the identified gap in existing knowledge, this study aims to examine the barriers to the adoption of emerging technologies for quality management in construction projects in Nigeria.

The study's findings contributed to more effective quality management studies by highlighting critical barriers to the adoption of emerging technologies in construction quality management. An understanding of these barriers could aid construction practitioners, organisations, government, and policymakers in developing strategies for minimising these barriers and promoting the application of emerging technologies for quality management in the sector. Overcoming these barriers enhances efficiency, reduces delays and costs, and improves build quality, leading to increased investor confidence and sustainable infrastructure development while also stimulating job creation, enhancing local skill development, and attracting foreign investments, ultimately driving industry growth and economic advancement in Nigeria and other developing countries.

2. Theoretical Framework

This section explains the theoretical foundations that encourage the adoption of emerging technologies for quality management in construction. The theoretical framework offers a broad representation of the associations between elements within a particular subject. In order to deepen the knowledge on how emerging technologies for quality management in construction are adopted, the study draws on established theories. Specifically, the **technology acceptance model** seems to be appropriate.

2.1. Technology Acceptance Model

Technology acceptance model (TAM) is the commonly used theory to explore user acceptance behaviour, rooted in social psychology, particularly drawing from reasoned action theory (Ma & Liu, 2004). This theory explains how technology's users arrive at accepting and utilising technology as shown in Figure 1 (Ma & Liu, 2004). TAM can be used to analyse the perceived usefulness and perceived ease of use of emerging technologies in construction quality management before accepting the technologies by either

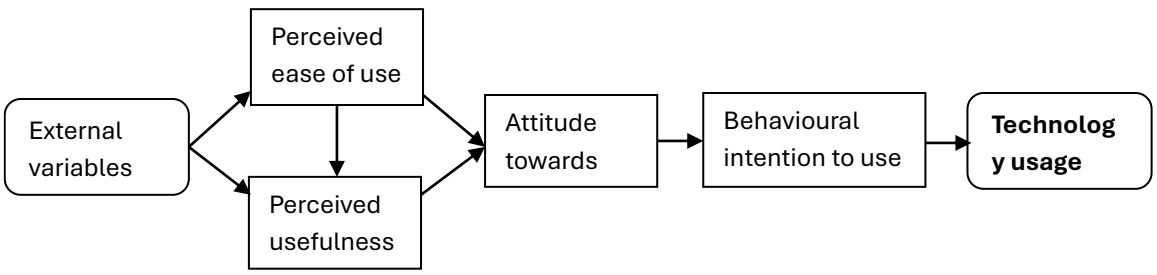


Figure 1: Technology acceptance model (Source: Ma & Liu, 2004)

organisations or individuals (Ma & Liu, 2004). In the context of quality management in construction, emerging technologies like quality management software, BIM, Blockchain, or Computer Vision are often encounter resistance as a result of challenges in these aspects (Tam *et al.,* 2024; Saka & Chan, 2019). For example, construction firms or workers may perceive these technologies as unnecessary or complex to use, resulting to low adoption rates. Factors such as security concerns, high costs of software and hardware, absence of standardised guidelines and practices, lack of market data for technology incorporation or the low level of knowledge/lack of training further compound this resistance, making it more difficult for the construction sector to take full benefit of emerging technologies.

Implications of technology acceptance model in surmounting barriers to emerging technologies in construction quality management are significant. Construction firms can develop approaches that encourage adoption of emerging technology by tackling both perceived ease of use and usefulness. This may include better training and education programmes to demonstrate the advantages of emerging technologies in enhancing quality control, or simplifying user interface to make the digital tools more instinctive and user-friendly for construction practitioners. TAM highlights the role of organisational culture and leadership in promoting a positive attitude towards technological change (Ma & Liu, 2004). Thus, construction organisations can mitigate barriers to adoption of emerging technology as well as improve project management quality by clearly communicating long-term benefits and promoting innovation.

3. Research Methodology

The study used quantitative research approach to determine the barriers to adoption of emerging technologies for quality management in construction projects in Nigeria. This research approach elicits numerical data for analysis, ranking, or grouping (Creswell, 2014) and allows broad population insights within a short time (Daniel, 2016). Quantitative research relies on statistical analysis for conclusions and predictions (Yilmaz, 2013), making it ideal for this study's broad sampling approach. A literature review on barriers to emerging technologies for quality management in construction was conducted so as to identify these barriers. A list of these barriers which was identified in the literature was utilised to develop questionnaire to attain the aim of the research. The questionnaire was utilised to gather data from the survey participants regarding the barriers to emerging technologies for quality management in construction. The study adopted purposive sampling technique in identifying the survey sample for distribution of questionnaire. The purposive sampling method is a non-probability approach, which based on features of study population. The research utilised key construction professionals and the respondents focus were builders, architects, electrical engineers, structural engineers, quantity surveyors and mechanical engineers, operating in construction projects within consulting, client and contracting firms in Nigeria. The study considered Nigeria because, the construction industry of Nigeria faces enormous challenges including poor management, project delays, and poor quality control among others which may be reason for the slow adoption of sustainable construction (Ogunmakinde *et al.*, 2019). These survey participants were selected due to their construction experience. A total of two hundred and nine (209) questionnaires were dispersed to survey participants, after scrutinising the collected questionnaires, only 127 were useful, representing a 60.8% response rate. The respondents completed the questionnaire by providing their feedback on the barriers to emerging technologies for quality management in construction, based on a 5-point Likert scale. The scale ranged from 1 (not critical) to 5 (very critical), with 2 representing slightly critical, 3 representing moderately critical, and 4 representing critical. Data collection of this research commenced in May 2024 and was completed in July 2024. The statistical package for social sciences analysed respondents' data using Cronbach's Alpha test, frequency, percentage, mean value and ranking. A reliability score of 0.904 exceeded the 0.70 minimum threshold (Taherdoost, 2016), guaranteeing strong internal consistency for the scale.

4. Findings and Discussion

4.1. Demographic Characteristics of Respondents

From the study, majority of respondents that involved in the survey are within the age bracket of 31-40 years, representing 40.93% (52). This is followed by age bracket 41-50 years, representing 37.8% (48), 21-30 years representing 15.7% (20) and 51 years and above, representing 5.5% (7). This shows that the survey participants are mature to involve in the research. Based on the respondents' professional background, builders are 54 (42.5%), followed by architects with 28 (22%), quantity surveyor with 20 (15.7%), electrical engineers 12 (9.4%), structural engineer 9 (7.1), and mechanical engineer 4 (3.1%). For the academic qualification of the respondents, 46.5% of the study population were bachelor degree holders, followed by postgraduate diploma holder with 30.7%, masters degree holder with 13.4%, higher national diploma with 5.5%, and doctorate degree holder with 3.9%. For work experience, 11-15 years and 16-20 years have same number of participants with 40 (31.5%), 21 years and above have 27 (21.3%), 6-10 years have 17 (13.4%), and 1-5 years experience have 3 (2.4%). These results confirmed respondent's eligibility to involve in the research. Furthermore, the consulting, contracting, and

client firms have 62 (48.8%), 62 (48.8%), and 3 (2.4%) respectively.

4.2. Barriers to Emerging Technologies in construction quality management

This section gives the data analysis of barriers to emerging technologies for quality management in the Nigerian construction industry. As shown in Table 1, **"**Cost **(**high costs of software and hardware)" has the highest mean value of 4.1260 and was ranked first. Then, followed by "resistance to change" with a mean value of 3.9764, ranked second, and "risk of technology obsolescence" with a mean score of 3.9055, and thus ranked third. From the rear, "limited resources" was ranked lowest with a mean score of 3.1417. The mean scores presented in Table 1 indicate that the barriers to emerging technologies for quality management are prevalent within Nigeria's construction industry.

financial limitations, making it difficult for the enterprise to assign resources to these emerging technologies (Nkwinika & Akinola, 2023). This lack of enthusiasm is driven by the perception that investments in emerging technologies may not yield immediate returns, because the industry is still majorly relies on traditional approach that may seem more economical in the short run (Owolabi *et al.*, 2019). In order to tackle this, government interference is a necessity, like tax incentives, public-private partnerships or subsides to reduce the cost burden on construction organisations. This could facilitate greater access to essential technology, improve buildability, and enhance overall project quality in construction industry (Liu *et al.*, 2023).

The second in rank of barriers to emerging technologies for quality management in the Nigerian construction industry is resistance to change. The finding by Tam *et al.* (2024) is similar to this finding, which revealed that the most significant barrier to advanced construction technology in Vietnam was social and usual resistance to change. This resistance frequently stems from deep-rooted practices and a preference for traditional approaches, which several construction practitioners are more familiar with and perceive as less disruptive (Lines *et al.*, 2015). Moreover, the adoption of advanced technologies such as quality management software and BIM among others requires a major transformation in mindset, skill sets, and workflows (Doumbouya *et al.*, 2016). In addition, the construction industry in Nigeria values personal expertise and manual practices, creating unwillingness to trust digital equipments over traditional human judgment (Olanrewaju *et al.*, 2024). Addressing this barrier will need focused initiatives like leadership support to promote a culture of innovation and adaptability, demonstrations of the long-term benefits of technology

Table 1: Ranking of barriers to emerging technologies in construction quality management

No.	Barriers	Mean Value	Rank
1	**Cost (**high costs of software and hardware)	4.1260	1
2	**Resistance to change**	3.9764	2
3	**Risk of technology obsolescence**	3.9055	3
4	**Uncertain return on investment (ROI)**	3.7953	4
5	Technology availability	3.7795	5
6	Integration Issues	3.7402	6
7	**Regulatory and legal challenges**	3.6850	7
8	**Complexity**	3.6693	8
9	**Limited industry collaboration and standards**	3.6693	8
10	**Industry fragmentation**	3.4646	10
11	**Overreliance on technology**	3.3858	11
12	**Skills gap**	3.3543	12
13	**Data security concerns**	3.3465	13
14	**Lack of awareness (low level of knowledge)**	3.3307	14
15	**Dependency on technology providers**	3.1575	15
16	**Limited resources**	3.1417	16

4.3. Discussion on Key Findings

Ranking of the sixteen (16) barriers to emerging technologies for quality management in construction demonstrates that cost **(**high costs of software and hardware) was considered the most critical barriers to emerging technologies for quality management in the Nigerian construction industry. This finding could be because of the high cost of initial investment to procure advanced technologies like quality management software and BIM among others (Maqsoom *et al.*, 2023). This finding is in support of previous studies that identified cost as a major factor that hinders the use of advanced technologies in construction (Tam *et al.*, 2024; Maqsoom *et al.*, 2023). The acquisition of these technologies involves not only the initial costs of software and hardware but also recurring expenses for specialised staff training, system maintenance, and upgrades. Several construction organisations, mostly small and medium sized enterprise, often encounter

application, and industry-wide education programmes in the construction sector (Askar *et al.*, 2021). Providing incentives and encouraging a gradual transition for early adopter could aid reduce resistance and foster a smoother incorporation of emerging technologies in construction.

Another significant factor that hinders the adoption and implementation of emerging technologies for quality management in the Nigerian construction industry is risk of technology obsolescence. This barrier was ranked third. This finding could be that hardware and software of these innovations can quickly become outdated, forcing organisations to continually invest in new systems to remain current, mainly as a result of fast pace of technological advancement. For construction firms in Nigeria, which usually operate on tight budgets (Ikechukwu & Akiohnbare, 2017), this poses a major operational and financial challenge. The fear of investing in digital tools that could quickly become obsolete leads to hesitation, as companies fear the costs of upgrading systems within a short time. Construction organisations should therefore focus on scalable, adaptable technologies with continual updates to ensure longevity and alleviate obsolescence risks so as to address this barrier (Askar *et al.*, 2021). Also, government policies fostering technology adoption and providing incentives could ease the financial tension of keeping up with emerging technologies (Hua *et al.*, 2023).

In summary, these identified barriers differ when compare to those identified in developed countries. Take for example; Chen *et al.* (2023) identified "status quo industry standards", "lack of client interest" and "lack of financial need/drive" as top three critical barriers to digital technology application in New Zealand. Barriers such as "lack of financial need/drive" and "status quo industry standards" stem from well-developed construction practices and profitability, reducing the urgency for digital technologies. On the other hand, in developing countries like Nigeria, financial constraints, high costs of software and hardware, and technology obsolescence present more fundamental obstacles, as construction organisations struggle with affordability and sustainability of digital tools. Furthermore, while resistance to change exists in both countries (i.e. Nigeria and New Zealand), it is often more pronounced in developing countries as a result of limited technical expertise and lower exposure to digital innovations in construction quality management.

5. Conclusion and Further Research

Nigerian construction industry is facing several factors that hinder the adoption and implementation of emerging technologies for quality management in construction projects. The Adoption of emerging technologies in construction projects help eliminate information barriers between design, prefabrication, and construction, enhance training, safety, and communication, reduce rework, enable process monitoring, preventive maintenance, site productivity assessment, real-time structural health tracking, and enhance defect detection and quality management. Emerging technologies have not been successfully integrated in construction sector of Nigeria as it has in global north. The study aimed at examining the barriers to the adoption of emerging technologies for quality management in construction projects in Nigeria. A questionnaire survey of 127 respondents comprising of builders, architects, electrical engineers, structural engineers, quantity surveyors and mechanical engineers, operating in construction projects within consulting, client and contracting firms in Nigeria was conducted to determine barriers to the adoption of emerging technologies in construction quality management in Nigerian construction industry. The results from the study have shown that cost **(**high costs of software and hardware), resistance to change, and risk of technology obsolescence are the top most three barriers to the adoption of emerging technologies for quality management in the Nigerian construction industry. The findings of the research offer detailed insights into the factors hindering emerging technologies in construction quality management. An understanding of these barriers could aid construction practitioners, organisations, government, and policymakers in developing strategies for minimising these barriers and promoting the application of emerging technologies for quality management in the sector. Overcoming these barriers enhances efficiency, reduces delays and costs, and improves build quality, leading to increased investor confidence and sustainable infrastructure development while also stimulating job creation, enhancing local skill development, and attracting foreign investments, ultimately driving industry growth and economic advancement in Nigeria and other developing countries.

Based on the data analysis, it is evident that cost **(**high costs of software and hardware) was the major factor hindering adoption of emerging technologies in construction quality management. The present findings suggest the need for government involvement, through tax incentives, or subsidies to reduce the cost burden on organisations. Such intervention could facilitate greater access to essential technology, improve buildability, and enhance overall project quality in construction industry. The study focuses on the views from Nigeria regarding barriers to adoption of emerging technologies in construction quality management which has not been sufficiently understood previously. The research was limited to barriers to adoption of emerging technologies in construction quality management in Nigeria using a quantitative research method. Hence, this research outlined the following area for further research. Future study can take a more comprehensive method by

incorporating qualitative insights from focus groups or in-depth interviews with a wider range of stakeholders, including policymakers, vendors, government officials, to enhance and complement the quantitative results. Secondly, future research may consider including case studies or best practices from other regions to enhance its impact. This information will add to the body of knowledge by providing comparative understanding into the effectiveness of emerging technologies in construction quality management across diverse nations, facilitating the adaptation of best practices and enhancing industry standards.

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SMME Collaboration Dynamics in International Construction Joint Ventures in Harare, Zimbabwe

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Abstract

This study explores the collaboration dynamics of local contractors, particularly small, medium, and micro enterprises (SMMEs), involved in international construction joint ventures (ICJVs) in Zimbabwe. It seeks to investigate the experiences, challenges, and opportunities faced by local contractors collaborating with international firms. The paper aims to identify and analyze the key obstacles that hinder their performance, as well as the strategies or practices that enhance their ability to thrive within these joint ventures. Using empirical data, the study identified success factors and potential barriers limiting SMME's in ICJV's. A qualitative approach was adopted using a semi-structured interview schedule to collect empirical data. A purposive sample of 20 Zimbabwean SMMEs that have been involved in ICJV's were interviewed. The findings revealed the primary challenges local SMMEs face in ICJVs. It also revealed strategies that have enabled some SMMEs to successfully navigate these joint ventures and achieve favourable outcomes. The limitation of this study was the potential for response bias, as participants' accounts may not reflect a broader context. Furthermore, the size of the sample restricts generalizability of the findings to the broader population.

Keywords: International construction joint ventures, small medium micro enterprises (SMME's), economic development, Zimbabwe

1. Introduction

International construction joint ventures (ICJVs) are integral to the global economy, providing significant advantages in skill transfer, technology acquisition, and market access (Bakri *et al.*, 2022; Oti-Sarpong and Leiringer, 2016; Panibratov, 2016). Nevertheless, the success of ICJVs hinges on effectively addressing cultural differences, managing risks, and ensuring regulatory compliance (Bakri *et al.*, 2022; Chao *et al.*, 2023; Hwang *et al.*, 2015). By comprehending the driving factors and challenges associated with ICJVs, businesses and policymakers can enhance these ventures for mutual benefit.

Small, medium, and micro enterprises (SMMEs) account for more than 90% of businesses and provide up to 40% of gross domestic product in developing countries (Habibi *et al.*, 2024). Many small, medium, and micro enterprises (SMMEs) face difficulties competing effectively in International construction joint ventures (ICJVs) due to constraints such as limited resources, inadequate technical expertise, and institutional barriers. For SMMEs in developing countries like Zimbabwe, participation in ICJVs involves challenges that may impede their ability to maximize these opportunities. These issues are especially evident in the construction sector, which feature intricate supply chains, substantial capital requirements, and stringent regulatory environments. Understanding the dynamics that SMMEs encounter in ICJVs is essential as developing nations like Zimbabwe work to rebuild their economy and infrastructure (Govender and Telukdarie, 2020; Mengistu *et al.*, 2024; Tetteh *et al.*, 2023).

This study seeks to address the research gap concerning the success of small, medium, and micro enterprises (SMMEs) in developing countries within the context of international construction joint ventures (ICJVs). While existing literature has thoroughly examined ICJVs from the perspective of multinational corporations or larger firms, there is a paucity of information regarding the experiences of local contractors, especially SMMEs, involved in these partnerships. Additionally, the distinctive socio-economic and institutional contexts of Zimbabwe make it essential to investigate how local SMMEs can navigate challenges and capitalize on opportunities within ICJVs.

The research is guided by the following questions:

1.What are the primary challenges faced by Zimbabwean SMMEs in ICJVs?
2.What strategies or practices have enabled SMMEs to navigate these challenges and achieve favorable outcomes?

There are three key objectives aligned with these questions, namely:

i. To identify the critical obstacles that limit the functioning of local SMMEs in ICJVs.

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ii. To analyze benefits and advantages that enhance the capacity of local SMMEs to thrive in global partnerships.
iii. To provide practical insights that can inform policymakers and business leaders in supporting SMMEs' participation in ICJVs.

This study contributes to the existing body of knowledge on ICJVs by highlighting the perspectives of local SMMEs, which are frequently overlooked in academic and policy discussions (Wang *et al.*, 2021). Additionally, the insights obtained from this research can inform the development of policies and support mechanisms aimed at increasing the competitiveness of SMMEs in global partnerships. The study also offers practical guidance to local contractors, helping them build resilience and improve their performance in ICJVs. This research addresses a gap in literature and provides actionable insights for stakeholders interested in promoting sustainable and inclusive growth in the construction industry. It emphasizes the role of local SMMEs in international collaborations, contributing to economic development and integration in developing markets (Ghauri and Elg, 2018).

2. Literature Review

Small, medium, and micro enterprises (SMMEs) in developing countries' construction sectors can drive economic growth (Mabasa *et al.*, 2023). However, they face challenges in international construction joint ventures (ICJVs) (Nxele and Hoque, 2022). This review covers the main obstacles, success factors, mitigating strategies, and theoretical frameworks related to local SMME participation in ICJVs.

2.1. Barriers faced by SMMEs in ICJVs

SMMEs frequently face resource limitations, including financial capital, technical expertise, and skilled labor. These constraints impact their ability to meet the requirements of ICJVs, which demand advanced project management and compliance with international standards. Institutional barriers, such as regulatory complexity, lack of government support, and corruption, further compound these challenges in many developing countries (Edeh *et al.*, 2024; Nwajiuba *et al.*, 2020). Additionally, cultural differences and power imbalances in ICJVs often disadvantage local contractors compared to their international counterparts. For example, decision-making processes are often dominated by international firms, reducing opportunities for knowledge transfer and capacity building for SMMEs (Liu *et al.*, 2020).

2.2. Positive impact of SMME engagement

Involving small, medium, and micro enterprises (SMMEs) in international construction joint ventures (ICJVs) is crucial for their growth and integration into global value chains. These ventures come with challenges that can be mitigated through strategic interventions. Building networks and forming alliances help SMMEs gain resources, expertise, and market opportunities (Sodangi, 2023). Partnerships with larger firms facilitate resource sharing and knowledge transfer, enhancing SMMEs' competitive positioning. Effective knowledge management, including training, mentorship, and experience-sharing, develops their technical and managerial capacity (Hernayanto *et al.*, 2024). Government policies promoting fair contracting, financing access, and local content requirements are essential. Such strategies enable SMMEs to thrive and sustain their participation in international ventures (Milosavljević *et al.*, 2023).

2.3. Mediating factors for SMME success in ICJV's

Mediating factors such as knowledge transfer, capacity building, institutional support, and trust mechanisms play a crucial role in enhancing the performance of SMMEs in international construction joint ventures (ICJVs). These factors bridge the gap between the challenges/barriers faced by SMMEs and their ability to achieve successful outcomes.

Knowledge Transfer, Capacity Building, Policy and Institutional Support and Trust and Communication

The transfer of knowledge from international firms to local Small, Micro, and Medium Enterprises (SMMEs) is essential for enhancing technical expertise and managerial capabilities (Siachou *et al.*, 2022). Hartini *et al.*, (2024) assert that effective knowledge transfer in joint ventures significantly improves the ability of smaller firms to adopt innovative practices and meet international standards. The willingness of international firms to mentor local enterprises and the absorptive capacity of SMMEs to utilize the transferred knowledge effectively are crucial for successful knowledge sharing. Capacity building involves initiatives that enhance the technical, operational, and managerial skills of SMMEs. Isaacs, (2007) suggest that targeted training programs, financial assistance, and technological support are fundamental in empowering SMMEs to overcome challenges in International Corporate Joint Ventures (ICJVs). Enhanced capacity enables these firms to compete with more established players and gain greater market access. Institutional support, such as favorable policies and regulatory frameworks, alleviates bureaucratic hurdles and corruption, common barriers in developing economies. In Zimbabwe, government interventions like subsidized training and grants have been recommended to boost the competitiveness of SMMEs (Bomani *et al.*, 2022). Such support ensures that these enterprises are better equipped to collaborate with international partners. Trust is a critical factor for success in cross-border partnerships. Effective communication channels foster mutual understanding and reduce the risk of opportunistic behavior. Research emphasizes establishing trust-based relationships to improve collaboration and minimize transaction costs within joint ventures (Xue *et al.*, 2018).

2.4. SMME Performance Outcomes

The outcomes for SMMEs involved in ICJVs can be classified into project-specific success metrics, growth opportunities, and the long-term sustainability of partnerships (Aulia *et al.*, 2024; Jo, 2024; Spence *et al.*, 2008).

2.4.1. Project outcomes, Growth opportunities and Partnership success

The success of projects, such as timely delivery and adherence to quality standards, is a primary measure of SMME performance. Recent research by Wang *et al.*, (2023) highlights that effective collaboration in ICJVs enhances project execution capabilities, enabling SMMEs to achieve benchmarks typically dominated by larger firms. Participation in ICJVs provides SMMEs with avenues for market expansion and increased competitiveness. A study by Kurukulasooriya *et al.*, (2024) depicts that collaboration with international firms helps local contractors gain exposure to global practices, enhancing their market reputation and enabling them to bid for larger, high-value projects. The longevity and sustainability of ICJVs depend on the ability of SMMEs to build strong, enduring relationships with their international counterparts. Research by Sunil *et al.*, (2020) indicates that SMMEs that successfully navigate cultural and organizational differences within joint ventures are more likely to secure repeat partnerships, ensuring continued business growth and stability.

3. Research Methodology

3.1. Research philosophy and approach

This study adopted a qualitative method underpinned by the interpretivist philosophy, which was selected for its capacity to analyze the complex and subjective nature of the research problem. Interpretivism facilitates a deeper exploration of participants' experiences, viewpoints, and interpretations (Creswell and Creswell, 2017). An **inductive approach** guided the research, focusing on theory development through data collection (Saunders *et al.*, 2023). This approach was deemed appropriate as it avoids preconceived hypotheses, aiming instead to explore the experiences of local SMMEs in international construction joint ventures (ICJVs) in Zimbabwe.

3.2. Research population and sampling process

The research population comprised construction firms in Zimbabwe, registered with the Construction Industry Federation of Zimbabwe (CIFOZ) and possessing prior experience in international joint ventures (ICJVs). Limiting the population to CIFOZ-registered firms ensured relevance, as CIFOZ serves as the official regulatory body overseeing Zimbabwe's construction industry (Saris and Gallhofer, 2014). This focus guaranteed that only legally recognized and established market participants were included, providing a robust basis for analyzing IJV experiences. Following Saunders *et al.*, (2023), the sample frame included construction contractors categorized by CIFOZ under classifications D, E, F, G, and H. These classifications reflect the diverse sizes and capacities of construction firms, ranging from medium-sized enterprises (categories D and E) to small- and micro-scale enterprises (categories F, G, and H). By including firms across these categories, the study aimed to capture a broad spectrum of perspectives and skill sets, offering a comprehensive understanding of the experiences of various construction organizations engaged in ICJVs. The targeted sample size consisted of 30 contractors, deemed sufficient to represent diverse viewpoints and experiences while maintaining feasibility for data collection and analysis. This aligns with Yin, (2015), who recommend a minimum of 30 participants in a population of 100 for robust and practical research. This sample size ensured adequate representation while facilitating manageable data analysis.

3.3. Data Collection

30 participants were invited on email to take part in the study. Only 20 participants responded and were interviewed in the study. The study utilized purposive techniques to select knowledgeable participants who had relevant experience in international construction joint ventures (ICJVs) in Zimbabwe. **Purposive sampling** ensured the inclusion of individuals with specific expertise, enabling the collection of meaningful insights (Cohen *et al.*, 2002). Additionally, **snowball sampling** was used to identify further participants through referrals, focusing on contractors within CIFOZ categories D to H to enhance the sample size and diversity. **Primary data** was collected through semi-structured interviews with contractors who had prior ICJV experience, allowing for detailed exploration of their challenges, benefits, and perspectives (Krueger and Casey, 2015). This method enabled the acquisition of rich, qualitative data directly aligned with the research objectives.

3.4. Development of the Research Instrument(s)

The research instrument was designed to ensure alignment with study objectives, employing thematic analysis to interpret data effectively (Yin, 2018). Table 1 outlines the objectives, data collected, and analysis methods, ensuring a comprehensive understanding of ICJVs within Zimbabwe's construction sector. This approach integrated primary insights with secondary evidence to provide a nuanced understanding of the challenges, benefits, and improvement strategies for local SMMEs in ICJVs.

Table 1: Data analysis and presentation methods

Objectives	Data Collection	Data Presentation	Data Analysis Method
To determine the benefits of local SMMEs enrolling in International Construction Joint Ventures?	The benefits associated with ICJVS to local Contractors	Text form	Thematic analysis
To determine disadvantages of local contractors enrolling in International Construction joint ventures?	The disadvantages associated with ICJVS to local contractors	Text form	Thematic analysis
To recommend strategies to improve the development of SMMEs through participation in international construction joint ventures?	The steps that can be taken to improve the development of local contractors	Text form	Thematic analysis

3.5. Data Analysis

The study employed a process of examining, categorizing, and recombining evidence to address its initial proposition (Yin, 2018). The data presentation was in text form, focusing on qualitative approaches and thematic analysis. Interviews with 20 participants resulted in a 67% response rate. These interviews were audio-recorded, transcribed verbatim, and analyzed based on study objectives and semi-structured questions. Emergent themes were coded from these interviews.

3.6. Ethical considerations

Participants received an information sheet about the study's purpose, procedures, and expectations to ensure transparency. Confidentiality was maintained, and informed consent was obtained before participation. Privacy was protected, responses remained anonymous, and participants were reminded of their right to withdraw at any time without repercussions. Consent was also obtained to record interviews for transcription and analysis.

3.7. Demographics of the study

The study gathered data from 20 professional stakeholders in Harare building projects using purposive and snowball sampling methods between May and July 2022. Of the participants, 85% were male and 15% female, with 60% aged 20-39. Formal professional training was present in 65%, including architects, engineers, and estimators (50%), while 35% lacked formal qualifications. The majority were Black Africans (65%), followed by White (20%) and Coloured individuals (15%). Most respondents (35%) had 0–9 years of experience, and 70% of their companies had 0–10 years of operational experience. These insights reflect the professional and demographic composition of Harare's construction sector but are limited by the small sample size and cannot be generalized.

4. Findings

20 SMME's from Harare's building sector participated, selected via purposive and snowball sampling. Most were aged 20–39, predominantly male (85%), and 65% held formal qualifications, reflecting relevant construction knowledge. Data saturation was reached as no new themes emerged, and trustworthiness was ensured through diverse roles. Below are the participant profiles (Table 2) and response rates (Table 3).

4.1. Advantages and benefits of ICJVs

The research findings, supplemented by participant interviews, underline the significant advantages Zimbabwean small, medium, and micro enterprises (SMMEs) gain through their involvement in International Construction Joint Ventures (ICJVs). These advantages span access to resources, market expansion, knowledge transfer, capacity building, and financial stability, all of which contribute to their growth and competitiveness in international markets.

Access to resources

Participants highlighted that ICJVs provide access to advanced resources like cutting-edge technologies and specialized equipment. One participant stated, *"Participating in ICJVs has provided us with access to cutting-edge technologies and specialized equipment that we would not have been able to afford on our own. This has boosted our productivity and project quality – R6."* Another example mentioned was the introduction of innovative construction technologies through ICJV partnerships, which significantly enhanced project efficiency and quality. These findings align with Barnes *et al.*, (2009), who emphasized the role of ICJVs in adopting technologies that improve operational capabilities and project outcomes for local firms.

Market expansion and business development

Participants emphasized that ICJVs help local contractors and SMMEs access larger markets, diversify opportunities, and leverage international partners' expertise. One respondent stated, "*ICJVs have enabled us to secure otherwise unattainable projects,*

Table 2: Profile of participants

Contractor Category (CIFOZ)	Tendering Capacity Maximum	Respondent	Designation	Qualification	Years of in industry
D	USD 1 500 000	R1	MD	NDip	6
D	USD 1 500 000	R2	MD	No qualification	9
D	USD 1 500 000	R3	SM	No qualification	8
D	USD 1 500 000	R4	CD	BArch	6
E	USD 1 000 000	R5	MD	BTech	5
E	USD 1 000 000	R6	Director	No qualification	8
E	USD 1 000 000	R7	PM	BSc	6
E	USD 1 000 000	R8	SM	No qualification	4
F	USD 800 000	R9	CD	BEng	5
F	USD 800 000	R10	Snr. QS	BScQS	7
F	USD 800 000	R11	PM	BScCM	3
G	USD 500 000	R12	MD	No qualification	5
G	USD 500 000	R13	CM	BEng	3
G	USD 500 000	R14	CM	No qualification	7
G	USD 500 000	R15	PM	BTech	3
H	USD 250 000	R16	MD	BArch	6
H	USD 250 000	R17	SPD	No qualification	9
H	USD 250 000	R18	SPD	BEng	8
H	USD 250 000	R19	CM	No qualification	4
H	USD 250 000	R20	SE	BScQS	9
Total		**30**	**20**		

Table 3: Response rate

Contractor Category (CIFOZ)	Tendering Capacity Maximum	Targeted	Respondents	Response Rate
D	USD 1 500 000	6	4	67%
E	USD 1 000 000	6	4	67%
F	USD 800 000	6	3	50%
G	USD 500 000	6	4	67%
H	USD 250 000	6	5	83%
Total Respondents		**30**	**20**	**67%**

strengthening our market presence – R9." This collaboration enhances local firms' competitiveness and operational capabilities. Examples include securing major infrastructure contracts and gaining new suppliers. These benefits lead to immediate financial gains and long-term growth. These findings align with Tong *et al.* (2008) on joint ventures facilitating market access and scalability for smaller firms.

Knowledge transfer and capacity building

ICJVs provide essential benefits in knowledge transfer and capacity-building. Participants have gained insights into advanced construction techniques and project management practices, enhancing their capabilities. *"Through ICJVs, we have gained insights into new construction techniques and project management practices, significantly improving our capabilities – R2."* These partnerships introduce SMMEs to skilled international professionals, fostering development in project management and adherence to global standards. This aligns with both Martin and Emptage, (2019) and Rose *et al.*, (2009) whom found that ICJVs effectively transfer technological expertise and managerial knowledge to local firms. These advantages not only improve SMMEs' technical capacity but also prepare them for larger, complex projects, enhancing their competitiveness in the construction industry.

Financial stability and funding opportunities

Enhanced financial stability and access to funding represent another significant advantage of International Corporate Joint Ventures (ICJVs). One participant noted, *"Access to funding through our ICJVs has given us the confidence to bid for more significant projects and expand our operations – R20."* In addition to financial backing, partnerships with larger firms have diversified revenue streams, thereby reducing financial

risks and enabled business expansion. Financial support through ICJV allowed their company to undertake large-scale projects that were previously beyond their means. These observations corroborate the assertion of Alcantara *et al.*, (2006) who advocate that joint ventures with international firms provide essential financial resources, thereby improving local firms' operational capacity and reducing barriers to market participation.

4.2. Difficulties and drawbacks associated with participating in international joint ventures (ICJVs)

The interviews with Zimbabwean SMMEs involved in ICJVs revealed significant challenges that impact their operations and outcomes. Key issues included complex decision-making processes, cultural and communication differences, unequal distributions of benefits and responsibilities, and navigating legal and regulatory requirements.

Complex decision-making processes

Participants consistently noted the complex nature of decision-making in ICJVs. Participant 19 stated: *"The involvement of multiple stakeholders from different cultural backgrounds and organizational structures often led to delays and difficulties in reaching consensus – R19."* Similarly, Participant R2 observed the administrative burdens caused by aligning the interests of all parties. These findings are consistent with Nash *et al.*, (2010), who report that diverse stakeholder involvement complicates negotiations and affects project timelines. The decision-making challenges underscore the need for efficient coordination and transparent mechanisms.

Cultural and communication differences

Language barriers, divergent communication styles, and cultural nuances were identified as significant challenges. Participant R7 observed: *"The cultural and communication differences between our local team and the international partner were a major challenge."* Similarly, Participant R10 highlighted: *"friction arising from misunderstandings about expectations and work approaches"*. Liu *et al.*, (2020) support these findings, suggesting that cross-cultural disputes often stem from ideological and linguistic disparities. Addressing these issues requires proactive communication strategies and cultural sensitivity.

Unequal distribution of benefits and responsibilities

Some participants highlighted imbalances in roles and benefits within ICJVs. Participant R13 explained: "*The international partner often had a dominant role in decision-making and project management, which limited our autonomy."* This perspective mirrors Shah, (2015), who noted that foreign partners often dominate key decision-making processes, limiting local SMMEs' ability to leverage their expertise. Addressing this imbalance necessitates clearly defined roles and equitable sharing of risks and rewards.

Legal and regulatory compliance

Navigating different legal frameworks was another challenge. Participant 11 shared: *"The differing legal frameworks and compliance standards added complexity and required substantial time and resources to ensure compliance."* Such difficulties resonate with Devarakonda *et al.*, (2021), who argue that navigating dual legal systems increases administrative burdens and the potential for legal risks. Establishing a robust understanding of applicable laws and allocating appropriate resources is critical for compliance.

5. Discussion and Recommendations

This section outlines the key findings from the study, highlighting the benefits and challenges faced by small to medium-sized enterprises (SMMEs) in Zimbabwe engaging in International Construction Joint Ventures (ICJVs).

5.1. Strategic benefits of ICJVs for local SMME's

International construction joint ventures (ICJVs) present significant strategic advantages for Zimbabwean SMMEs, particularly in the areas of resource access, market reach, skills development, and financial resilience. Participants consistently highlighted how collaboration with international partners granted them access to advanced technologies, specialized equipment, and innovative construction methods, all of which contributed to improved productivity, quality, and competitiveness. This aligns with Khan *et al.*, (2015), who emphasize the transformative role of ICJVs in equipping local firms with state-of-the-art technologies and practices.

Knowledge transfer and capacity-building were also central themes. ICJVs served as platforms for the transfer of advanced construction techniques and project management competencies, significantly enhancing local firms' technical and managerial proficiency. These contributions played a crucial role in narrowing disparities in expertise and access to resources. Supporting this, Ndlovu (2022) observed that training interventions within ICJVs helped bridge knowledge and software gaps, enabling local contractors to align with global standards through structured capacity-building efforts.

Furthermore, the exposure to experienced international professionals accelerated local skill development and readiness for large-scale infrastructure delivery. This resonates with findings by Martin and Emptage, (2019) and Rose et al., (2009), who underscore the value of ICJVs in transferring technical and managerial expertise to host-country firms.

Finally, financial stability was reported as a major advantage. International partnerships introduced funding streams and shared financial risk, empowering local contractors to bid competitively for substantial projects and invest in business growth. These financial buffers not only enhanced operational stability but also positioned SMMEs to scale sustainably and compete within both domestic and international markets. Overall, ICJVs are seen as powerful enablers of long-term development in Zimbabwe's construction industry.

5.2. Challenges and constraints of SMME's in ICJV participation

Zimbabwean SMMEs in ICJVs face several challenges affecting their efficiency and success. Complex decision-making processes with diverse stakeholders often cause delays, as noted by (Chan *et al.*, 2022). Cultural and communication differences lead to misunderstandings, highlighting the need for proactive communication strategies and cultural sensitivity (Sunil *et al.*, 2020). Uneven distribution of benefits and responsibilities allows international partners to dominate projects, limiting local firms' autonomy (Devarakonda *et al.*, 2021). Navigating different legal frameworks further complicates these ventures, requiring substantial time and resources to comply with dual systems. These factors underscore the necessity for equitable role distribution, transparent decision-making, and understanding of regulatory requirements to support local SMMEs in ICJVs.

5.3. Strategies for positioning SMMEs for sustained growth

To help SMMEs grow in global markets, several strategies can be employed. Building capacity through training and mentorship will improve technical and managerial skills. Strategic partnerships like ICJVs can offer access to technology and expertise, enhancing capabilities and compliance with international standards. Governments and industry bodies should create supportive environments with subsidies, tax incentives, and streamlined regulations. SMMEs should focus on developing robust business networks and leveraging digital tools for efficiency and visibility. Connecting with professional bodies and trade associations provides resources, funding, and insights. Participation in trade expos and workshops promotes knowledge sharing and exposure to trends. Policymakers should facilitate affordable finance and skill-sharing mechanisms. These efforts will help SMMEs build resilience and sustain growth in competitive global markets.

6. Conclusion

The study presents an analysis of Zimbabwean small and medium-sized enterprises (SMMEs) participating in international construction joint ventures (ICJVs), addressing the research questions and objectives. The findings indicate significant challenges, including cultural and communication barriers, disparities in benefits, complex decision-making processes, and issues with regulatory compliance. Despite these impediments, SMMEs gain considerable advantages from ICJVs, such as access to advanced technologies, market expansion, knowledge transfer, and financial stability. The study identifies key success factors that enable SMMEs to overcome obstacles, including leveraging the expertise of international partners, adopting proactive communication strategies, and enhancing technical and managerial capabilities through training and mentorship. These strategies not only enhance the competitiveness of SMMEs but also position them for sustained growth in global markets. Practical recommendations for policymakers and industry leaders include establishing ICJV frameworks that promote equitable partnerships, addressing training deficiencies, and fostering a supportive regulatory environment. These initiatives can help local SMMEs flourish in international collaborations, contributing to the sustainable development of Zimbabwe's construction sector. Future research could examine the long-term impacts of ICJVs on SMMEs and the broader construction industry, providing insights into strategies for promoting inclusive economic growth through international partnerships.

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ACADEMIC PAPERS: THEME 5 - SUSTAINABILITY AND FACILITY MANAGEMENT/SME

Readiness of Facilities Management Organisations for BIM Adoption in Facilities Management Functions

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Abstract

This study aimed to understand the policy challenges stakeholders face in implementing sustainable construction practices in the Nigerian construction industry. The research aim was achieved through the literature review and semi-structured interviews conducted among eleven built environment professionals in both Lagos and Abuja cities. Thematic analysis was conducted using NVivo 14, resulting in seven themes. The findings reveal a need for improved regulatory policies to support sustainable construction with strict implementation. Adequate awareness of this policy is stressed before its enforcement. Results also suggest that to achieve the maximum result in the application, the government, policymakers, and professionals should effectively synergise on innovation and improved policy adaptation mechanisms for the industry. The study is of value to researchers within the built environment, as it provides insights into the policy formation and implementation challenges faced by the Nigerian construction industry, particularly in relation to sustainable construction practices.

Keywords: Policy implementation, professionals, stakeholders, sustainable construction.

1. Introduction

The adoption of Building Information Modelling (BIM) in facility management (FM) offers significant benefits, including enhanced asset management, energy efficiency, and optimised spatial planning (Naghshbandi, 2016). However, its application in FM remains underutilised, particularly in South Africa, where Facilities Management Organisations (FMOs) face challenges such as technological, financial, and capacity constraints. This reluctance hinders BIM adoption, which is crucial for improving FM operations. The concept of 'readiness' refers to an organisation's preparedness to embrace BIM technology, focusing not only on technical proficiency but also on attitudes toward digital transformation. While research on BIM has mainly focused on the design and construction phases, less attention has been given to its role in the post-construction phase, particularly FM, which is the most cost-intensive stage of a building's lifecycle. Despite various frameworks to assess organisational readiness for BIM adoption, including those by Deloitte (2017) and Haron (2013), there is limited research on BIM readiness in South African FMOs. This study aims to evaluate the technological readiness of FMOs in South Africa and propose a framework to facilitate the adoption of BIM, addressing barriers and offering practical strategies for integration. Using the Technology Readiness Index (TRI) framework, this research seeks to contribute to the understanding of BIM adoption readiness in the South African context, enabling FMOs to leverage BIM for enhanced efficiency and sustainability.

2. Literature Review

The TRI, developed by Parasuraman and Colby (2014), provides a structured framework for evaluating the preparedness of organisations and individuals to adopt new technologies. The TRI, comprising Optimism, Innovativeness, Discomfort, and Insecurity dimensions, has been widely applied across industries to analyse digital transformation (Allen Consulting Group, 2010). In the context of FMOs, technological advancements such as Building Information Modelling (BIM) are redefining operational efficiencies, asset management, and lifecycle planning. BIM enhances building performance by integrating real-time data to support predictive maintenance, energy efficiency, and space optimisation (Eastman et al., 2011). Despite these advantages, BIM adoption in FMOs, particularly in South Africa, has been inconsistent due to several readiness challenges (Calitz & Wium, 2022). A primary impediment to BIM adoption in FMOs is resistance to change, closely linked to the Discomfort and Insecurity dimensions of the TRI. Organisations exhibiting high levels of discomfort towards digital tools often perceive them as complex and challenging to implement, which discourages investment in necessary training and infrastructure (Durdyev et al., 2021). Additionally, concerns regarding data security and a lack of trust in digital platforms further hinder adoption (Dixit et al., 2019). Similar challenges are observed in Nigeria, where organisations face significant hurdles related to perceived complexity and high initial costs (Abubakar et al., 2014).

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Despite these barriers, some FMOs have successfully implemented BIM, highlighting the role of the Optimism and Innovativeness dimensions of the TRI in fostering a positive attitude toward technology (Lin, Shih & Sher, 2007). Research indicates that proactive investment in training and digital infrastructure significantly enhances BIM adoption (Atkinson et al., 2014). Research suggests that organisational readiness for BIM adoption extends beyond technical capacity, encompassing cultural and strategic dimensions (Haron, 2013). Organisations with proactive digital strategies are better positioned to overcome barriers related to cost, training, and interoperability (Atkinson et al., 2014). However, studies indicate that the absence of government enforcement and industry-wide standards significantly contributes to slow adoption rates (Alshawi, 2007). In South Africa, BIM adoption is further hampered by skills shortages and fragmented industry practices, resulting in inconsistent implementation across FMOs (Adebowale, 2018). A study by Charef, Alaka, and Emmitt (2018) underscores the significance of an organisation's digital ecosystem maturity in determining its readiness for BIM. Organisations with integrated digital workflows are better equipped to leverage BIM for improved decision-making and long-term asset management. However, the lack of standardised BIM protocols and inconsistent regulatory frameworks exacerbates challenges to widespread adoption (Genesis Analytics et al., 2020).

Another critical factor influencing BIM adoption in FMOs is the perceived return on investment (ROI). Agha-Hossein et al. (2013) argue that organisations hesitant to implement BIM often cite high initial costs and uncertainty regarding tangible benefits as primary concerns. Although BIM has the potential to improve cost efficiency and operational effectiveness, many FMOs struggle to justify the short-term financial outlay required for software acquisition, training, and workflow adjustments (Abubakar et al., 2014). Currently, industry-wide collaboration in BIM adoption within the South African FM sector remains limited, impeding the full realisation of BIM's potential. Integration with other digital tools, such as Geographic Information Systems (GIS) and the Internet of Things (IoT), is still in its early stages, with fragmented implementation across organisations. This lack of seamless data exchange and interoperability presents significant barriers.

Additionally, leadership and change management approaches vary considerably, with many organisations lacking structured strategies to address resistance and drive innovation. Consequently, cultural transformations necessary for a fully digital FM environment are progressing at an uneven pace. Table 1 summarises the key technology readiness dimensions influencing BIM adoption, categorised according to the TRI framework. While Optimism and Innovativeness facilitate adoption, Discomfort and Insecurity present substantial barriers. Findings from FMOs in Nigeria suggest that high initial costs and complexity hinder the adoption of these initiatives. In contrast, proactive training and a digital strategy enhance adoption, offering valuable insights for the South African context.

Table 1: Key psychological factors influencing BIM adoption

Category	Description	Implications for BIM Adoption	Source
Optimism	The belief that technology enhances control, efficiency, and flexibility in personal and professional life.	Encourages a positive attitude towards adopting BIM tools	(Parasuraman and Colby, 2014); (Syamfithriani et al., 2021).
Innovativeness	Tendency to be forward-thinking and willing to embrace new technologies.	Fosters an environment conducive to the integration of BIM	(Parasuraman and Colby, 2014); (Syamfithriani et al., 2021).
Discomfort	Feelings of being overwhelmed by technology and a lack of control over it.	Acts as a barrier to the acceptance and use of BIM systems.	(Parasuraman and Colby, 2014); (Syamfithriani et al., 2021).
Insecurity	Mistrust in technology and its capabilities.	Contributes to the reluctance to adopt BIM and related technologies	(Parasuraman and Colby, 2014); (Syamfithriani et al., 2021).

(Source: Syamfithriani et al., 2021)

3. Research Methodology

This study adopts a quantitative research approach to generate numerical data that can be analysed. A quantitative approach is appropriate because it enables the objective measurement of technology readiness characteristics across different FMOs (Creswell, 2014). Unlike qualitative methods, which explore subjective experiences in depth, the quantitative approach ensures a structured and replicable assessment of BIM readiness, making it well-suited for identifying generalisable patterns within the industry (Bloomfield & Fisger, 2019). A structured, closed-ended survey

questionnaire was chosen as the primary research strategy to gather participants' perspectives on the readiness of FMOs to adopt BIM for maintenance functions. The structured nature of the questionnaire ensures consistency in responses and enables efficient data analysis. Alternative methods, such as interviews, were considered but deemed less practical due to time constraints and the need for a large dataset. The questionnaire utilised a five-point Likert scale, where respondents rated their level of agreement with statements regarding technology readiness characteristics related to BIM.

The scale consisted of 1 – Strongly Disagree (SD), 2 – Disagree (D), 3 – Neutral (N), 4 – Agree (A), and 5 – Strongly Agree (SA). The key dimensions assessed included Optimism, Innovativeness, Discomfort, and Insecurity, as defined by the TRI framework. The target population for this study consisted of 209 registered members of the South African Facilities Management Association. A non-probability sampling technique, specifically convenience sampling, was employed due to accessibility constraints and the voluntary nature of participation. While convenience sampling may introduce selection bias, it was deemed suitable for obtaining insights from a diverse set of industry professionals. The survey was distributed to 150 respondents across 64 organisations. A total of 51 fully completed questionnaires were returned, yielding a 34% response rate. The 34% response rate could be attributed to challenges associated with online surveys, including potential survey fatigue and the time commitment required from a specific professional target group. Data collection was conducted via an online survey administered through Google Forms to enhance accessibility and streamline the response process. Statistical analysis was performed using SPSS version 28, a widely used software for quantitative research in the built environment. Descriptive statistics, specifically mean scores (MSs) and Standard Deviations (SDs), were used to interpret the data. The MSs of constructs were employed to rank the factors influencing BIM readiness, providing a clear indication of which dimensions had the most significant impact. To ensure instrument validity, a pilot study was conducted with three industry experts, who reviewed the survey for relevance, clarity, and alignment with BIM readiness factors. Their feedback led to minor refinements in wording to enhance comprehension. Reliability was reinforced by grounding the survey in established literature and industry standards. The methodological choices in this study ensure a systematic and objective assessment of BIM readiness among FMOs in South Africa.

4. Findings and Discussion

Table 2 presents the demographic characteristics of the respondents, offering insights into the workforce composition and BIM adoption trends within the South African construction industry. The majority of respondents (37%) are aged between 31 and 40 years, followed by 25% in the 25–30 age group and 20% in the 41–45 category. The least represented groups include those over 51 years (12%) and those under 25 years (6%). This distribution suggests that individuals aged 25–40, who collectively constitute 62% of the sample, are the most actively engaged in the industry. When including those aged 41–45, this figure rises to 82%, indicating a strong presence of mid-career professionals.

The limited representation of respondents under 25 may reflect the time required to gain industry experience, aligning with prior studies that highlight challenges faced by younger professionals in establishing themselves within the construction sector (Adebowale, 2018). Conversely, the lower participation of individuals over 51 could be attributed to reduced engagement with emerging technologies such as BIM (Alshawi, 2007). Regarding industry experience, respondents with 0–5 years form the largest group (37%), followed by those with 6–10 years (27%) and 11–15 years (20%). The least represented are individuals with 16–20 years (12%) and over 21 years (4%). This indicates that 84% of respondents have between 0 and 15 years of industry experience, further reinforcing the dominance of early- to mid-career professionals in the sample. Previous research has suggested that professionals with fewer years of experience tend to be more open to digital transformation initiatives, including BIM adoption (Charef, Alaka & Emmitt, 2018). In terms of BIM adoption, 76% of respondents reported that their organisations would require 1–5 years for

Table 2: Demographic characteristics of respondents

Characteristic	Category	Percentage (%)
Age Group	Under 25	6
	25–30	25
	31–40	37
	41–45	20
	Over 51	12
Experience (Years)	0–5	37
	6–10	27
	11–15	20
	16–20	12
	Over 21	4
BIM Adoption Timeframe (Years)	1–5	76
	6–10	6
	BIM Already in Use	6

implementation, while 6% estimated a timeframe of 6–10 years. An additional 6% indicated that BIM is already in use within their organisations. These findings suggest that 88% of respondents anticipate a 1–10-year period for BIM adoption, reflecting a slow transition within the facilities management and construction sectors in South Africa. The low proportion (12%) of organisations that have already implemented BIM is consistent with previous studies that highlight challenges such as cost and a lack of technical expertise. Expertise and resistance to change are identified as barriers to BIM adoption (Durdyev et al., 2021; Calitz & Wium, 2022). The gradual pace of adoption underscores the need for strategic interventions to facilitate a smoother digital transition, including targeted training and policy support (Atkinson, Amoako-Attah & B-Jahromi, 2014).

4.1 Readiness of organisations to adopt BIM

The TRI model, based on Parasuraman and Colby (2014), was used to assess the readiness of FMOs to adopt BIM (see Table 1). The TRI value was determined using four factors: Optimism (OPT), Innovativeness (INN), Discomfort (DIS), and Insecurity (INS), each weighted at 25% (Syamfithriani et al., 2021). Each factor's weight was distributed equally across its respective equations:

OPT = 25% ÷ 4 = 6.25%
INN = 25% ÷ 4 = 6.25%
DIS = 25% ÷ 4 = 6.25%
INS = 25% ÷ 4 = 6.25%

Table 3 (see Appendix 1) presents the TRI values for each statement. The weight of each section (6.25%) was multiplied by the average score of the corresponding questions. The average score was obtained by dividing the total score by the number of respondents (Table 4). The total scores for each category in Table 4 were obtained by summing the values of their respective statements. For Optimism, the four statements yield: OPT 1 (0.25) + OPT 2 (0.25) + OPT 3 (0.25) + OPT 4 (0.23), resulting in a TRI value of 0.98. For Innovativeness, the calculation is INN 1 (0.21) + INN 2 (0.20) + INN 3 (0.22) + INN 4 (0.20), totalling 0.83. Discomfort is derived from DIS 1 (0.16) + DIS 2 (0.17) + DIS 3 (0.16) + DIS 4 (0.17), amounting to 0.66. Insecurity is calculated as INS 1 (0.17) + INS 2 (0.14) + INS 3 (0.14) + INS 4 (0.25), equalling 0.70 (Table 3).

4.2 Total TRI per category

The results in Table 4 show that Optimism holds the highest value (0.98), indicating that FMOs are confident in their readiness to adopt BIM for facilities management. This aligns with Osunsanmi et al. (2018), who reported a high readiness level for a virtual reality tool in South Africa. Innovativeness scores 0.83,

Table 4: TRI Values by category

Variable	TRI Value (Sum of categories)	Rank
Optimism	0.98	1
Innovativeness	0.83	2
Insecurity	0.70	3
Discomfort	0.66	4
Total TRI Score	**3.15**	

Authors' field data (2024)

indicating receptiveness to new technologies. However, Insecurity and Discomfort scored lower at 0.66 and 0.70, respectively. The results highlight that these are barriers to adopting innovative technologies. Despite these challenges, the higher Optimism and Innovativeness scores indicate a generally positive attitude toward technological advancements. The cumulative TRI value of 3.15 (Table 4), based on the thresholds established by Syamfithriani et al. (2021) in Table 5, reflects a medium level of readiness for BIM adoption in FM functions within South Africa.

insecurity. Strategic policy development and technological investment are necessary to create an enabling environment for BIM adoption.

Additionally, strong leadership commitment can drive digital transformation, while phased implementation allows FMOs to build confidence and capability gradually. Finally, fostering collaboration and knowledge sharing among the FMO industry through workshops, professional networks, digital platforms, and academic-industry partnerships can facilitate best

Table 5: Technology readiness thresholds

Level of technology readiness	**TRI Value**
Low Technology Readiness Index	If the TRI value <= 2.89
Medium Technology Readiness Index	If the TRI value is between 2.90 and 3.51
High Technology Readiness Index	If the TRI value >3.51

(Syamfithriani et al.,2021)

5. Conclusion and Further Research

This study investigated the technological readiness of FMOs in South Africa to adopt BIM for their operations, utilising the TRI framework. The findings reveal a complex picture: while FMOs demonstrate significant Optimism and Innovativeness regarding BIM, indicating a positive attitude towards technological advancement, they also experience considerable discomfort and insecurity, suggesting apprehensions about implementation challenges and potential skill gaps. The resulting medium overall TRI score of 3.15 underscores this mixed readiness. This suggests that while FMOs recognise the potential benefits of BIM, they are not yet fully prepared to integrate it effectively into their workflows.

The high scores for Optimism and Innovativeness provide a strong foundation upon which to build. However, the identified discomfort and insecurity must be addressed to unlock the full potential of BIM in FM. These findings have significant implications for FMOs and policymakers in South Africa. The findings suggest that targeted interventions, such as training programs focused on BIM implementation and management, along with clear demonstrations of BIM's practical benefits, are essential for mitigating discomfort and

practices and accelerate BIM readiness. This study contributes to the limited body of knowledge on BIM readiness in the South African FM sector by providing empirical evidence of key drivers and barriers.

Future research could further explore these findings. Qualitative studies, involving interviews and case studies, could provide richer insights into the specific challenges faced by FMOs and the strategies they employ to overcome them. Longitudinal research tracking the progress of FMOs as they implement BIM would be valuable in understanding the long-term impact of readiness factors. While inferential statistics were not the primary focus, future research could expand on this study by incorporating regression analysis or hypothesis testing to examine causal relationships. No formal reliability test (e.g., Cronbach's alpha) was conducted in this study; therefore, future research could validate the instrument's internal consistency.

Finally, comparative studies with other developing economies could offer valuable lessons and best practices for promoting BIM adoption in the South African context.

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Appendix 1

Table 3: TRI values per item

TRI Values
Optimism
BIM contributes to a better quality of life. $$OPT\ 1 = \frac{202}{51} \times 6.25\% = 0.25$$
BIM has the potential to give me more freedom of mobility $$OPT\ 2 = \frac{204}{51} \times 6.25\% = 0.25$$
BIM gives people more control over their daily lives $$OPT\ 3 = \frac{202}{51} \times 6.25\% = 0.25$$
BIM technology makes me more productive in my personal life $$OPT\ 4 = \frac{186}{51} \times 6.25\% = 0.23$$
Innovativeness
Other people come to me for advice on new technologies such as BIM. $$INN\ 1 = \frac{171}{51} \times 6.25\% = 0.21$$
In general, I was among the first in my circle of friends to acquire BIM technology when it was available. $$INN\ 2 = \frac{164}{51} \times 6.25\% = 0.20$$
I can usually figure out new high-tech BIM products and services without help from others. $$INN\ 3 = \frac{177}{51} \times 6.25\% = 0.22$$
I keep up with the latest technological developments in the field of BIM. $$INN\ 4 = \frac{186}{51} \times 6.25\% = 0.20$$
Discomfort
When I get technical support from a provider of a high-tech product such as BIM, I sometimes feel as if I am being taken advantage of by someone who knows more than I do. $$DIS\ 1 = \frac{127}{51} \times 6.25\% = 0.16$$
Technical support lines for BIM are not helpful because they explain things using excessive jargon and technical terminology. $$DIS\ 2 = \frac{138}{51} \times 6.25\% = 0.17$$
Sometimes, I think that technology systems are not designed for use by ordinary people. $$DIS\ 3 = \frac{130}{51} \times 6.25\% = 0.16$$
There is no such thing as a manual for a high-tech product or service that's written in plain language. $$DIS\ 4 = \frac{140}{51} \times 6.25\% = 0.17$$
Insecurity
People are too dependent on technology, such as BIM, to do things for them. $$INS\ 1 = \frac{136}{51} \times 6.25\% = 0.17$$
Too much BIM technology distracts people to a point that is harmful. $$INS\ 2 = \frac{112}{51} \times 6.25\% = 0.14$$
BIM lowers the quality of relationships by reducing personal interaction. $$INS\ 3 = \frac{118}{51} \times 6.25\% = 0.14$$

Whenever a technology gets automated, e.g. BIM, you need to check carefully that the system is not making mistakes. $$INS\ 4 = \frac{200}{51} \times 6.25\% = 0.25$$

Authors' field data (2024)

An Exploratory Evaluation of the Factors impacting the Adoption of Innovative Sustainable Building Materials in Housing Construction Across Socio-Economic Contexts

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Abstract

This research examines the adoption patterns and key factors influencing the adoption of innovative sustainable building materials in housing construction across socio-economic contexts in Cape Town, South Africa. In South Africa, the adoption of sustainable building practices is hindered by socio-economic constraints, technological limitations, economic barriers, and a lack of awareness. Despite notable advancements in sustainable building practices, several factors contribute to uneven adoption patterns, hindering the widespread implementation of these practices. A mixed-methods approach was used to collect data, employing semi-structured interviews and a survey questionnaire randomly distributed to Cape Town residents and purposively selected professionals working on housing construction projects. Furthermore, the data collected were analysed using descriptive, thematic, and inferential statistical techniques. The study found that most respondents from both classes were aware of sustainable building technology and materials, and perceived that environmentally friendly building materials help mitigate the environmental impact of construction. They also indicate that, compared to middle- to high-class respondents, most low-class respondents lack access to resources such as government assistance and financial support, and both groups often utilise recycled materials. The study found no significant difference in the main variables influencing respondents' choices regarding sustainable building materials across middle-high-class and lower-class groups. In conclusion, this study advances the understanding of how socio-economic circumstances influence the use of sustainable building materials and technologies in housing construction at various levels. The study recommends that governments and financial institutions establish initiatives through training and financial incentives to equip stakeholders with the necessary information, thereby improving the likelihood of adopting sustainable practices.

Keywords: Environmental Impact, Housing, Income Level, South Africa, Sustainable building materials

1. Introduction

The adoption patterns of sustainable building materials in housing construction vary significantly across different socio-economic contexts and are influenced by many factors (Eze *et al.*, 2021). This research uses the terms "sustainable building practices" and "sustainable building materials" interchangeably. Economic and socio-cultural contexts are particularly pivotal in shaping the acceptance of sustainable housing technologies (Okitasari *et al.*, 2022). These socio-economic contexts encompass various social and economic factors that influence housing construction, including cost considerations, access to information and education, regulatory environment, cultural factors, infrastructure and resources, and the impacts of climate change.

Housing construction is fundamental to societal development; however, conventional practices often lead to environmental degradation and social inequities (Kennedy *et al.*, 2009). Historical perspectives reveal a trajectory of resource-intensive construction methods that have led to ecological harm and economic disparities (Kennedy *et al.*, 2009). Wang *et al.* (2018) and AlSanad (2015) stated that the building and construction industries consume a significant amount of global resources and have a substantial impact on the environment, contributing to high energy consumption and greenhouse gas emissions (GHG). In the same line of thought, Kennedy et al. (2009) confirmed that the housing industry produces approximately a third of GHG and uses up to 40% of total energy consumption across several phases, including raw material extraction, processing, manufacture, transportation, construction, and building operation.

In many countries, the adoption of sustainable building practices is hindered by socio-economic constraints, technological limitations, economic barriers, and inadequate awareness (Marsh *et al.*, 2020). While some regions readily adopt sustainable alternatives, others continue to rely on traditional, resource-intensive construction methods. This imbalance is particularly evident in South Africa and other regions, where disparities exist in the knowledge and affordability of sustainable building materials (Marsh *et al.*, 2020). For instance, developers in countries such as Malaysia face obstacles in meeting the growing demand for housing while upholding social and ecological responsibility

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(Abidin, 2010). Nigeria faces barriers to adopting sustainable construction practices (Osuizugbo *et al.*, 2020). Despite significant progress in researching the uptake of green buildings in developing countries, recent studies reveal a continued gap in understanding the theoretical and contextual factors influencing the adoption of innovative building materials in Africa (Mushi *et al.*, 2023).

Therefore, it is imperative to understand the adoption patterns of innovative sustainable materials in housing construction across diverse socio-economic contexts. This research examines the key factors influencing adoption rates, assesses barriers to implementation, and proposes targeted interventions to promote sustainable practices.

2. Literature Review

The increase in human population and urbanisation causes the demand for infrastructure, buildings, and facilities to outweigh the supply, resulting in the need to build more infrastructure, buildings, and facilities to meet the needs of the current and future generations (Mehmood & Ishak, 2024; Ngoy et al., 2023). The construction sector is a significant contributor to global carbon dioxide emissions, primarily due to the use of conventional building methods and materials. The industry's impact on environmental degradation highlights the need to adopt a circular economy approach in construction to mitigate adverse effects (Saha *et al.*, 2021). Addressing environmental challenges and climate change issues in the construction sector is crucial, as buildings account for a significant portion of global energy consumption and greenhouse gas emissions.

Huang et al. (2018) highlighted that the construction industry is the most significant contributor to carbon dioxide emissions globally, primarily due to the materials and methods used in traditional building practices. This sector is a significant factor in environmental degradation, posing risks to future generations. Estimates suggest that construction activities contribute to 25% of global deforestation, with additional emissions from industrialised nations accounting for 10%. Emissions include 39% carbon dioxide, 49% sulfur dioxide, and 25% nitrous oxide, with 40% attributed to raw material extraction (Eze *et al.*, 2023).

2.1. Key Principles of Sustainable Construction

Sustainable construction seeks to create comfortable and healthy indoor environments while minimising the environmental impact of buildings and their operational structures. By examining documents from the International Union for Conservation of Nature (IUCN), Purvis *et al.* (2019) sought to trace the origins of the three key pillars of sustainability: environmental, economic, and social. They found that these three pillars are deeply connected to sustainable development.

2.2. Sustainable Building Materials

The construction industry is adopting sustainable building materials and technology to reduce environmental impact and improve long-term viability (Javaid *et al.*, 2022). Sustainable methods currently transforming South Africa include using innovative materials like bamboo, precast concrete, cross-laminated timber, and straw bales and incorporating technologies like BIM and 3D printing.

2.3. Socio-Economic Context and Adoption of Sustainable Building Materials in South Africa

2.3.1. Low-Income Households in South Africa

According to Swilling *et al.*(2016), South Africa is the most unequal society in the world. Most people from low-income housing in South Africa live in low-cost RDP housing areas, and poor black South Africans mostly occupy them. These townships consist of a mix of old and new housing occupied chiefly by poor, black South Africans, as Shackleton *et al.* (2018) stated. As a result of poverty, they settle on vacant land on the outskirts of towns or unused land within the city and construct houses from low-cost or scavenged materials (Shackleton *et al.*, 2018). Similarly, new migrants to a town in South Africa usually occupy unused land, forming informal housing areas (Pauw *et al.*, 2022). They do this, hoping to be allocated an RDP house (Makole *et al.*, 2022). This suggests that high initial costs significantly impact the adoption rates of sustainable materials for low-income housing, as most households rely on government grants to cover their living expenses.

2.3.2. Middle-income Households in South Africa

According to Wright *et al.* (2019), middle-income households in the country have substantially better access to health, education, and other services than their low-income counterparts. They also live in urban areas with easy access to various services and private establishments (Alabi & Fapohunda, 2021). Compared to the low-income class, the middle class has higher educational attainment and puts a high value on human capital development (Albert *et al.*, 2018). Middle-income households in rural areas and certain regions have low access to social services (McKenzie & Hanass-Hancock, 2017). The government needs to reexamine its social protection policies and recognise that while the poor are mostly vulnerable to future poverty, even the middle class is vulnerable and needs to establish RDP houses and social housing for the middle class (Temidayo *et al.*, 2018).

2.3.3. High-Income Households in South Africa

Shackleton *et al.* (2018) found that suburbs ranging from middle to high-income areas are occupied mostly by white South Africans, but now there is an increasing presence of other racial groups. Ward and Shackleton

(2016) state that wealthier urban households tend to have high-income-earning jobs, measured mainly by the number of assets and electricity spending. They are also associated with high education levels, and these households are primarily located in the CBD and town areas of South Africa. According to Tetteh and Amponsah (2020), smart homes contribute to sustainable development. This implies that homeowners who choose innovative housing are typically high-income earners who can afford the associated expenses. They have the resources to fall back on alternative energy sources, such as generators and solar energy, during load shedding, which people with low incomes cannot afford (Williams *et al.*, 2020). This means that high-income households have sufficient monetary resources and knowledge to adopt sustainable materials at a high rate.

3. Research Methodology

This study employs a mixed-methods research approach to collect data from low-, middle-, and high-income populations regarding their experiences and perceptions of the factors influencing the adoption of sustainable building materials. The mixed methods approach encourages further refinement of the data beyond the results obtained by either qualitative or quantitative data. It leads to a deeper understanding of the research problem that would not be achieved if a single method were used in isolation. Residents of the Cape Town metropolitan area, Western Cape, South Africa, from various socio-economic backgrounds were randomly surveyed to draw statistical inferences from the data (Andrews *et al.*, 2007), while professionals working on housing construction projects were conveniently selected and interviewed. The rationale for using the mixed method approach was to mitigate bias and ensure data reliability. The data collected was analysed using inferential, thematic, NVivo software, and descriptive analysis.

4. Findings and Discussion

4.1. Participant demographics

Table 1 presents the demographic characteristics of respondents, including their education level, employment status, income levels, and home ownership status. Table 1 reveals that the more educated the household, the greater the probability of being proactive in seeking sustainable building solutions. In contrast, the less educated the household, the less access to knowledge they have, and they may prioritise immediate financial requirements over long-term environmental advantages. This was confirmed by Wang *et al.* (2014), indicating that education plays a significant role in determining the development of behavioural intention, environmental knowledge, environmental sensitivity, environmental value, perceived behavioural control, and response efficacy. It is based on the fact that education not only helps people

Table 1: Participant demographic characteristics

Race	**Low-class Respondent**	**Middle to high class Respondents**
Black	89,66%	56,41%
White	3,45%	25,64%
Colored	6,90%	17,95%
Education Level	**low-class Respondent**	**Middle to high class Respondents**
High School	75,86%	15,38%
Bachelors	10,34%	61,54%
Master's Degree	3,45%	2,56%
Others	10,34%	20,51%
Employment Status	**low-class Respondent**	**Middle to high class Respondents**
Employed Full-Time	44,83%	87,18%
Employed Part-Time (Retired*)	24,14%	61,54%
Unemployed	17,24%	2,56%*
Students	13,79%	5,13%
Income Level	**low-class Respondent**	**Middle to high class Respondents**
R0 to R54 344	31,03%	0%
R151 727 to R363 930	68,97%	33,33%
R363 931 to R631 120	-	35,90%
R631 121 to R863 906	-	17,95%
R863 907 to R1 392 844	-	12,82%
Home ownership status	**low-class Respondent**	**Middle to high class Respondents**
Built my Own House	32,14%	35,90%
Bought an Existing Home	7,14%	35,90%
Rent	46,43%	20,51%
Other	14,29%	7,69%

better understand environmental issues, but it also helps people realise their environmental responsibility.

4.2. Location of respondents

Table 2 shows that 38.46% of respondents live in the township, 38.46% in a suburban neighbourhood, 12.82% in the urban city centre, and 10.26% in the outskirts.

Table 2: Location of Respondents

Outskirts	Township	Urban City Centre	Suburban Neighborhood
10,26%	38,46%	12,82%	38,46%

Housing inequality occurs within and between different Population groups. Low-income groups, predominantly minority ethnicities, and those with migrant backgrounds are more likely to encounter poor-quality housing and reside in rental tenures as a result of poor access to ownership. These affordability gaps are particularly pronounced among low-income households, renters in the private sector, and youth (Kährik & Pastak, 2023), indicating that those in more permanent or higher-quality housing are often more flexible in implementing sustainable practices, as they are willing to invest in quality.

4.3. Nature of regulatory environment, Knowledge of sustainable building materials, and Effect of sustainable building materials on reducing environmental impact

According to Table 3, 23 out of 39 respondents in the middle-high class and 18 out of 29 respondents in the low-class categories indicated an informal regulatory environment. Overall, both the middle-class and upper-class groups have an informal regulatory environment regarding the use of sustainable building materials. Additionally, it demonstrates that 22 of the 29 respondents from the lower socio-economic classes were aware of sustainable building materials. Of the 39 middle and high school respondents, 34 were aware of sustainable building materials. Most responders from both classes/groups were aware of sustainable building technology and materials. Lastly, the title reveals that 14 low-income respondents strongly agreed, 11 agreed, two were neutral, and two disputed that using sustainable building materials helps reduce environmental impact. Most respondents from both groups think that environmentally friendly building materials can lessen their impact.

Results indicate that government policies are directly proportional to some extent to the awareness of sustainable building materials, together with incentives. Saha et al. (2021) found that regulatory frameworks on sustainable materials are still lacking in developing countries and need to be fostered. The study conducted by Luthra et al. (2015), which focused more on sustainable technology, states that the lack of public interest litigation is one of the barriers identified for promoting sustainable technologies. This shortfall in legal advocacy results in decreased motivation and lower public awareness. To address this, the government should increase its efforts to clearly label the energy usage of appliances and machinery, along with providing certification to verify their energy-saving efficiency.

4.4. Use of Sustainable building materials and Frequency of using sustainable materials

Table 4 shows that 22 out of 39 respondents in the middle-high class and 16 out of 29 respondents in the low class have never utilised solar panels. The findings indicate that although a sizable portion of both groups

Table 3: Nature of regulatory environment, Knowledge of sustainable building materials, and Effect of sustainable building materials on reducing environmental impact

Regulatory Environment	**Low-class Respondent**	**Middle to high class Respondents**
Informal	18	23
Formal	11	16
Knowledge of Sustainability	**Low-class Respondent**	**Middle to high class Respondents**
No	7	5
Yes	22	34
Effect on Reducing Environmental Impact	**low-class Respondent**	**Middle to high class Respondents**
Strongly Disagree	0	0
Disagree	2	0
Neutral	2	5
Agree	11	13
Strongly Agree	14	19

have used solar panels, most have not. Additionally, it reveals that whereas 31 out of 39 respondents from the middle-class and upper-class groups have not used green roofs, 24 out of 29 respondents from the lower-class group have not. They equally indicate that both respondent groups use green roofs reasonably infrequently. Regarding recycled materials, 22 out of 39 respondents in the middle-high class and 17 out of 29 respondents in the low class had used them. Both groups utilise recycled materials more often than they do not. Finally, it reveals that although 23 out of 39 respondents from the middle-high class have used rainwater gathering systems, 17 out of 29 respondents from the low-class group have done so. This demonstrates that more people in both groups utilise rainwater harvesting systems than those who do not.

Table 4: Use of Sustainable building materials and Frequency of using sustainable materials

Sustainable Building Material	Response	Low-class Respondents	Middle to high class Respondents
Use of solar panels	Yes	13	17
	No	16	22
Use of recycled materials	Yes	12	22
	No	17	17
Use of green roofs	Yes	5	8
	No	24	31
Use of rainwater harvesting	Yes	12	23
	No	17	16
Frequency of using sustainable materials			
Always		2	2
Frequently		6	8
Occasionally		11	16
Rarely		7	10
Never		3	3
Affordability of sustainable building materials			
Very Affordable		4	5
Affordable		10	8
Neither Expensive not Affordable		3	5
Expensive		11	18
Very Expensive		1	3

Regarding the affordability of sustainable building materials, over half of middle-class respondents considered the materials expensive or extremely expensive, and a similar proportion of respondents from lower socio-economic classes shared the same view. Both categories believe sustainable building materials are more costly than conventional ones.

The results reflect the shift in the South African construction industry as more people become aware of environmental issues and seek greener building methods (Windapo, 2014). With problems such as limited resources and climate change, the focus has shifted to materials that can benefit the country's environment and economy (Korhonen *et al.*, 2018). Sustainable materials can significantly influence how buildings are designed and constructed, offering a future where both the planet and its inhabitants benefit (Raji *et al.*, 2015). Each alternative considered sets new standards for eco-friendly construction, offering access to buildings that are better for the environment, affordable, and meet the growing demand for sustainable living (Korhonen *et al.*, 2018). Thus shaping a more sustainable world.

These materials are cost-effective, durable, and have a low environmental impact. Their versatility makes them excellent choices for a wide range of projects, from residential homes to commercial buildings. South Africa's commitment to sustainable development is evident in its increasing use of these innovative materials. Despite barriers to adoption, they help reduce harmful emissions and promote a greener future.

4.5. Factors influencing the adoption of Sustainable Materials

To identify the main variables influencing respondents' choices of sustainable building materials, the RII scores for the factors are displayed in Tables 5 and 6 for middle-class and low-income individuals, respectively. The three most important aspects of the low-cost option were initial cost, environmental impact, and long-term cost savings. The three variables that the middle class considered were initial cost, environmental effect, and long-term cost savings, revealing that the variables influencing adoption in the middle-class and lower-class groups were the same.

Table 5: Influencing factors - low-class

Rank	Influencing factors	RII
1	Cost savingsin the long run	0,7
1	Environmental impact	0,7
2	Initial cost	0,6
2	Availability	0,6
2	Awareness and knowledge	0,6
2	Complying with building codes	0,6
2	Aesthetic appeal	0,6
2	Influence of media and adverts	0,6
2	Maintenance and ease of use	0,6
3	Government incentives	0,5

Table 6: Influencing Factors Middle-High class

Ranking	Influencing factors	RII
1	Cost savingsin the long run	0,7
1	Initial cost	0,7
1	Environmental impact	0,7
1	Awareness and knowledge	0,7
1	Maintenance and ease of use	0,7
2	Availability	0,6
2	Complying with building codes	0,6
2	Aesthetic appeal	0,6
3	Government incentives	0,5
3	Influence of media and adverts	0,5

The study found that it sometimes costs more to embark on green building projects because green materials are mostly more expensive than their conventional counterparts. A comparison of construction costs between 'green' and conventional office buildings reveals that soft green building costs are higher than those of conventional projects, primarily due to incremental costs associated with achieving a green building rating (Chan *et al.*, 2017). This involves application costs and additional consulting required under the various rating tools. It is therefore necessary to provide financing options to encourage sustainable construction practices. Oguntona *et al.* (2019) corroborate the findings of this investigation, indicating that more financing alternatives, such as government incentives, can improve the implementation of green technologies.

The results of this investigation also prove that environmental factors significantly influence the Adoption of sustainable building materials. Ahn *et al.* (2016) and Ngoy et al. (2023) argue that one of the primary environmental factors driving the adoption of sustainable practices is the need to mitigate climate change, as building construction and operation contribute significantly to global greenhouse gas emissions.

5. Conclusion

This research examines the factors influencing the adoption of innovative sustainable building materials in housing construction across two socio-economic contexts. Key factors impacting adoption patterns include economic incentives, awareness and education, government policies, cultural values, and the availability of resources. The research highlighted significant differences in these factors based on socio-economic status, underscoring the need for targeted strategies to address the unique challenges different communities face. In conclusion, this study contributes to understanding how socio-economic contexts influence the adoption of sustainable building materials in housing construction. The insights gained can guide stakeholders such as policymakers, industry professionals, and community organisations in fostering more sustainable practices in the construction sector.

6. Acknowledgment

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Factors Influencing the Adoption of Sustainable Practices in Facility Management

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Abstract

Minimising environmental impacts and maximising economic and social benefits are critical in facilities management (FM). This study identified factors affecting the adoption of sustainable practices in FM. A quantitative approach was employed in the study, utilising a questionnaire survey administered to FM professionals selected through purposive and convenience sampling. Respondents were approached at three recent Africa FM conferences. The data from 89 respondents were analysed using descriptive statistics, including frequencies, percentages, and mean item scores. Findings revealed that awareness of sustainability practices, financial knowledge relevant to adopting sustainable practices, competencies and skills, and management support are critical factors in adoption. The study can contribute to advancing the adoption of sustainable practices in FM and developing support initiatives with an understanding of these identified influences. The study provides a crucial knowledge base for future FM research, training, and policymaking.

Keywords: Facility management, organisations, sustainability, sustainable development goals, sustainable practices

1. Introduction

Facility management (FM) is increasingly gaining recognition and attention due to the flexibility provided to organisations in the rapidly changing era (Lee et al., 2021). The use, operation and maintenance of buildings and the built environment have the most significant environmental impact, affecting organisations, society and future generations' access to resources (Hauashdh et al., 2024). Hence, sustainability (ensuring that future generations' needs are not compromised) has become imperative in response to environmental, societal, and economic challenges and impacts to ensure that tomorrow's generation will enjoy the benefits of efforts today. Minimising environmental impacts and maximising economic and social benefits have become crucial. The role of FM in realising organisational and sustainable development through daily activities, processes, and procedures is critical. Despite these potential contributions, there is still a low sensitivity to sustainability in FM. In present-day FM, professionals face a vital issue of 'sustainability' for the rapid development of built infrastructures, and there is a need to be more proficient in sustainable development and practices (Islam et al., 2019). Facility management should benefit an organisation in response to its needs, be impactful within and outside the organisation, and consider sustainability imperatives (Jensen et al., 2013). Sustainable FM adds value to companies, organisations, and governments that integrate it into their vision (Alfalah & Zayed, 2020). There is also 'added value' in customer and relationship values related to physical resources, such as building-related facilities and services (Islam et al., 2019).

Standards and frameworks exist to guide FM practices for specific objectives, eg, ISO 41001, ISO Green Building Standards (Codes), ISO 15932 and the Balanced Scorecard (BSC) (Graubner et al., 2016). Studies have focused on maintenance strategies for public buildings using a multicriteria decision-making model (Ighravwe & Oke, 2019) and barriers to adopting sustainable FM practices in higher education institutions (Radebe & Ozumba, 2021). Others have reviewed SFM research and observed limited attention in Africa (Nielsen et al., 2016; Okoro, 2023). Kwawu and Elmualim (2011) observed that the integration of sustainability with core business strategies evolves continually, and as such, the emphasis on different drivers may differ for organisations. Thus, this research is essential to analyse what is considered important especially in the African context, where SFM is gaining momentum as the continent grapples with rapid urbanisation, poor infrastructure performance and needs, increasingly strained infrastructure, growing need for climate change, resource scarcity, unpredictable institutional challenges, inadequate skills and capacity development in FM, financing constraints, lack of awareness of FM's enhanced role and levels (operational, tactical and strategic), reactive rather than proactive management and environmental degradation. There is a need to develop solutions in the local context (Radebe & Ozumba, 2021). The attainment of SDGs and sustainability imperatives in Africa will remain a mirage unless there is an inclination toward resilience, prevention and preparedness. Therefore, the current study focused on perspectives in Africa on the factors that influence the adoption of sustainable practices. The study's findings provide evidence for FM organisations and stakeholders to plan for current and future eventualities by identifying key factors to focus on and

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prioritise in strategic planning and implementing sustainability objectives to ensure long-lasting value.

2. Literature Review

2.1. Sustainability in Facility Management

Sustainability in FM is becoming increasingly significant, and organisations are revising current procedures and processes to incorporate sustainability into their daily activities. The FM profession faces more demands and challenges as the goals of sustainability agendas change over time, and it must be equipped with new knowledge, tools, and competencies to overcome these challenges (Elmualim, 2013). The International Facility Management Association's (2023) research on emerging trends transforming the industry also holds relevance for future or sustainability-centred initiatives. These trends include Proptech, artificial intelligence, circular economy, ESG reporting, climate change and wellbeing.

The concept of sustainability has evolved from an add-on to an integrated approach in management and business thinking and practices. The sustainability theory is a core aspect of modern facilities management theories, which are dynamic and evolving to meet the need for environmental sustainability and increased efficiency. For example, this includes the Corporate Social Responsibility (CSR) theory and the green innovation and economy theory (Fosu et al., 2024). In Islam et al.'s (2019) view, assets in the built environment must perform optimally beyond their expected lifespan, at the nexus of people's and processes' operational efficiency and reduced costs. Therefore, sustainability theory in facilities management incorporates innovative business thinking and the long-term performance of physical structures.

Globally, sustainability is an essential business consideration in building and facility management. Organisations acknowledge the financial and environmental benefits of sustainable practices and continually seek ways to optimise their operations, streamline processes, and reduce costs in areas such as energy efficiency, water conservation, and waste reduction (Pandit, 2024). Ageing buildings and the negative impacts of maintaining such include solid waste generation, water and land degradation, and depletion of natural resources and valuable materials (Hauashdh et al., 2024).

In the United States, SFM is focused on optimising the operation and maintenance of buildings, lowering costs, and minimising their environmental impact (Hauashdh et al., 2024). The approach involves strategies to enhance energy efficiency, minimise waste, conserve water, and integrate sustainable practices into the daily operations of facilities. Likewise, in the UK, concerns centre on energy efficiency and policies, such as the Netherlands' Minimum Energy Efficiency Standards (MEES), which require buildings to meet a specific energy rating for letting or selling, thereby guiding practice (McAllister & Nase, 2023). In Ghana, companies have begun to adapt and implement strategies to comply with environmentalism concepts and CSR goals, focusing on effective energy use, pollution reduction, recycling, and waste disposal management, as well as cost reduction (Fosu et al., 2024). Organisations are encouraged to adopt sustainable practices to realise targeted objectives and the SDGs. However, there is limited attention to the factors influencing the adoption of these practices, especially in the African context.

2.2. Factors Influencing the Adoption of Sustainable Practices in Facility Management

Studies revealed that the poor implementation of policies is a significant factor that hinders the adoption of sustainable practices. According to Elmualim (2013), FM focus areas and functions (energy management, waste management, recycling, health and safety, and carbon footprint management) have been part of the profession's agenda before the emergence of sustainable development or sustainability interests. However, the real problem lies in the implementation process of sustainability policies. The study by Elmualim (2013) also identified awareness of sustainable practices, items included in organisations' sustainability policy and organisational effectiveness in implementing and managing sustainability practices as adoption factors. Other studies shared these views, revealing that strategic management and planning from financial, customer, and stakeholder, as well as process and organisational capacity, standpoints are crucial (Rohm & Montgomery, 2019). Roper (2013) opined that the future management of the built environment will be influenced by change management and new technology applications, including robotics, augmented and virtual realities and educational opportunities.

Lee et al.'s (2021) comprehensive review revealed a gap in organisational strategy for performance measurement, specifically in evaluating, planning, maintaining, and controlling quality in facilities management. Morganti and Bragadin (2025) stated that a maintenance planning strategy is of capital importance in improving the life cycle of assets and the efficiency of maintenance processes.

In relation to organisational or corporate strategy, culture, which encompasses the values and behaviours that make up a business's unique environment, can affect how people or groups interact and conduct business; it may influence the sustainable practices adopted (Hamsa, 2025). This could be the responsibility of occupants, the facility management organisation, or the demand organisation. The study by Weerasinghe et al. (2022) revealed that organisational culture, in terms of its strategy to address occupants'

preferences, contributes to the adoption of sustainable practices. Radebe and Ozumba (2021) supported the idea that competence, skills, and knowledge in specialised areas, such as green building and new technologies, might hinder adoption. In addition to the maintenance culture, situational or environmental circumstances contribute to the ageing and damage of building facilities, requiring continuous engagement with industry stakeholders and the participation of FM in the planning phase to ensure that targeted objectives are met with minimal environmental impact (Mewomo et al., 2022).

Furthermore, Rasmussen et al. (2023) observed that individual and organisational ambitions, motivators, and willingness to implement or increase sustainable practices, as well as tenants' expectations and demands (aesthetics), environmental and climate action considerations, finance, and the cost of incorporating sustainable products (for example, energy-efficient products) influence adoption. Technical factors, such as maintenance requirements, types, frequency, and teams (in-sourced and outsourced), as well as privacy and interoperability concerns, influence sustainable practices (Rasmussen et al., 2023; Muniandi et al., 2024).

Organisational structure and size, the FM organisation's data availability to monitor resource consumption, lack of incentives, limited knowledge about relevant environmental themes, inadequate time and resources, user participation, and community-based strategies and involvement all influence the adoption of sustainable practices in FM (Nielsen et al., 2009). Compliance with legislation, regulatory changes, reputation and corporate image (organisations wanting to be seen as environmentally and socially responsible entities), organisational ethos, behaviour and use from the residents and owners, purely technical qualities of the building and misalignment between regulatory and organisational objectives, business contexts and senior management leadership style are also important considerations (Kwawu & Elmualim, 2011).

The identified factors include elements related to the organisation, individuals' knowledge and skill, finance and support, and regulatory, technological and technical factors. As supported by Kwawu and Elmualim (2011), the considerations given to these factors may differ within and between organisations. Different regions may view the extent of their influence differently.

3. Methods

The study adopted a quantitative approach. A closed-ended questionnaire was used to collect data, enabling the derivation of statistical data to achieve the study's objectives (Sundram & Romli, 2023). The questionnaire was hosted online via Google Forms, and the link was circulated among facilities managers and practitioners who attended three conferences held in 2023 and 2024 in African countries. Participants were approached at conferences attended by the author from the time the study was conceptualised (2023). This population was purposively targeted for the study, as they are practising facilities managers who are already adopting or are likely to adopt sustainable practices in their organisations or those that demand them. A similar technique was adopted in a previous study (Musonda & Okoro, 2021). Purposive sampling enables the deliberate identification and selection of individuals in specific settings or events to gather relevant information on the subject or phenomenon of interest, based on their knowledge and/or experience (Taherdoost, 2016).

Additionally, convenience sampling was employed to select participants who were willing to participate in the study. According to Golzar et al. (2022), researchers can select participants with whom they have ready access. Therefore, the total population included all attendees at the three conferences, which were attended by facility management practitioners (approximately 320) from different African countries. As Althubaiti (2022) explained, the population for descriptive studies can be defined by various elements, including the time frame and geographical locations. However, while the time frame was considered (2023–2024), the countries of origin or geographical locations were not included as part of the study's scope, as the delegates convened from various African countries. The views of practitioners in Africa, in general, were sought. The online link was also circulated on two WhatsApp groups to increase the response rate. WhatsApp is an ethically responsive online data collection method for qualitative and quantitative data collection (Mwanda, 2022). Eighty-nine responses were received during the data collection period. The amassed data were analysed using descriptive analysis in the Statistical Package for Social Sciences (SPSS). Cronbach's Alpha was used to assess the internal consistency reliability of the questionnaire constructs, with acceptable values of 0.7 and above. Mean and standard deviation scores were then computed to identify the most important factors influencing the adoption of sustainable practices.

4. Results

The respondents' demographic characteristics are summarised in Table 1. The analysis revealed that the respondents were from South Africa (40.4%), Nigeria (25.8%), and Ghana (23.6%). There was also minimal representation from Egypt, Botswana and Namibia. 39.3% held a Master's degree qualification, 29.2% a Bachelor's degree, 10.1% a PhD, and 7.9% other qualifications, such as certificates. The backgrounds of the participants included: 29.2% in Facilities Management (FM), 18% in Estate Management, 10.1% in Quantity Surveying, and 33.7% in other areas. Their

Table 1: Demographic characteristics of respondents

Attribute	Percentage	Attribute	Percentage
Educational qualification		**Professional qualification**	
Masters	39.3	FMP certification	20.2
Bachelor's	29.2	SFP certification	3.4
PhD	10.1	Other	27.0
Other	7.9	None	47.2
Work experience		**Sector**	
More than 15 years	31.5	FM industry	58.4
5-10 years	31.5	FM Education	3.4
11-15 years	21.3	Other (Building Construction, Engineering, and Research and Development)	25.8
Less than 5 years	15.7	Not specified	12.4

work experience in the FM industry spanned more than 15 years (31.5%), 5-10 years (31.5%), 11-15 years (21.3%), and less than 5 years (15.7%). Regarding professional qualifications, 20.2% of respondents were FMP certified, 3.4% held SFP certificates, and 27% held other professional qualifications. The remaining 47.2% did not have a professional qualification certification. Regarding the sector, 58.4% of respondents indicated they were FM Practitioners, 25.8% were in other sectors such as Building Construction, Engineering, and Research and Development, 3.4% were FM Educators, and 12.4% opted not to specify their sector. Many respondents (41.57%) were involved in combined FM activities (security, waste management, water management, sanitation, energy, landscaping, lifts, HVAC systems, and generators), 34.83% in security, waste management, water management, and corporate services, 4.9% in investment services, and 3.7% in energy services. The remaining 12.36% indicated that they offer other non-listed services. The diverse backgrounds and professional qualifications provided balanced insights from both theoretical and practical perspectives.

The Cronbach's alpha test for internal consistency reliability was 0.967 (N = 20), indicating that the individual items accurately measured what was intended. Table 2 shows the descriptive analysis results. Awareness of sustainability practices emerged as the most important factor (mean=4.37), followed by finance (mean=4.34; SD=1.14), relevant knowledge to adopt sustainable FM practices (mean=4.33), competencies and skills (mean=4.29; SD=1.00) and management support (mean=4.29; SD=1.05). The lowest-ranked factors were environmental control measures (mean = 3.67, SD = 1.17), performance objectives (mean = 3.67, SD = 1.18), and community engagement/involvement (mean = 3.79, SD = 1.03). Two of these factors exhibited relatively higher standard deviations, suggesting respondents were divided on their relevance in adopting sustainable FM practices. All the factors had a range of 4, indicating that responses covered the whole Likert scale of 1 to 5. The low standard deviations, especially on the top factors, indicate respondents' agreement on the relative importance of these factors in adopting sustainable FM practices.

5. Discussion

Awareness, the first-ranked factor, is crucial for the adoption of sustainable FM practices. The study by Elmualim (2013) identified the awareness of sustainable practices and organisations' sustainability policy items as an adoption factor. Its criticality was also supported by Zulu et al. (2020), who ranked the factor highly due to its role in enhancing the adoption of sustainable practices in the construction industry in Zambia. Fosu et al.'s (2024) findings also supported the notion that most organisations in Ghana are unaware of some sustainability imperatives; initiatives like environmental CSR were considered unrealistic and unnecessary without awareness of environmental degradation. Without understanding the concept of sustainability, organisations cannot implement the required sustainability strategies effectively. Hence, spreading awareness is essential for successfully adopting sustainable FM practices.

The respondents also considered finance as an important factor in implementing sustainability initiatives. This suggests that FM organisations with stronger financial support are more likely to adopt sustainable practices. This aligns with the findings of Radebe and Ozumba (2021) and Rasmussen et al. (2023), which showed that financial constraints and the cost of incorporating sustainable products, such as energy-efficient ones, as well as environmental and climate action considerations, are key drivers of adoption. Organisations will be unwilling to invest substantially if it does not yield a return, a view shared by Fischer et al. (2023). This suggests a balance or trade-off necessary to implement sustainable practices.

Table 2: Factors influencing the adoption of sustainable practices in FM

Items	Mean	Standard deviation	Rank
Awareness of sustainability practices	4.37	1.04	1
Finance	4.34	1.14	2
Relevant knowledge to adopt practices	4.33	1.02	3
Competencies/skills needed	4.29	1.00	4
Management support	4.29	1.05	4
Organisational culture	4.18	1.03	6
Cost of environmental programmes	4.13	1.20	7
Technological/technical requirements	4.10	1.12	8
Sustainability tools/standards	4.10	1.21	8
Individual willingness	4.06	1.14	10
Ethics and professionalism	4.04	1.12	11
Procurement/outsourcing support	4.03	1.08	12
System/organisational capacity/size of firms]	4.00	1.07	13
Exposure to international programmes	4.00	1.12	13
Cybersecurity/Safety	3.98	1.13	15
Knowledge management concerns	3.92	1.06	16
National/ Government policies/Legislation	3.92	1.21	16
Community engagement involvement	3.79	1.03	18
Environmental control measures	3.67	1.17	19
Performance objectives	3.67	1.18	19

Knowledge of sustainability concepts ranked third, indicating that respondents largely agree that relevant knowledge is a prerequisite for effectively implementing sustainable practices. Implementing sustainable practices in the FM industry may require a certain level of specialised knowledge, such as energy-efficient technologies and green building standards. Furthermore, the fourth most important factor was competencies/skills needed to implement sustainable practices. These findings were supported by Radebe and Ozumba (2021), who demonstrated that the level of competence, skills, and knowledge in specialised areas, such as green building and new technologies, may either hinder or drive adoption.

Management support was also ranked highly in the descriptive analysis, suggesting that organisational leadership is pivotal in adopting and enabling sustainable practices in FM. This finding was also consistent with Radebe and Ozumba's (2021) observation that a lack of senior management commitment can adversely affect the adoption of sustainable practices in higher education institutions, and that the responsibility for developing policies towards sustainability lies with them. As Ighravwe and Oke (2019) suggested, multicriteria decision-making and multi-objective programming approaches can facilitate more strategic choices and sustainable practices. Management's role in educating staff and end-users about sustainable practices, implementing policies to reduce carbon emissions, or choosing suppliers with a track record of sustainable practices, is essential in SFM practice. These will also spill over to organisational culture, values, and monitoring processes, which ranked sixth.

On the contrary, the result for one of the least-ranked factors (environmental measures) was surprising, as FM sustainability entails minimising the environmental impact of buildings and their operations while maximising resource efficiency. In addition, policies and legislation, although deemed important by many respondents, ranked the lowest. This is inconsistent with views shared by Graubner et al. (2016) on the relevance of codes, standards and policies in sustainability practice in FM. By implementing policies such as green building and complying with regulations, SFM can be ensured. These mixed findings are supported by Kwawu and Elmualim's (2011) observation that different organisations could be driven by differing factors, which may evolve with time.

6. Conclusion

The study evaluated the factors that influence the adoption of sustainable practices in FM using descriptive analysis of data collected from FM practitioners in Africa. Findings revealed the most

important factors as awareness, finance, knowledge, competencies and skills, and management support. The study provides evidence for FM stakeholders' decision-making in assessing and prioritising factors that affect the adoption of sustainable practices in their spaces. Although organisational responsibility for committing resources to sustainability goals rests on the highest level of management, FM professionals can integrate sustainable practices into their operational and management activities. Investing financial resources and strategic support in sustainability initiatives will be instrumental in ensuring that buildings and workplaces are sustainable. Facility managers can create long-lasting organisational value by developing, implementing and maintaining sustainable practices. The current study provides evidence for decision-making regarding policy and strategic support for sustainable FM practice and education.

Future research can be undertaken with a more diverse sample of built environment professionals and a larger sample from more African countries. Alternative research approaches, such as interviews, can be undertaken for more in-depth accounts and a better understanding of the manifestation of these factors in different sectors and organisations. Future research could also employ inferential analysis to examine the contributory effects of the identified factors to sustainability, singly or collectively. In addition, the relationships between the identified factors can be examined to determine which factors can be grouped and prioritised for optimal performance and sustainability in FM. It might also be helpful to investigate future views on the influences considered in the current study, as they may evolve and differ across different organisations and contexts. Further, strategies to encourage the adoption of sustainable practices could be the focus of future studies.

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Growth Constraints of Domestic Construction Firms in Emerging Economies

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Abstract

Domestic construction firms in emerging economies face multiple constraints that hinder their growth. This study aimed to explore the significant constraints that impede the growth of local construction firms working in the prevalent fierce construction market. The theoretical underpinnings of the study were institutional and resource-based view theories. A systematic literature review was the preferred research approach for the study. Out of 435 initially identified documents from Scopus, Web of Science, and ProQuest databases, 18 were selected through a rigorous screening process for in-depth analysis. Using thematic analysis, ATLAS.ti25, five major categories of constraints were explored from the screened publications, including financial, market/competitiveness, workforce and skills, institutional and regulatory, and management and operational. Addressing these constraints through targeted policies and strategic interventions is crucial for enhancing the competitiveness and sustainability of domestic construction firms in emerging economies.

Keywords: Constraints, Construction firms, Emerging Economies, Growth, Systematic literature Review

1. Introduction

The construction industry is a vital component of the global economy, serving as a significant engine for economic growth and recovery. According to Oxford Economics (2021), the construction sector is projected to generate an estimated revenue of $15 trillion by 2025, up from $10 trillion, highlighting its critical role in economic development. The industry not only creates jobs—enrolling over 100 million people globally—but also contributes approximately 6% of the global GDP, and this figure is expected to rise to over 8% in developing countries (World Economic Forum, 2016).

The construction industry is crucial in emerging economies as it delivers the essential infrastructure for human well-being and economic growth. However, despite its significant contributions, the construction industry in emerging economies faces numerous challenges (Alinaitwe, 2021). Moreover, globalisation has intensified competition within the construction industry, with domestic firms often struggling to compete against well-established international contractors (Kirchberger, 2020). This competitive landscape necessitates that domestic construction firms enhance their performance standards and organisational capabilities to survive and thrive. The growth of domestic construction firms is not only an important indicator of a thriving economy but also essential for achieving sustainable development goals (Alinaitwe, 2021).

Emerging economies are characterised by rapid urbanisation and increasing demand for infrastructure, which presents opportunities and challenges for domestic construction firms. As cities expand and populations grow, the need for housing, transportation, and public services becomes more pressing. However, the ability of domestic firms to capitalise on these opportunities is often constrained by different constraints. Addressing these constraints is crucial for enabling domestic firms to compete effectively, innovate, and contribute to the sustainable development of their economies (World Economic Forum, 2016).

The local construction firms of emerging economies are not growing at a pace that could match the prevalent fierce market competition (Tesha et al., 2017). A study by Windapo (2017) in South Africa also indicated that construction firms are not developing and growing sustainably and need sustainable growth strategies. Tesha et al. (2017) also noted a similar condition in Sub-Saharan African countries where local construction firms encounter fierce competition from international contractors. However, there is a knowledge gap in identifying the specific constraints that hinder the growth of local construction firms. This paper aims to explore these growth constraints and propose strategies for enhancing the capacity and competitiveness of local construction firms in emerging economies.

2. Literature Review

The construction industry in emerging economies faces significant growth constraints that hinder the development of domestic construction firms. A study by Somiah et al. (2022) on the Ghanaian construction industry identified four principal components of these constraints: political and economic, capacity, external support, and belief constraints. Political and economic constraints include a lack of political will to develop local content laws, which are essential for promoting indigenous firms. Additionally, the high costs associated with developing local competencies and

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inadequate media debate about local content laws further exacerbate these challenges.

Capacity constraints are particularly detrimental, as they encompass the financial limitations that indigenous firms face in accessing funding for their activities. According to Somiah et al. (2022), the under-capacitated financial market is a leading factor, alongside a limited pool of competent labour and insufficient expertise to design effective local content laws. These constraints prevent domestic firms from competing effectively against foreign counterparts, who often have better access to resources and expertise. The lack of industry pressure groups to advocate for local content laws also contributes to the stagnation of domestic firms in the construction sector (Somiah et al., 2022).

In addition to these findings, corruption (Ofori, 2015), lack of technological advancement (Zhang et al., 2023), and bureaucratic inefficiencies (Ivanov & Aldeen, 2018) are key institutional barriers limiting the growth of construction firms in emerging economies. The study found that delays in permit approvals, inconsistent regulations, and unclear procurement processes create uncertainties that hinder the smooth operation of local firms. Furthermore, weak financial support mechanisms, such as high-interest rates and a lack of collateral, prevent small and medium-sized domestic firms from securing funding for large projects.

Ye & Tekka (2020) emphasised that workforce-related challenges, including a shortage of skilled labour and inadequate training programs, limit the capacity of local firms to execute complex projects. The lack of well-structured vocational training and professional development opportunities leaves domestic construction firms at a disadvantage compared to international competitors. The same study recommended government-led initiatives to improve training programs and increase incentives for knowledge transfer between foreign and domestic firms.

Market and competitiveness constraints are also significant issues. (Ofori, 2015) underscored that foreign construction firms dominate large infrastructure projects due to their financial stability, technological edge, and experience, which leaves domestic firms with limited opportunities to grow. They also noted that domestic firms struggle with branding and strategic partnerships, which affect their ability to win competitive bids. These constraints force many local firms to operate at the subcontracting level rather than leading major projects, thereby limiting their long-term growth prospects.

Moreover, a study by Mousa (2015) pointed out that ineffective management practices and a lack of innovation in construction processes further contribute to growth challenges. Many local firms fail to adopt modern project management methodologies, digital tools, and sustainable construction practices, which are becoming essential for competitiveness in the global market. The theoretical underpinnings for this study are Institutional Theory and Resource-Based View (RBV). Institutional theory explores how organisations respond to pressures from regulatory, normative, and cognitive (Lammers & Garcia, 2017). The Resource-Based View (RBV) complements this by emphasising the importance of firm-specific resources and capabilities in achieving competitive advantage (Utami & Alamanos, 2022). This study aimed to examine the existing scholarly publications on growth constraints of domestic construction firms.

3. Research Methodology

A systematic literature review (SLR) was employed to examine the existing scholarly publications in the study area (Saunders, Lewis & Thornhill, 2016). In contrast to traditional reviews, SLR employs a scientific, transparent, and replicable procedure that involves a thorough assessment of the literature based on the analysis of previous studies (Mase, 2020). The authors followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) 2020 to conduct the SLR (Matthew et al., 2021). The data were acquired from Scopus and Web of Science databases. The query strings used for the search were: (“constraints” or "challenges") and ("local construction firms" or "domestic construction firms"). The authors discarded duplicate articles and articles written in languages other than English. Book chapters and book reviews were also excluded. Studies done in the context of developing countries were included. Studies on social sciences, Engineering, decision sciences, business, management, and accounting were encompassed. Studies conducted from 2006 to 2025 were included. The procedures followed for the article selection are presented in Figure 1.

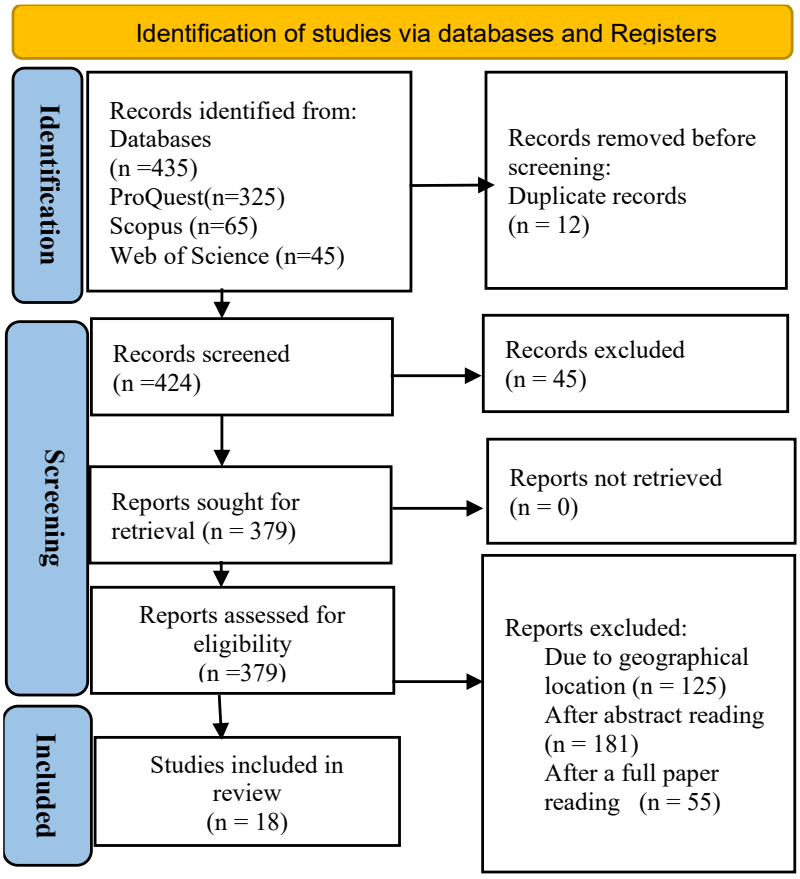


Figure 1: PRISMA 2020 flow diagram for identification of studies for synthesis

Then, the 18 screened publications, illustrated in Figure 1, were examined to identify the existing literature on the different constraints of the growth of local construction firms in emerging economies. A thematic analysis was done on the screened articles using ATLAS—ti25 software.

4. Findings and Discussion

For the analysis using ATLAS.ti25, different codes were initially generated from the quotations extracted from the screened articles. Then, different code groups were created under the theme of constraints of local construction firms. The different constraints to the growth of local construction firms in emerging economies were identified at this stage.

In addition to providing a general understanding of the growth of local firms, the results of the coded data analysis also point to specific constraints. To offer a more profound knowledge, this section explores the significant elements that have been identified as constraints to the growth of local construction firms in the construction industry of emerging economies.

4.1. Growth Constraints of Domestic Construction Firms in Emerging Economies

The constraints identified in the analysis point out various factors hindering construction firms' growth in emerging economies. Table 1 illustrates these drivers with their references. This information was retrieved from the ATLAS—ti25 code document analysis output.

Next, the constraints limiting the growth of domestic construction firms in emerging economies will be discussed. The constraints stem from financial, market, workforce and skills, institutional and regulatory, and management and operational areas.

4.1.1. Financial

Financial constraints significantly hinder the growth potential of domestic construction firms in emerging economies, primarily due to limited access to capital and high borrowing costs. Many of these firms struggle to secure financing from traditional banking institutions, which often view the construction sector as high-risk. This perception leads to stringent lending criteria, including higher collateral requirements and elevated interest rates, making it difficult for smallerfirms to obtain the necessary funds for project execution (Oladimeji, 2019). The lack of financial transparency among many domestic firms further

Table 1: Constraints that impede the growth of construction firms in emerging economies

Constraints	References
Financial Constraints	(Offei et al., 2019; Oladimeji, 2019; Somiah et al., 2022; Ye & Tekka, 2020)
Market / Competitiveness	(Belay et al., 2021; Kesto & Tsega, 2022; Somiah et al., 2022)
Workforce and Skills	(Belay et al., 2021; Ofori, 2015; Ye & Tekka, 2020)
Institutional and Regulatory	(Offei et al., 2019; Somiah et al., 2022; Ye & Tekka, 2020)
Management and Operations	(Kesto & Tsega, 2022; Offei et al., 2019; Oladimeji 2019; Somiah et al., 2022; Ye & Tekka, 2020)

(Source: Summarised by the author from ATLAS.ti25 code-document analysis table)

exacerbates this issue, as lenders may be reluctant to extend credit without a clear understanding of the firm's financial health. Consequently, these financial barriers can stifle innovation and limit the ability of construction firms to undertake larger, more lucrative projects, ultimately affecting their competitiveness in the market.

Moreover, the liquidity challenges faced by construction firms compound the effects of financial constraints. The construction industry is characterised by long project timelines and delayed payments from clients, which can create significant cash flow issues. Firms often find themselves in a position where they must maintain higher liquidity levels to manage ongoing projects and meet financial obligations, which can divert resources away from growth initiatives. This reliance on internal funds for future investments can lead to missed opportunities and a reluctance to expand operations. As a result, financial constraints not only limit the immediate operational capabilities of domestic construction firms but also have long-term implications for their growth trajectories and overall sustainability in an increasingly competitive landscape (Belay et al., 2021).

4.1.2. Market/ Competitiveness

The growth of domestic construction firms in emerging economies is significantly hindered by market competitiveness, as local contractors often struggle to compete with well-established foreign firms. These foreign entities typically engage in larger and more complex projects, resulting in a stark contrast in average contract values. Domestic firms, constrained by limited resources and capabilities, frequently deliver projects that do not meet quality expectations, further exacerbating their competitive disadvantage.

The reliance on foreign contractors not only reflects the high demand for infrastructure development but also highlights systemic issues faced by local firms, such as inadequate training and outdated technology (Kesto & Tsega, 2022). To overcome these competitive barriers, domestic construction firms must implement strategic initiatives aimed at enhancing their operational efficiency and project management skills. Investing in modern technologies and fostering workforce development are critical steps toward improving quality and performance (Somiah et al., 2022). Additionally, cultivating strong relationships with key stakeholders can provide local firms with a competitive edge in securing contracts. By addressing these challenges and leveraging growth opportunities, domestic contractors can better position themselves within the construction industry, ultimately contributing to the economic development of their respective regions.

4.1.3. Workforce and Skills

The growth of construction firms in emerging economies is significantly hindered by the Workforce and Skills constraint, which encompasses a range of challenges related to labour availability and training inadequacies. A critical issue is the persistent shortage of skilled labour, which stems from educational systems that fail to equip graduates with the necessary technical competencies. The demand for a diverse skill set in the construction industry is paramount, yet existing educational frameworks often fall short, leaving firms with a workforce that is ill-prepared for modern challenges (Belay et al., 2021; Ye & Tekka, 2020).

In addition to the shortage of skilled labour, the inadequacy of training programs and insufficient investment in human capital further complicate the landscape for construction firms. The lack of sustainable funding for training initiatives has emerged as a significant barrier to enhancing workforce skills, which are essential for improving the overall performance of the construction sector. Ofori (2015) emphasised that effective leadership and a skilled workforce are critical for the advancement of the construction industry in developing countries. Consequently, addressing the "Workforce and Skills" constraint through targeted investments in education and training is imperative for cultivating a capable

workforce that can propel the growth and sustainability of construction firms in emerging economies.

4.1.4. Institutional and Regulatory

Navigating the complex landscape of construction in emerging economies is fraught with challenges, particularly due to Institutional and Regulatory constraints that stifle growth and innovation. These constraints manifest through inadequate legal frameworks, poor regulatory compliance, and insufficient institutional capacity, creating an environment where construction firms struggle to thrive (Somiah et al., 2022; Ye & Tekka, 2020).

A notable issue is the lack of political will to enforce existing laws and regulations, which results in ambiguous guidelines for firms. Poorly designed local policies and regulatory frameworks lead to inefficiencies and reduced competitiveness among indigenous firms. Additionally, the absence of coherent local content laws further complicates matters; without such regulations, local firms find it challenging to secure contracts and enhance their capabilities (Offei et al., 2019; Somiah et al., 2022).

The challenges do not end with poorly designed regulations; the implementation of existing frameworks is often undermined by inadequate institutional capacity, which affects the enforcement of laws and governance within the construction sector. Therefore, addressing these institutional and regulatory constraints through improved governance, capacity building, and the establishment of clear legal frameworks is crucial for enhancing the growth and sustainability of construction firms in emerging economies.

4.1.5. Management and Operations

Gaps in organisational, financial, and operational management significantly impact the growth trajectory of construction firms in emerging economies. Effective organisational management is crucial for ensuring that construction firms can adapt to changing market conditions and efficiently allocate resources. However, many domestic construction firms struggle with establishing clear organisational structures and processes, which can lead to confusion and inefficiencies. This lack of clarity often results in poor decision-making and ineffective communication within teams, ultimately hindering project execution and firm performance (Kesto & Tsega, 2022).

Financial management is another critical area where construction firms face substantial challenges. Local construction firms usually encounter financial constraints, including cash flow issues and limited access to credit, which severely impact their ability to fund projects and manage operational costs effectively. Research indicates that these financial difficulties can lead to project delays and cost overruns, further exacerbating the challenges faced by these firms (Somiah et al., 2022; Ye & Tekka, 2020).

Additionally, operational management is often compromised due to inadequate planning and resource allocation, which can result in inefficiencies and increased project risks. The reliance on unskilled labour, driven by financial limitations, further complicates operational management, as it can lead to subpar quality and performance. Therefore, addressing these constraints through improved organisational structures, robust financial management practices, and effective operational strategies is essential for enhancing the growth and sustainability of construction firms in emerging economies.

5. Conclusion and Further Research

The growth of domestic construction firms in emerging economies is constrained by multiple interrelated factors that hinder their competitiveness and sustainability. This study, grounded in Institutional Theory and the Resource-Based View (RBV), systematically identified five major categories of constraints: financial, market/competitiveness, workforce and skills, institutional and regulatory, and management and operational. The findings highlight that limited access to financial resources, intense competition from foreign firms, inadequate workforce training, weak institutional support, and inefficient management practices significantly impede the expansion of local construction firms.

Addressing these challenges requires a multifaceted approach involving policy interventions, industry-wide capacity building, and strategic internal improvements. Governments and regulatory bodies must create an enabling business environment by refining institutional frameworks, ensuring fair competition, and facilitating access to financial resources. Additionally, domestic firms need to enhance their internal capabilities by adopting modern construction technologies, investing in workforce development, and improving financial and operational management practices.

Ultimately, overcoming these constraints is critical for the sustainable growth of domestic construction firms, enabling them to contribute more effectively to infrastructure development, job creation, and economic progress in emerging economies. Future research should explore targeted strategies for mitigating these constraints, as well as the role of digital transformation and emerging construction technologies in enhancing firm competitiveness.

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ACADEMIC PAPERS: THEME 6 - CONSTRUCTION HEALTH AND SAFETY

Exploring Shame in Construction Health and Safety in South Africa

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Abstract

This study examines the role of shame as an emotional and ethical factor influencing health and safety practices in the South African construction industry. Using a literature review methodology, the research synthesises existing studies on emotional responses, construction health and safety, and ethics to analyse how shame impacts professional behaviour and decision-making in the construction industry. The study focuses on the unique challenges of health and safety in South Africa, including high rates of workplace accidents, non-compliance with safety standards, and ethical lapses that compromise worker well-being. Shame often arises when construction professionals fail to uphold health and safety standards, leading to potential reputational damage and emotional distress. This response can act as a driver for improved accountability and adherence to safety protocols, but may also result in defensiveness or avoidance behaviours that hinder progress. The research findings highlight the cultural dimensions of shame in South Africa, where collectivist values and community-focused approaches influence how shame is experienced and addressed. The study also emphasises the critical role of education and training in promoting ethical awareness and emotional intelligence among construction professionals. By addressing shame constructively, the industry can enhance compliance with health and safety regulations, promote worker well-being, and contribute to a culture of ethical responsibility. This study offers insights into leveraging emotional dynamics to improve health and safety outcomes, with implications for policy development and professional practice in the South African construction industry.

Keywords: Shame, Health and Safety, Construction Industry, South Africa, Ethical Accountability

1. Introduction

The construction industry plays a vital role in South Africa's economic development, yet it continues to face significant challenges regarding workplace health and safety compliance (Agumba & Haupt, 2018). Despite regulatory frameworks and professional standards, the sector reports persistently high rates of accidents, injuries, and fatalities compared to other industries in the region (Construction Industry Development Board [cidb], 2023). While technical and procedural aspects of safety management have been extensively studied, the emotional and psychological dimensions that influence safety behaviours remain understudied, particularly in the South African context.

The concept of shame, as a powerful emotional response to perceived failure or transgression, emerges as a critical yet unexplored factor in construction health and safety practices. Shame differs from guilt in that it focuses on the self rather than the behaviour, potentially triggering more profound psychological responses that affect professional decision-making and compliance (Tangney et al., 2019). In the construction industry, where decisions can have life-or-death consequences, understanding the role of shame becomes particularly relevant. South Africa's construction sector operates within a unique cultural and social context, characterised by strong collectivist values and community-oriented perspectives (Emuze & James, 2013; Oyeowbi et al, 2020). These cultural dimensions significantly influence how shame is experienced, expressed, and managed within professional settings. The intersection of traditional African values with modern construction practices creates a complex environment where emotional responses to safety violations may differ from those observed in Western contexts (Sherratt, & Aboagye-Nimo, 2022). The high prevalence of workplace accidents in South African construction sites often stems from systematic failures in safety protocol implementation. Recent statistics indicate that the construction sector accounts for approximately 12% of all workplace fatalities in the country, despite employing only 8% of the formal workforce (Department of Employment and Labour, 2022). These numbers suggest underlying issues beyond mere technical compliance, pointing to deeper psychological and emotional factors that influence safety-related behaviours and decisions.

Shame can manifest in various ways within the construction industry, from individual responses to safety violations to organisational cultures that either suppress or acknowledge emotional responses to safety failures. Construction professionals may experience shame when their actions or decisions lead to accidents or near-misses, when they fail to maintain safety standards, or when their organisations face public scrutiny for safety lapses. This emotional response can either motivate improved safety practices or lead to defensive behaviours that perpetuate unsafe conditions (McCall & Pruchnicki, 2017). The role of leadership in

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addressing shame within construction organisations cannot be understated. Research indicates that leaders who acknowledge and constructively address emotional responses to safety failures are more successful in building sustainable safety cultures (Asad et al., 2022). However, in South Africa, where hierarchical organisational structures often prevail, addressing emotional aspects of safety management may present unique challenges and opportunities.

Education and training emerge as critical components in managing shame's influence on safety practices. Traditional safety training programs typically focus on technical knowledge and procedural compliance, often neglecting the emotional competencies necessary for effective safety management (Wang et al., 2021). Incorporating emotional intelligence and ethical awareness into professional development programs could enhance the industry's capacity to address shame constructively. The relationship between shame and ethical accountability in construction safety presents a complex dynamic. While shame can serve as a natural deterrent to unsafe practices, excessive or mismanaged shame may lead to the concealment of safety issues or resistance to reporting incidents (Daniels & Robertson, 2019). Understanding this dynamic is crucial for developing effective safety management strategies that balance emotional responses with professional responsibilities.

This study examines the intricate relationships between shame, safety practices, and professional behaviour in the South African construction industry. By analysing how shame influences decision-making and compliance with safety regulations, the research aims to contribute to a more nuanced understanding of emotional factors in construction safety management. This understanding is crucial for developing more effective approaches to safety training, policy implementation, and organisational culture development. The findings of this research have significant implications for both practice and policy in the construction industry. By acknowledging and addressing the role of shame in safety behaviours, organisations can develop more effective strategies for promoting compliance and promoting a culture of safety.

Additionally, policymakers can benefit from understanding how emotional factors influence safety outcomes when designing regulatory frameworks and enforcement mechanisms. Through examining shame's role in construction health and safety, this study aims to bridge the gap between emotional responses and practical safety management in the South African construction industry. The insights gained may contribute to developing more holistic approaches to safety management that acknowledge the technical and emotional aspects of workplace safety.

2. Literature Review

2.1. Exploring Shame in Construction Health and Safety in South Africa

Shame, a deeply personal and emotional response to perceived failures or ethical lapses, significantly impacts professional behaviour and decision-making (Tangney et al., 2007). In the construction industry, where compliance with health and safety standards is critical, shame can arise when lapses result in harm or public scrutiny. South Africa's construction sector faces unique challenges, including high rates of workplace accidents, systemic corruption, and non-compliance with safety protocols. For instance, the Construction Industry Development Board (cidb) reported over 10,000 workplace incidents in a single year, reflecting a pressing need for improved safety practices (cidb, 2009). Understanding how shame influences these dynamics is crucial, as it can either motivate adherence to health and safety standards or create barriers to accountability. This literature review synthesises research to explore the dual role of shame as a driver and barrier to health and safety compliance within South Africa's construction industry. By examining cultural dimensions and educational implications, it aims to provide actionable insights for enhancing ethical accountability and promoting safer practices.

Shame is a complex and multifaceted emotion, deeply tied to ethical and moral considerations, which arises when individuals perceive themselves as failing to meet societal or professional standards (Lewis, 1971). Unlike guilt, which relates to specific actions, shame implicates the self, often triggering feelings of worthlessness and inadequacy (Tangney et al., 2007). In professional settings, shame functions as both an emotional response and a regulatory mechanism, influencing behaviour and decision-making. This dynamic is particularly evident in industries such as construction, where adherence to health and safety standards is critical. In South Africa, the construction industry is marked by high rates of workplace accidents and fatalities, with two workers reportedly dying weekly due to safety lapses (cidb, 2009). These incidents often evoke shame among professionals and organisations, impacting their ability to comply with safety regulations. Shame in this context not only reflects personal failure but also carries reputational and ethical implications, driving individuals and organisations to address safety lapses (Daniels & Robinson, 2019; Mayer et al., 2017).

South Africa's collectivist cultural framework amplifies the significance of shame, linking it to communal values and shared responsibility (Gade, 2012). Professionals in this setting are influenced by personal ethics and societal expectations, which shape how shame is experienced and addressed. Understanding these dynamics is crucial for leveraging

shame constructively to promote compliance with health and safety standards. Additionally, recent research highlights the intersection of shame with structural factors such as corruption and resource constraints, which exacerbate safety challenges in South Africa's construction industry (Kwinika & Marnewick, 2018). These insights underscore the need for a nuanced approach to addressing shame, integrating emotional intelligence, ethical training, and policy reforms to enhance health and safety outcomes.

When constructively addressed, shame can serve as a motivator for accountability and reform. Research suggests that public scrutiny following safety lapses often drives organisations to implement stricter safety measures and enhance compliance (Ali et al., 2024). For example, the Tongaat Mall collapse in 2013, attributed to structural failures, led to increased regulatory scrutiny and safety reforms in South Africa (Kwinika & Marnewick, 2018). Leadership plays a pivotal role in channelling shame into positive outcomes. Leaders who acknowledge organisational failures and foster a culture of accountability can harness shame constructively to promote a proactive safety culture (Daniels & Robinson, 2019; Yazdi, 2025). In South Africa, initiatives such as the Green Building Council's safety guidelines have encouraged ethical practices and fostered industry-wide improvements. Conversely, shame can act as a barrier to compliance when it leads to defensiveness or avoidance. Excessive shame, particularly when unresolved, can result in individuals concealing mistakes or resisting safety interventions out of fear of reputational damage (Tangney et al., 2007). This dynamic is evident in South Africa's construction industry, where systemic challenges such as corruption exacerbate the negative impacts of shame (CIDB, 2009). The Tongaat Mall collapse highlights how unaddressed shame can hinder accountability. Investigations revealed attempts to deflect blame rather than address systemic issues, delaying meaningful reforms (Kwinika & Marnewick, 2018). Such behaviours perpetuate unsafe practices and undermine efforts to improve health and safety standards.

South Africa's cultural framework significantly shapes how shame is experienced and managed in professional contexts, including the construction industry. Central to South African cultural identity is the philosophy of Ubuntu, which emphasises community, interconnectedness, and shared responsibility (Gade, 2012). In this context, shame is often perceived as not just an individual failure but a collective shortcoming, where the actions of one can reflect on an entire group or community. This cultural orientation can drive collective efforts to address health and safety lapses, as the well-being of the group is prioritised over individual accountability (Chasi, 2014). However, this collectivist perspective can also create barriers to openly addressing safety failures. Admitting to mistakes or ethical breaches may result in stigma, ostracism, or damage to an individual's social standing within their professional or personal community (Bilal, et al., (2021). Such dynamics may lead professionals to conceal errors, perpetuating unsafe practices rather than addressing them transparently.

Additionally, South Africa's history of apartheid and systemic inequalities continues to influence workplace dynamics. Structural inequities in the construction sector often exacerbate feelings of vulnerability among workers, amplifying the emotional impact of shame when safety standards are compromised (cidb, 2009). Understanding these cultural and historical nuances is essential for designing interventions that address shame constructively, encouraging both individual and collective accountability while respecting cultural values. By integrating cultural sensitivity into health and safety policies, organisations can create environments where shame is managed constructively, fostering a culture of learning and improvement.

Addressing the role of shame in safety practices requires incorporating emotional intelligence and ethical reasoning into construction education. Case-based learning that explores psychological barriers, ethical dilemmas, and safety failures can prepare professionals to navigate these challenges effectively (Lingard & Turner, 2017). For instance, incorporating emotional intelligence training into health and safety curricula has been shown to enhance resilience and ethical decision-making in high-risk professions (Iyanda et al., 2024). In South Africa, training institutions have begun emphasising ethical accountability in their programs. However, there remains a need for targeted interventions that address the cultural and emotional dimensions of shame, ensuring that professionals are equipped to manage these dynamics constructively.

Despite the growing recognition of emotional factors in workplace ethics, research on shame's impact on health and safety practices in South Africa's construction sector remains limited. Key gaps include a lack of longitudinal studies on shame-driven interventions and limited exploration of how gender, socio-economic status, and organisational culture shape experiences of shame. Comparative studies between South Africa and other developing nations could also provide valuable insights into the role of cultural context in shaping these dynamics. Future research should focus on interdisciplinary approaches that integrate psychology, ethics, and construction management to address these gaps effectively. Shame is a powerful emotional and ethical factor influencing health and safety practices in South Africa's construction industry. When constructively managed, it can drive accountability and compliance with safety protocols. However, if left unaddressed, shame can lead to defensiveness and resistance, undermining efforts to improve safety

outcomes. By recognising the cultural dimensions of shame and integrating emotional intelligence into education and training, the industry can foster a culture of ethical responsibility and enhance overall safety performance.

3. Research Methodology

This study employs a literature review methodology to explore the role of shame as an emotional and ethical factor influencing health and safety practices in the South African construction industry. A literature review approach is well-suited for synthesising knowledge from diverse fields, identifying trends, and highlighting gaps in the existing research (Snyder, 2019). The methodology integrates interdisciplinary perspectives, including emotional psychology, construction management, and cultural studies, to understand the topic. The review systematically retrieved peer-reviewed articles, academic books, and credible industry reports from established databases such as Scopus, Web of Science, JSTOR, and Google Scholar. Keywords such as "shame in construction," "health and safety in South Africa," "ethical accountability," "emotional dynamics in workplace ethics," and "cultural influences on workplace behaviour" guided the search. Articles published between 2005 and 2023 were prioritised to ensure a balance between foundational theories and recent developments in the field. Specific inclusion criteria included:

- Empirical or theoretical studies addressing shame in professional or ethical contexts.
- Research on health and safety practices within the construction industry, particularly in South Africa.
- Studies examining the intersection of culture, emotion, and professional behaviour.
- Additionally, South African construction industry reports, such as those from the Construction Industry Development Board (CIDB), were included to provide regional context and relevance.

Thematic analysis was employed to identify and categorise key themes across the selected studies (Braun & Clarke, 2006). The analysis focused on three core areas: shame as a driver for health and safety improvements, exploring how shame motivates professionals and organisations to adhere to ethical and safety standards; shame as a barrier to compliance, examining the negative impacts of shame, such as avoidance behaviours and resistance to accountability; and the cultural dimensions of shame in South Africa, investigating the influence of collectivist values and Ubuntu philosophy on the experience and expression of shame. Each theme was further analysed for its implications on education, policy development, and professional practices in South Africa. Several steps were implemented to ensure the methodological robustness and credibility of the review. Articles were screened for relevance, methodological rigour, and citation frequency. Multiple databases were utilised to reduce selection bias and capture diverse perspectives. Additionally, findings were cross-referenced with regional reports and industry guidelines to ensure alignment with the realities of the South African construction industry.

While the literature review methodology provides a synthesis of existing knowledge, it is inherently limited by the availability of published research. Specific gaps in empirical studies on shame in South Africa's construction sector necessitate reliance on broader interdisciplinary insights. Future research is recommended to address these gaps through primary data collection and regional studies. This methodology enables a nuanced and contextually grounded exploration of shame in South Africa's construction industry. By synthesising interdisciplinary insights and regional data, the study contributes to understanding emotional and ethical dynamics in professional health and safety practices. The approach aligns with the study's objective to provide actionable recommendations for policy, education, and industry practices.

4. Findings

The findings of this study, derived from a literature review and thematic analysis, reveal critical insights into the role of shame as an emotional and ethical factor in shaping health and safety practices within South Africa's construction industry. These findings are organised around three central themes: shame as a driver for improvement, shame as a barrier to compliance, and the cultural dimensions of shame.

4.1. Shame as a Driver for Health and Safety Improvements

Shame emerged as a powerful motivator for improving health and safety standards when constructively addressed. The literature indicates that incidents of publicised safety failures often trigger a collective sense of accountability within organisations, prompting corrective actions. For example, the aftermath of the Tongaat Mall collapse in 2013 saw increased regulatory scrutiny and organisational efforts to comply with safety protocols (Kwinika & Marnewick, 2018). Shame experienced by professionals due to such high-profile failures motivated efforts to restore personal and organisational integrity. Leadership plays a pivotal role in leveraging shame positively. Supportive leaders who acknowledge safety lapses without punitive measures foster environments conducive to learning and improvement (Yazdi, 2025). Such leadership encourages open dialogue about safety challenges, reinforcing a culture of ethical accountability. These findings suggest that shame, when managed

appropriately, can catalyse embedding safety-oriented practices in organisational culture.

4.2. Shame as a Barrier to Compliance

Conversely, shame can act as a significant barrier to compliance with health and safety standards. The review highlights instances where excessive or unresolved shame leads to defensive behaviours, denial, or concealment of errors. For instance, the initial investigation into the Tongaat Mall collapse revealed attempts by stakeholders to deflect blame, undermining efforts to identify root causes and implement systemic reforms (cidb, 2009; Kwinika & Marnewick, 2018). Fear of reputational damage and punitive consequences discourages transparency, particularly in smaller construction firms where resources for compliance are limited (Tangney et al., 2007). This behaviour perpetuates unsafe practices and hampers efforts to build trust and accountability within the industry. These findings underscore the importance of addressing shame constructively to prevent it from obstructing health and safety improvements.

4.3. Cultural Dimensions of Shame in South Africa

The collectivist cultural framework in South Africa, deeply rooted in the philosophy of Ubuntu, profoundly influences how shame is experienced and managed. The literature shows that shame is often perceived as a communal failure rather than an individual shortcoming, prompting collective responses to address health and safety issues (Gade, 2012). For example, when safety violations occur, organisations and teams often come together to implement corrective measures, reflecting shared responsibility. However, this cultural orientation also creates challenges. Professionals may fear stigmatisation or loss of standing within their community, leading to reluctance in admitting mistakes or reporting violations (Bilal et al., 2021).

Additionally, the historical and systemic inequities in South Africa's construction sector amplify feelings of vulnerability, particularly among marginalised workers, intensifying the emotional impact of shame (cidb, 2009). The findings highlight the need for culturally sensitive interventions that align with South Africa's collectivist values while promoting transparency and accountability. Policies and training programs that emphasise collective learning and shared responsibility can help mitigate the negative impacts of shame.

4.4. Education and Training Implications

The role of education and training in addressing shame constructively emerged as a critical finding. The literature underscores the need for integrating emotional intelligence and ethical training into construction education to help professionals navigate the complexities of shame. Programs that incorporate case-based learning and emphasise collective problem-solving are particularly effective in fostering resilience and ethical accountability (Lingard & Turner, 2017).

While South African institutions have made progress in incorporating health and safety modules, there is limited emphasis on the emotional and cultural dimensions of shame. Addressing this gap through targeted training initiatives can equip professionals with the tools to manage shame constructively, enhancing compliance and improving overall safety outcomes. These findings illuminate the dual role of shame as both a motivator and a barrier to health and safety compliance in South Africa's construction industry. They emphasise the critical influence of cultural dimensions and leadership in shaping how shame is experienced and addressed. By fostering supportive environments, integrating cultural sensitivity, and enhancing educational frameworks, the construction sector can leverage shame constructively to drive ethical accountability and safer practices.

5. Implications of the Findings

The findings of this study provide several critical implications for theory, policy, and practice in the South African construction industry and offer broader insights into managing shame as an emotional and ethical factor in professional settings.

The dual role of shame, as both a driver and barrier, underscores its complexity as an emotional and ethical construct. Within the South African context, the findings extend the literature by highlighting how collectivist cultural values, such as Ubuntu, shape the experience and management of shame. This contributes to global discussions on moral emotions in professional behaviour by offering a culturally specific perspective (Gade, 2012). Future theoretical models of workplace ethics and safety compliance should incorporate cultural dimensions and consider the communal aspects of shame, particularly in contexts where collective accountability is a dominant value. The findings have direct implications for health and safety policies in South Africa. Current approaches often focus on punitive measures to enforce compliance, which may inadvertently exacerbate the negative impacts of shame. Instead, policies should integrate mechanisms that constructively address shame, such as fostering open communication, promoting restorative justice practices, and encouraging collective problem-solving. By aligning with South Africa's collectivist cultural values, such policies can mitigate defensive behaviours and encourage transparency, leading to sustained improvements in health and safety outcomes (cidb, 2009). At the organisational level, the study highlights the critical role of leadership in managing shame constructively. When leaders cultivate a supportive environment where accountability is encouraged without punishment, shame can become a powerful driver of ethical behavior and improved safety practices

(Yadzi, 2025). Training programs for construction managers should emphasise emotional intelligence, cultural sensitivity, and strategies for creating psychologically safe environments.

The findings emphasise the need for integrating emotional and ethical training into construction education in South Africa. While existing programs address technical aspects of health and safety, there is a gap in preparing professionals to navigate the emotional complexities of shame. Incorporating case-based learning, role-playing scenarios, and discussions on cultural dimensions of ethics can help professionals better manage shame and foster resilience in high-stakes environments (Iyanda et al., 2024). South Africa's unique cultural and historical context offers valuable lessons for other developing countries with similar socio-economic and cultural frameworks. The emphasis on collective accountability and shared responsibility can serve as a model for addressing shame in other collectivist cultures.

Furthermore, the systemic challenges faced by South Africa's construction industry, such as resource constraints and historical inequities, highlight the importance of culturally tailored interventions to improve health and safety outcomes globally. Finally, these findings highlight gaps in the broader literature that future research can address. Comparative studies across different geographic and cultural contexts can deepen understanding of how shame operates in various professional settings. Longitudinal research is also needed to evaluate the long-term impacts of interventions that leverage shame constructively. Such studies would further refine strategies for integrating emotional and ethical dimensions into health and safety practices worldwide. The study provides actionable insights for improving health and safety practices in the construction industry. Constructively addressing shame through culturally sensitive policies, leadership practices, and education can not only enhance compliance but also contribute to a broader culture of ethical accountability and resilience in professional settings. These implications extend beyond South Africa, offering lessons for other regions grappling with similar challenges in health and safety management.

6. Conclusion and Recommendations

This study explored the role of shame as an emotional and ethical factor influencing health and safety practices in the South African construction industry. The findings demonstrate that shame serves a dual function: it can motivate positive change by driving accountability and adherence to safety standards. However, it can also act as a barrier when it leads to defensiveness and avoidance. South Africa's collectivist cultural context, deeply influenced by Ubuntu, amplifies these dynamics, framing shame as both an individual and communal concern. The study underscores the critical role of leadership, education, and policy in managing shame constructively to enhance health and safety outcomes. Despite progress in addressing health and safety challenges, systemic issues such as corruption, resource constraints, and inequities remain pervasive in South Africa's construction industry. Addressing these challenges requires an integrative approach that considers the emotional, cultural, and ethical dimensions of professional behaviour. By fostering environments emphasising transparency, shared accountability, and continuous learning, the construction industry can better navigate the complexities of shame and its impact on health and safety compliance.

Based on the findings and implications of this study, several key recommendations can be proposed to enhance health and safety practices in South Africa's construction industry. First, there is a need to shift from punitive to restorative approaches to addressing health and safety violations. Policies should prioritise the promotion of accountability through constructive dialogue, corrective actions, and support mechanisms while also integrating cultural sensitivity into frameworks that align with South Africa’s collectivist values and the philosophy of Ubuntu. Leadership training is essential, equipping leaders in the construction industry with skills in emotional intelligence and cultural competence to manage shame constructively within their teams. Leaders should adopt transparent and supportive approaches to addressing safety lapses, promoting a culture of openness and continuous improvement.

Additionally, education and training programs for construction professionals should incorporate emotional and ethical dimensions, including modules on managing shame, fostering resilience, and addressing ethical dilemmas. Case-based learning and role-playing exercises can further simulate real-world scenarios, preparing professionals to navigate challenges effectively. At the organisational level, mechanisms such as anonymous reporting systems and restorative justice practices should be established to address safety violations without fear of stigma or reprisal. Encouraging collective problem-solving and team-based accountability will also align interventions with cultural values, fostering collaborative approaches to safety. Finally, research and evaluation efforts should focus on conducting longitudinal studies to assess the effectiveness of interventions aimed at managing shame and improving compliance. Comparative research across regions would provide insights into how shame and cultural dynamics influence safety practices globally. At the same time, further investigation into the intersection of gender, socio-economic status, and organisational culture could deepen understanding of shame's role in the construction industry. These recommendations

collectively aim to create an environment that constructively addresses shame, enhances accountability, and improves health and safety outcomes.

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Developing a Safety Competence Evaluation Framework for Artisans in the Nigerian Construction Industry

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Abstract

The construction industry is recognised worldwide as one of the most dangerous industries related to accidents, especially in developing countries. This is because the artisans, who play a crucial role in construction activities, have inadequate safety competencies, thereby contributing significantly to these unsatisfactory safety outcomes. However, despite considerable efforts to improve the safety competencies of construction artisans, initiatives aimed at evaluating safety-related competencies remain limited. Consequently, this research aims to address this deficiency by developing a safety competence assessment framework specifically for artisans in the Nigerian construction industry. A cross-sectional survey approach was used to gather data from 470 safety managers and supervisors, followed by exploratory factor analysis to identify factors influencing safety competence regarding knowledge and practical skills. The findings emphasise the complex nature of safety competence, providing insights into practical safety skills, decision-making, and the interpersonal and communication dimensions of safety competence. In addition, the framework presents a visual-based method for assessing competencies across the corresponding dimensions. The framework must be tailored to enhance safety outcomes on construction sites. Consequently, the study offers theoretical insights for improving artisan training, which would ultimately reduce the incidence of accidents, along with practical applications that would benefit safety managers significantly.

Keywords: Artisans, Competence Evaluation Framework, Construction Industry, Safety, Safety Competence

1. Introduction

The construction industry, particularly in developing countries such as Nigeria, is characterised by high rates of accidents due to poor safety performance, often arising from the incompetence of artisans (Ojo et al., 2025; Adebowale & Agumba, 2023; Williams, 2019). Artisans play a crucial role on construction sites, and their safety awareness directly influences safety performance (Boakye et al., 2023; Yap & Lee, 2020). Despite regulatory efforts and safety training programs, there remains an absence of frameworks to gauge the safety competence of artisans (Zou & Sunindijo, 2021). Existing studies have primarily focused on the managerial level, ignoring the organisational safety commitments of artisans, who are most exposed to on-site hazards (Sherratt & Aboagye-Nimo, 2022; Danso, 2022).

Prior assessment tools frequently ignore the educational and contextual realities of artisans, resulting in little or no effectiveness (Siabi, 2022; Tremblay & Badri, 2018). This raises important questions: What are the main elements for developing a safety competence assessment framework for Nigerian artisans? Which indicators best reflect their competence for improving safety performance? This study addresses these gaps by developing a framework for artisans in the Nigerian construction industry. Distinct from generic frameworks, this framework offers practical tools for safety managers to assess the readiness of artisans for safe work, to reduce accidents, and to improve safety outcomes, specifically in developing nations.

2. Literature Review

2.1. Introduction

The construction industry has been widely recognised as one of the most hazardous industries globally, especially in developing countries such as Nigeria. The high number of accidents and fatalities in this industry can be attributed to various factors, including inadequate safety training and competencies among artisans (Antoniou & Agrafioti, 2023). Artisans who are pivotal in executing construction tasks often lack the necessary safety skills and knowledge, contributing to adverse safety outcomes (Hasanzadeh et al., 2017). Consequently, the need for a framework to evaluate and improve the safety competencies of these artisans has become increasingly urgent. This literature review examines relevant research on safety competencies in the construction industry, focusing on the Nigerian context, and highlights the gaps that the proposed framework seeks to address.

2.2. Understanding Safety Competence in Construction

Safety competence refers to the knowledge, skills, and behaviours necessary to execute construction tasks safely (Rahman et al., 2022; Liang, 2019). It includes

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technical awareness, hazard detection, communication, and decision-making. In developed nations, safety competence is often cultivated through formal training and regulation (Bautista-Bernal et al., 2024; Pilbeam & Karanikas, 2023). However, this ideal model does not reflect realities in developing countries such as Nigeria, where formal safety training is infrequent and regulatory enforcement is poor (Umeokafor et al., 2022; Umeokafor, 2017).

2.3. Nigerian Safety Landscape

Artisans form the operational pillar of construction sites, performing critical tasks such as masonry, carpentry, and plumbing works (Ebekozien et al., 2025). While their roles largely influence safety performance, Nigerian artisans characteristically enter the construction industry through informal apprenticeship systems, lacking formal safety education (Ebekozien, 2022; Abdullahi et al., 2015). Thus, many do not participate in formal safety practices such as risk assessments or safety audits, which remain the purview of engineers and supervisors.

2.4. Existing Frameworks and Gaps

Globally recognised safety competence frameworks, including OSHA regulations and European frameworks, are developed for formal training settings and managerial-level roles (Umeokafor et al., 2020; Zou et al., 2015; Hardison et al., 2014). These frameworks assume a level of knowledge, standardisation, and regulatory structure absent in the Nigerian construction industry. Therefore, existing models are insufficient for assessing and developing artisan-level competence in Nigeria.

2.5. Defining Artisan Safety Competence

This study uses a two-dimensional view of safety competence, comprising knowledge (e.g., hazard identification, PPE use, recognising unsafe conditions) and skills (e.g., safe tool handling, task-specific precautions) (Pourmazaherian & Musonda, 2022; Zou & Sunindijo, 2021). Acknowledging that several artisans cannot carry out formal risk assessments, the framework targets competencies achievable through incremental, experience-based learning. Thus, competence is conceptualised as developmental, varying across basic, intermediate, and advanced levels.

2.6. Contextual Influences on Competence

Artisan safety competence is influenced by numerous factors: age, education, experience, site culture, and supervision (Boakye et al., 2023). Informal skill acquisition and variable work conditions hinder consistent safety behaviour. Additionally, low literacy and limited access to resources limit the adoption of proper safety training methods (Chetty, 2024). These realities necessitate a framework that is adaptable, observable, and grounded in context-specific behaviours.

2.7. Rationale for a Context-Sensitive Framework

There is a need for an assessment framework tailored to the competencies attainable by artisans in the Nigerian construction industry. Such a framework must be practical and inclusive of both current competences and aspirational behaviours (Jadallah et al., 2021). This framework offers a roadmap for progressive safety improvement in developing countries by acknowledging the context while aligning with global best practices.

3. Research Methodology

This study employed a cross-sectional research design, using a structured questionnaire survey to assess artisans' safety competence in Abuja, Nigeria. Safety managers and supervisors, who supervise artisans on construction sites, were asked to appraise the competencies of artisans in terms of knowledge and skills. The objective was to gather insight from those with direct supervisory responsibilities over artisans, given that most artisans in Nigeria are not literate and cannot reliably self-assess competence using questionnaires.

3.1. Sampling and Respondent Recruitment

The study targeted safety managers and supervisors working on construction projects across the six municipal area councils of Abuja: Gwagwalada, Kuje, Bwari, Kwali, Abuja Municipal, and Abaji. Due to the lack of a publicly available sampling frame of all safety professionals in the area, a non-probability convenience sampling approach was used. This strategy was necessary given field access limitations and the informal employment structure of the Nigerian construction industry. The contact details of safety managers and supervisors were obtained through a multi-step approach: Collaboration with local chapters of professional bodies such as the Nigerian Institute of Building (NIOB), Council of Registered Builders of Nigeria (CORBON), and Nigerian Institute of Safety Professionals (NISP). Site visits to active medium and large-scale construction sites, with formal introductions to site safety professionals through the main contractors. Referrals using the snowballing technique, where recognised safety officers introduced the research team to others in the industry.

Through this method, 744 questionnaires were distributed physically by hand between August 2023 and July 2024, across over 60 construction sites in the Abuja metropolis. Efforts were made to distribute the questionnaires evenly across public, private, residential, and commercial construction projects. Out of the 744 questionnaires distributed, 470 valid and complete responses were obtained and used for analysis, yielding a response rate of 63%. This rate is significantly higher than typical response rates in construction management research, which often fall below 30% (Baruch & Holtom, 2008). The relatively

high response rate can be attributed to in-person distribution, relationship-building with gatekeepers, and follow-up visits to collect completed questionnaires.

3.2. Instrument Development and Pilot Study

The questionnaire instrument was adapted from previously validated scales in the literature (e.g., Pourmazaherian & Musonda, 2022; Møller et al., 2021). It was organised into two sections: safety knowledge (32 items) and safety skills (13 items), all measured on a five-point Likert scale (1 = strongly disagree to 5 = strongly agree). Before the survey, a pilot test was conducted with 16 safety supervisors from different construction sites in Abuja. The pilot aimed to assess the clarity, relevance, and contextual appropriateness of the items. Based on the results from the pilot test, Technical terms (e.g., "ergonomic hazard") were simplified. Questions were condensed to improve readability. Some double-barrelled items were divided into two for precision. Additional items relevant to local site operations (e.g., understanding of local safety signage and PPE usage practices) were added. Moreover, the final questionnaire was reviewed by a panel of three PhD holders in Construction Management and Health and Safety from a Nigerian university, all of whom had prior site-based experience in construction safety practice in Abuja and Lagos. Their expertise ensured that the instrument achieved both content and contextual validity for the Nigerian construction environment.

3.3. Data Analysis and Competence Categorisation

Descriptive statistics, including means and standard deviations, were computed to summarise the data. Exploratory Factor Analysis (EFA) was performed using principal axis factoring with oblique rotation to identify latent constructs within the knowledge and skill variables (Field, 2018). Variables were grouped under broader categories, including: Safety knowledge: hazard identification, safety regulations, risk assessment, and emergency procedures. Safety skills: practical safety skills, decision-making skills, and communication. The competence levels were then categorised using defined thresholds (Walliman, 2021) and presented using radar charts for interpretability. This approach allowed the study to identify areas of strength and deficiency in the perceived competence of artisans from the supervisors' perspective.

3.4. Justification for Methodological Choices and Scope

While the study relied on the perceptions of safety managers and supervisors rather than artisans themselves, this was a deliberate methodological decision informed by contextual realities: Most artisans in Abuja have limited literacy levels and are not well-versed in theoretical safety concepts or regulations. Direct observation methods, while ideal, were logistically and ethically challenging given the large sample size, site access limitations, and variability in site conditions. Thus, the study prioritised contextual validity and feasibility over theoretical purity. Generalisations were limited to artisans working in Abuja and may not apply uniformly across all regions of Nigeria. The findings are most applicable to metropolitan areas with active construction sites, relatively formalised safety practices, and an accessible supervisory workforce.

4. Findings and Discussion

This section presents and interprets the results from the questionnaire responses, built around respondent demographics, knowledge and skill variables, factor loadings, and radar chart visualisation.

4.1. Demographic Characteristics

As depicted in Table 1, the most significant percentage of respondents (24.46%) have between 1–5 years of experience, followed by 21.49% with 6–10 years, demonstrating early-career and mid-career professionals. Only 11.06% reported over 30 years of experience. Educationally, most respondents held a Bachelor's degree (28.51%), followed by HND (20.21%) and Master's degree holders (18.72%). This suggests a relatively well-educated safety professional. However, there is an underrepresentation of doctoral-level professionals (14.56%). A majority of the respondents work in building and civil engineering firms (42.18%), with another 34.47% in general building construction and 23.40% in civil engineering-specific roles. In terms of job designation, 53.62% of participants identified as safety supervisors and 46.38% as safety managers.

Table 1: Demographics of the respondents

Demographics	Frequency	Percentage
Years of Experience		
1-5 years	115	24.46
6-10 years	101	21.49
11-15 years	78	16.6
16-20 years	69	14.69
20-25 years	55	11.7
Above 30 years	52	11.06
Education		
National Diploma	86	18.3
High National Diploma	95	20.21
Bachelors	134	28.51
Masters	88	18.72
Doctorate	67	14.56
Organisation		
Building	162	34.47
Civil	110	23.4
Building and Civil	198	42.18
Project Size		
Medium	217	46.17
Large	253	53.83
Job Title		
Safety Manager	218	46.38
Safety Supervisors	252	53.62

(Source: Field Survey, 2024)

4.2. Knowledge Dimensions of Safety Competence

Table 2 (Appendix 1) categorises safety-related knowledge into four dimensions: hazard identification, safety regulations, risk assessment, and emergency procedures. High mean scores in hazard identification (e.g., knowledge of fall protection systems, M = 4.36) and general hazard recognition (M = 4.24) suggest strong awareness of essential safety issues. However, knowledge related to adapting to changes in work systems (M = 3.66) and consulting on safety concerns (M = 3.64) received lower ratings, demonstrating gaps in adaptability and consultation procedures. These findings imply that while knowledge is strong, soft knowledge areas involving dynamic safety environments and interpersonal communication are relatively weaker. This understanding, however, is tempered by social desirability bias (Bryman, 2016). Although safety knowledge seems strong, respondents seem less assured in evolving safety situations and interpersonal aspects. These gaps are critical in high-risk settings where better communication and system awareness can prevent accidents.

4.3. Safety Skills Assessment

As shown in Table 3, the participants reported strong proficiency in practical safety skills such as techniques for controlling hazards (M = 4.10), but lower competency in using technology for hazard. identification (M = 3.86). Decision-making skills showed relatively high scores for communication (M = 4.29) and knowledge retention (M = 4.22). However, foresight (M = 3.86) and the ability to determine risk levels (M = 3.87) scored lower, highlighting a need for targeted interventions in predictive safety decisions. The technological gap may reflect broader infrastructural constraints in the Nigerian construction industry, where advanced safety technologies are not yet available. This limits the generalisability of results to settings with higher resource availability. These findings highlight a practical workforce with solid corrective skills but weak preventive and technical-driven skills. This may reflect systemic shortcomings in the Nigerian construction industry, where access to digital technologies for safety and predictive training is limited.

4.4. Inter-skill Relationships

Figure 1 illustrates the correlation matrix among different skill categories. There is a strong correlation (r = 0.71) between practical safety skills and decision-making skills, underpinning the argument that practical ability assists effective safety-related decisions. Communication skills showed moderate correlations with all categories (r = 0.46–0.56), while leadership had the weakest relationship with practical safety skills (r =

Table 3: Classification skill variables

Category	Skill variables	Mean	Std Dev
Practical Safety	S1: Techniques for identifying hazards in job hazards analysis	3.90	0.880
	S2: Techniques for hazard control	4.10	0.880
	S6: Using technological tools for hazard identification	3.86	0.999
	S9: Ability to maintain sensitivity to risks	3.82	0.887
	S10: Ability to anticipate mistakes co-workers make	3.93	0.990
	S11: Ability to learn and develop from co-workers	3.83	1.050
Decision-Making	S3: Ability to determine risk level at work	4.13	0.842
	S4: Timely decision when the worker identifies a hazard	4.05	0.867
	S5: Management of personal character	4.12	0.874
	S7: Ability to foresee abnormal situations and what to do if such a situation occurs	3.86	1.024
	S8: Ability to predict risk	3.87	0.931
Communication	S12: Ability to communicate clearly	4.22	0.858
	S13: Ability to retain acquired knowledge	4.29	0.834

(Source: Field Survey, 2024)

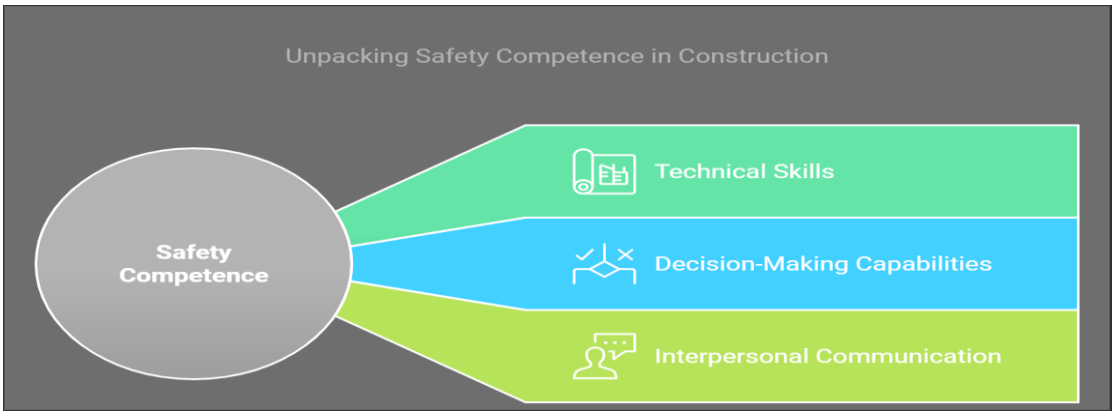


Figure 1: Safety Competence in the Construction Industry

0.29). This indicates that leadership skill in safety management requires a different developmental trajectory, not strongly associated with operational safety performance. Thus far, due to the absence of direct observational measures or third-party evaluations, these correlations must be seen as indicative rather than conclusive. These patterns show that although decision-making and technical skills are interdependent, leadership skill may depend on personality traits, organisational culture or training. This understanding emphasises the need for targeted leadership training as part of safety competence interventions.

4.5. Competence Levels Distribution

Figure 2 illustrates a bimodal distribution, with competence levels clustered at Intermediate and Advanced (each 50%). No participants were identified as Novices or Experts. This may reflect either a well-developed workforce or limitations in the categorisation instrument used—particularly its inability to capture extremes. The lack of novice or expert ratings suggests potential limitations in respondent self-assessment accuracy. A deeper insight using task-based assessments could provide a more reliable distribution.

4.6. Factor Loadings and Underlying Competence Structures

Table 4 details the results of factor analysis, identifying seven latent factors. Factor 1 combines skill S4 with knowledge variables K30 and K14, suggesting a foundation in procedural and hazard management competence. Factor 2 blends S12 and K29, pointing to integrated frameworks where both skill and knowledge describe safety competence. Factor 3 is dominated by

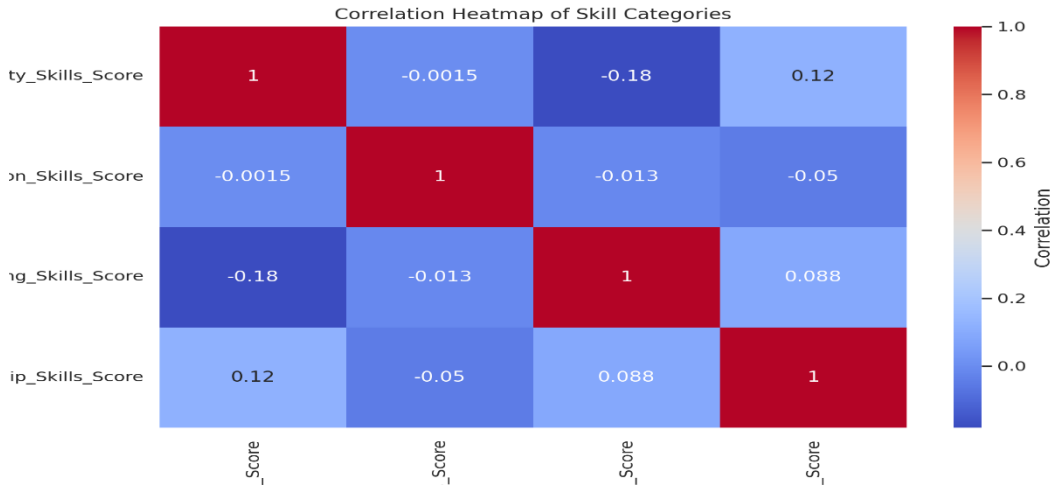


Figure 2: Correlation between skill categories, the distribution of competence levels, and a summary of team averages and individual scores (Source: Data analysis)

Table 4: Top five variables for each factor

Factors Number	Factors	Loadings
1	S4	0.5316
	K30	0.5192
	K14	0.4204
	K16	0.4101
	K28	0.3761
2	S12	0.5362
	K29	0.4500
	K3	0.3704
	K5	0.3543
	K17	0.3245
3	K4	0.4422
	K25	0.4165
	S8	0.3435
	K24	0.3426
	K37	0.3010
4	K17	0.4947
	K9	0.3685
	K20	0.3133
	K1	0.2896
	K26	0.2883
5	S3	0.4578
	K32	0.3884
	K34	0.3375
	K5	0.3331
	K20	0.3311
6	K2	0.3348
	K10	0.3042
	S2	0.2945
	K13	0.2822
	S4	0.2612
7	K30	0.4800
	K12	0.3235
	K14	0.2831
	K2	0.2722
	K17	0.2616

cognitive foundation in hazard planning and recognition. Factor 6, with high loadings for K15 and K17, highlights the role of regulatory understanding in safety management, resonating with a previous study by (Umeokafor et. al., 2022). The emergence of multidimensional competence constructs is consistent with literature identifying cognitive, behavioural, and contextual dimensions of safety competence (Møller et al., 2021; Hardison et al., 2014), supporting a more holistic understanding of competence. These structures show the interdependency of knowledge and skills across regulatory, predictive and procedural domains. However, it must be noted that factor interpretation is inherently subjective and sensitive to sample size and item quality—both of which may limit the strength of these findings.

4.7. Visualising Competence Dimensions: Radar Chart Analysis

Figure 3 presents a radar chart showing six dimensions of safety competence: risk assessment, hazard identification, safety regulations, communication skills, practical safety skills, and emergency procedures. High competence levels were observed in hazard identification and safety regulations, whereas communication and decision-making showed weaker performance. The chart shows an unequal safety competence profile—signifying strengths in basic knowledge areas but gaps in interactive and proactive domains. These findings are in line with prior studies emphasising the critical role of hazard identification (Carter & Smith, 2006), regulatory awareness (Yılmaz, 2023), and communication (Dai et al., 2021) in improving safety outcomes. Nevertheless, the radar chart provides a visual summary and should not be interpreted as an objective performance measure due to its dependence on subjective inputs. These results echo prior studies highlighting the significance of communication and situational responsiveness in accident prevention (Carter & Smith, 2006; Dai et al., 2021; Yılmaz, 2023).

5. Conclusions and Future Research Directions

This study developed a Safety Competence Assessment Framework (SCAF) for construction artisans in Nigeria—an industry that has received little attention in empirical safety research. Using quantitative methods, the study identified and assessed key predictors of safety competence, including hazard identification, safety regulations, risk assessment, communication, emergency preparedness, and practical decision-making skills. The framework highlights the interrelationship among these competencies and their role in allowing safer work practices on construction sites.

One of the main contributions of this study lies in its integration of both knowledge and skill-based factors into a single empirical model tailored to the artisanal workforce. Prior literature tends to focus on safety at organisational levels; this study shifts the attention to the operational level, where artisans directly engage with safety-critical tasks. The study addresses a critical research gap and improves understanding of grassroots-level safety competence by focusing on artisans and empirically validating safety variables that matter in the Nigerian construction industry. Another contribution is the visual diagnostic tool (the radar chart), which operationalises the framework into a practical assessment tool for construction site managers and

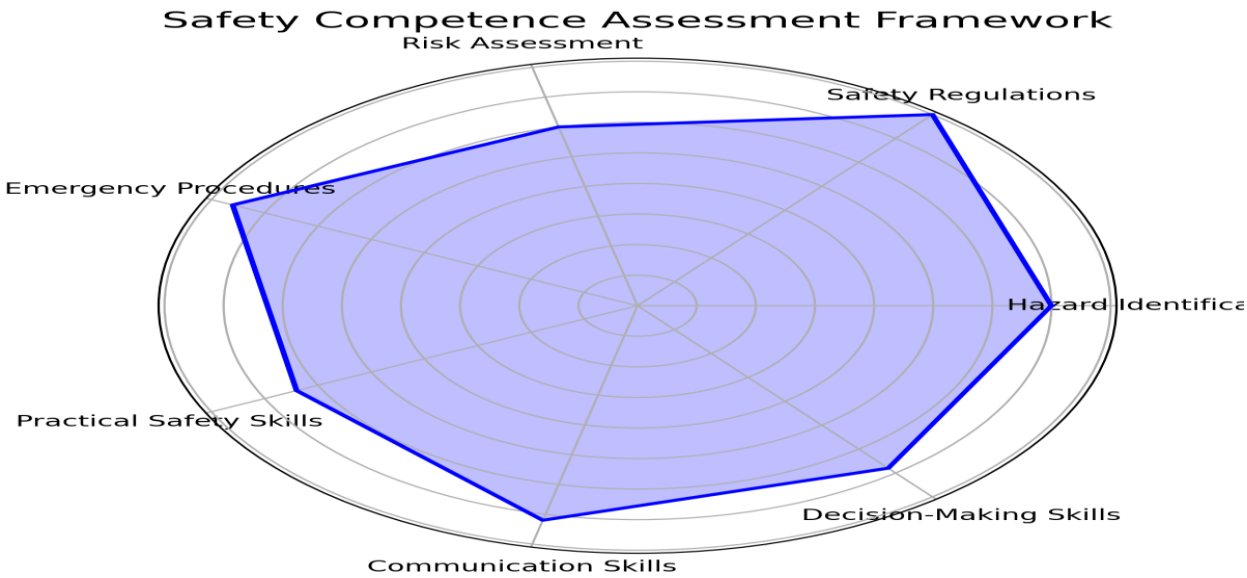


Figure 3: Radar chart for assessing various dimensions of safety competence

health and safety professionals. This instrument provides a multidimensional view of safety competence levels and aids data-driven programmes for safety planning and training. Besides, the radar chart is in line with the literature's call for hands-on assessment tools capable of highlighting gaps in specific areas of safety competence (e.g., communication and decision-making), especially in developing countries.

The results extend theory by echoing the multidimensional nature of safety competence and offer empirical support for frameworks that combine both cognitive and behavioural dimensions. Notably, the research advances existing frameworks of safety competence—mainly derived from developed countries—by validating them for a developing country, high-risk construction environment, hence providing a context-specific framework applicable to similar regions across Sub-Saharan Africa and other developing nations.

5.1. Implications for Future Research

While the framework provides a novel contribution, further validation is necessary. Future studies should test the framework's robustness across sub-sectors (e.g., road and industrial construction) and more diversified samples. Comparative research across countries could determine whether the framework will be valid in different safety cultures and regulatory environments. Additionally, longitudinal studies are recommended to explore how safety competence develops with continuous training and exposure to real-world hazards. Further research should also investigate psychosocial, behavioural, and socio-cultural influences—such as motivation, peer pressure, and communication hierarchies—that may mediate or moderate the development of safety competence among artisans. These insights would be beneficial in fine-tuning the assessment framework and ensuring its relevance in improving safety performance in construction.

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Appendix 1

Table 2: Classification of knowledge variables

Category	Knowledge variables	Mean	Std Dev
Hazard Identification	K2: Understanding critical safety issues at the construction site	4.24	0.785
	K3: Knowledge of hazard recognition and controls	4.27	0.830
	K10: Understanding the risks of different hazards	4.06	0.698
	K12: Knowledge of the risks to which workers are exposed	4.30	0.756
	K22: Understanding in-depth hazard and risk techniques	4.19	0.796
	K23: Knowledge of fall hazards	4.19	0.811
	K24: Understanding the use of fall protection systems	4.12	0.846
	K25: Know the level of fall protection that should be provided	3.74	1.050
	K26: Know the areas and activities where fall protection should be provided	3.88	0.947
	K28: Understanding the kind of material to store within feet of working edges	3.83	0.779
	K29: Understanding how to erect and use a scaffold	3.98	0.882
Safety Regulations	K1: Understanding the safety policies, goals, and procedures of the construction company	4.15	1.044
	K6: Know when to use PPE	4.02	0.858
	K7: Know how to wear PPE	4.02	0.882
	K8: Understanding the risk that PPEs can avoid	4.18	0.829
	K11: Understanding how to keep the PPE in an efficient state, working order, and good repair	4.04	0.753
	K13: Understanding the new technology introduced	3.66	0.940
	K14: Understanding changes in the work system	4.03	0.838
	K15: Understanding the meaning of construction safety signs	4.03	0.838
Risk Assessment	K4: Do you know how to report hazards and injuries?	4.23	0.880
	K5: What to do in an emergency?	4.28	0.882
	K16: Understanding of manual handling (Loads, lifting, and carrying)	3.91	0.818
	K17: Understanding the conditions for the use of work equipment	3.74	1.050
	K18: Understanding the risks associated with the use of work equipment and the precautions to be taken	3.88	0.956
	K19: Understanding the classification, identification, and verification of known and unknown materials	3.90	0.824
Emergency Procedures	K20: Understanding how to use the local emergency response plan	4.07	0.947
	K21: Understanding the state emergency response plan	3.88	0.956
	K31: Understanding the effect of fatigue on safety	3.64	0.774
	K32: Who to consult on safety concerns	4.01	0.851

(Source: Field Survey, 2024)

Assessment of Factors Affecting Workers' Hazard Recognition in Construction

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Abstract

The construction safety management process relies significantly on the hazard recognition of construction workers. This is due to the existence of poor safety practices recorded within the construction industry, which is correlated with construction workers' inability to recognise and manage work hazards effectively. This study, therefore, assesses the factors affecting the hazard recognition ability of construction workers. A questionnaire survey was employed, where questionnaires were distributed to construction workers (both professionals and artisans) in Nigeria. Data was analysed using Mean, Standard Deviation, and a normality test. Kruskal-Wallis H-test was then employed to determine the hazard recognition capability level of the workers based on their various characteristics. 52 out of the 53 identified factors were significant. The study then found significant differences in the hazard recognition ability of the workers based on their years of experience and level of education. On the other hand, job type, designation and profession of the workers do not affect their hazard recognition ability factors. The paper recommends the development of the capacity of construction workers in their experience and education for hazard recognition.

Keywords: Construction workers, hazard recognition, safety management

1. Introduction

The construction industry is notorious for its poor safety records characterised by frequent accidents resulting from multiple hazard sources (Zhou, Goh and Li, 2015). This poor reputation cuts across both advanced and developing countries of the world (Sunindijo and Zou 2012; Patel & Jha, 2014). Efforts have been made to address the problem through safety management and technological approaches (Alruqi et al., 2018; Tam and Fung, 2012; Zhang et al., 2015; Riaz et al., 2014). However, poor hazard recognition limits construction workers' ability to escape from workplace accidents (Goh and Binte Sa'adon, 2015; Namian, Zuluaga, & Albert, 2016).

Hazard recognition capability of workers is a significant enabler for addressing safety challenges on construction sites (Lu et al, 2011). Addressing accidents relies on managing the identified hazards, which result from close interaction of workers, equipment and materials with unsafe conditions (Namian, Zuluaga, et al., 2016; Teizer & Cheng, 2015). These hazards, when not recognised and managed, lead to serious safety incidents. The situation is further compounded as many of the construction workers are unskilled and unlettered, thus unable to recognise safety signs and give proper attention to the safety scenarios at work.

Studies have reported poor ability of construction workers to identify hazards in construction environments (Fu et al., 2024; Carter and Smith, 2006; Perlman et al., 2014). Haslam et al. (2005) observed that 42% of accidents involve inadequate hazard identification and appraisal skills of workers. This was corroborated by Bahn (2013), Zhou et al. (2024) and Albert et al. (2014), who reported the failure of construction workers to recognise an average of 40% to 57% of hazards in different work contexts.

Improving hazard recognition capability of construction workers relies on understanding the factors that aid or hinder the ability of the workers to recognise safety hazards on construction sites (Abubakar et al., 2020; Namian et al., 2016). Once the significant factors are determined, strategies can be developed to strengthen the workers' ability to recognise and manage various work hazards effectively. This will then lead to the desired improvement in the overall safety performance of the construction industry.

2. Hazard Recognition in Construction and Factors Affecting Hazard Recognition Capability

Over time, studies on construction safety management have focused on, among others, hazard identification, accident investigation, and risk assessment. Researchers have documented factors responsible for

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poor safety performance, which manifests in several accidents and fatalities in the construction industry (Mitropoulos et al. 2005; Rajendran and Gambatese 2009; Suraji et al. 2001). According to Abdelhamid and Everett (2000), the root causes of workplace accidents comprise the failure of workers to identify a hazardous condition that occurs before starting an activity or that develops afterwards.

Among the antecedent factors responsible for the poor safety performance, hazard recognition of construction workers has recently received significant attention of researchers (Albert, Hallowell, & Kleiner, 2013; Carter & Smith, 2006; Namian, Zuluaga, & Albert, 2016; Pereira, Ahn, Han, & Abourizk, 2018; Goh and Chua 2009). Hazard is the potential for harm, or an aspect of technology or activity that leads to risks (Bahn, 2013). Hazard recognition is the ability of managers and workers to sense, analyse and extract physical or mental stimuli that indicate the existence of a hazardous situation in a complex and dynamic scenario of construction environments (Albert, Hallowell, & Kleiner, 2014; Namian, Zuluaga, et al., 2016) This may arise from unsafe equipment; unsafe environment; or unsafe work practices" engaged by the workers.

Hazard recognition is central to addressing the safety challenges of construction sites (Lee and Hasanzadeh, 2024). Safety management efforts are always designed to manage the identified hazards, which occur in various forms. When hazards are not recognised and managed, the likelihood of calamitous and sudden injuries increases. Studies have reported that more than 42% of injuries in construction occur because of inadequate hazard recognition and evaluation (Carter & Smith, 2006; Haslam et al., 2005; Perlman, Sacks, & Barak, 2014). Bahn (2013) reported that workers failed to recognise an average of 57% of hazards in occupational environments in Australia. In a study of several projects across the United States of America, Albert, Hallowell, and Kleiner (2014) discovered that more than 40% of hazards were not recognised at the time of pre-job safety meetings. These problems have been aggravated by the inherent characteristics of the industry, such as frequent rotation and interaction of teams, constantly changing weather and environmental conditions, a higher proportion of unskilled labourers, and high labour turnover, among other factors.

Literature on construction safety has reported the importance of hazard recognition to any safety management initiative. The persistence of poor safety records of the construction industry has been linked to the inability of workers to recognise and manage work hazards (Namian et al., 2016; Chen et al., 2024; Uddin et al., 2023) This is undoubtedly among the primary reasons for the growing research interests on the improvement of hazard recognition performance of construction workers. To avert the negative consequences of poor hazard recognition of workers, it is inevitable to understand the factors that influence their hazard recognition capabilities (Abubakar et al., 2020). This will enable the development of appropriate strategies to improve the level of hazards recognised and managed by the workers, thereby achieving the desired improvement in the general safety performance of the construction industry.

Previous studies have documented the factors contributing to the inability of workers in construction and allied sectors to recognise hazards at workplaces. Notable among them is the work of Namian et al. (2016) and Chen et al. (2024), in which they established factors that influence hazard recognition performance of construction workers. The factors were identified through a literature review and interviews with construction managers and safety professionals. They assembled the factors into five categories: personal, organisational, social, situational, industry-related, and miscellaneous factors (Jeelani et al., 2017). Other researchers further expanded these to cater for omissions and other contextual factors related to geography or inherent characteristics of workers (Abubakar et al., 2020). Many other studies considered the factors and their influence on different aspects of hazard recognition. Assessing the specific influence of these factors and their relative importance will help industry practitioners to devise effective strategies for dealing with them in improving the hazard recognition capability of construction workers.

3. Research design and approach

This study employed a quantitative approach to evaluate the hazard recognition capability of construction workers. This is appropriate given the nature of the quantitative data and the analytical tools involved.

The research identified a series of factors related to hazard recognition capability from existing literature (Abubakar et al., 2020), which were subsequently used to construct a semi-structured questionnaire, with closed-ended questions aimed at evaluating 53 factors related to hazard recognition capability. Two types of questionnaires were designed to address different respondent groups: tradesmen (workers) and professionals (construction managers, safety managers, and site supervisors). The questionnaire was structured in two sections: Part A and Part B. The information solicited in Part A varied slightly between the two questionnaire types to effectively capture the pertinent demographics for each respondent category. For tradesmen, inquiries included their specific trade, years of experience, educational background (including any formal schooling), and the nature of the jobs undertaken by their organisations.

The demographic data solicited from the professionals encompassed details regarding the types of projects

they are involved in, their job titles, years of experience in the field, and their educational backgrounds. Both parts of the questionnaires contained identical information. A Likert scale ranging from 1 to 5, with 1 being the lowest and 5 being the highest, was utilised to assess the perceived impact of various factors on the hazard recognition capabilities of the construction workers. The questionnaires were disseminated both in person and online, with a total of 1,200 questionnaires distributed across Nigeria. Six hundred five completed questionnaires were returned, representing a response rate of 50.42%. Out of these, 561 questionnaires (46.75%) were deemed suitable for analysis.

A range of statistical analyses was performed to assess the reliability and appropriateness of the data analysis methods for the research. The Statistical Package for the Social Sciences (SPSS v.25) was utilised for the various analyses. The internal consistency reliability of the survey instrument was evaluated, employing Cronbach's Alpha, which ranges from 0 to 1. A higher Alpha value, approaching 1, indicates greater reliability of the dataset. Tavakol and Dennick (2011) suggest that a minimum acceptable Alpha score is 0.7. The reliability of the dataset was assessed, yielding a Cronbach's Alpha of 0.802, which signifies a robust internal consistency. To ascertain the suitability of parametric versus non-parametric statistical methods for data analysis, an assessment of the dataset's normality was conducted. The Shapiro-Wilk test was employed similarly to the study of Dandago et al. (2025). The results of the Shapiro-Wilk test indicated P-values below 0.05 for all factors (see Table 1 in Appendix 1), implying that the dataset does not follow a normal distribution. Consequently, this finding advocates for the application of non-parametric statistical methods to evaluate the appropriateness of the dataset for factor analysis. In light of this result, the Kruskal-Wallis H-Test, which is a non-parametric technique based on ordinal data, was utilised to investigate whether the responses from experts across different professions exhibited significant differences (as in Dandago et al., 2025).

4. Data analysis and results

Respondents' background information

Results from the analysis of the background information of the respondents (Table 2) show that the majority of the respondents have years of experience ranging from 0 to 10 years, with 69%. The result also shows that 67% of the respondents have a diploma or a bachelor's degree. The respondents also comprise tradesmen and professionals from various fields, contributing a diverse and well-rounded expertise essential for assessing the factors influencing hazard recognition capabilities, with 54% workers and 46% professionals handling different types of jobs, primarily including building and civil engineering construction. This shows that the respondents have the requisite knowledge and skills to provide reliable responses for the study.

4.1 Significant hazard recognition factors of construction projects

The significant hazard recognition factors of construction workers in construction projects were assessed via mean score analysis. A mean score of 3 or higher on the 5-point Likert scale utilised in this study indicates that a hazard recognition factor is significant. The findings related to the mean score of hazard recognition factors are presented in Table 1. The mean score analysis reveals that only one of the 53 hazard recognition factors was insignificant. The expert deemed 'Race and ethnicity' with a mean score of 2.86 to be an insignificant hazard recognition factor. The respondents, however, considered 'Level of experience in the job', 'Knowledge of the job', 'Good visual ability', 'Prior knowledge of the hazards', and 'Safety training to recognise hazards' with respective mean scores of 3.92, 3.90, 3.85, 3.73 and 3.71 to be the top 5 significant hazard recognition factors. Consequently, investors, contractors, and project managers must focus on these factors, warranting a more in-depth examination.

4.2 Hazard recognition factors of construction projects based on the respondents' attributes

This section evaluates the differences in the hazard recognition capability of the workers based on their demographic attributes. The Kruskal-Wallis H-test was employed to determine whether significant differences exist in the hazard recognition capability of the workers, taking into account variables such as the Years of Experience, Educational Qualification, Job Type Handled by Firms, Designation, and Profession of the workers.

As illustrated in Table 3 (in Appendix 1), based on the Years of Existence of the workers, the hazard recognition capability of the workers shows significant. differences in 33 of the factors, while responses on 20 factors show no significant differences. This shows that there is a significant overall difference in the hazard recognition capability of the workers based on their years of experience. This can be attributed to the findings of Zhou et al. (2024), who opined that novices have better hazard recognition performance than experienced workers because they are more sensitive to hazards. This may result in novice and experienced workers having different understandings of what significant hazard recognition factors are, depending on their experience.

Regarding the educational qualification, the responses of the workers indicate significant differences in 30 hazard recognition capability factors, while 23 factors exhibited no statistically significant differences. This shows a statistically significant overall difference in the respondents' hazard recognition capabilities. Although

Table 2: Respondents' background information

Characteristics	Classification	Frequency	%
Years of Experience	01-05 years	190	34
	06-10 years	194	35
	11-15 years	82	15
	16-20	54	10
	21-25	26	5
	26-30	10	2
	Above 30 years	5	1
	Total	**561**	**100**
Educational Qualification	SSCE and below	130	23
	National Diploma	131	23
	Higher National Diploma	85	15
	Bachelors	164	29
	Masters	43	8
	Doctorate	8	1
	Total	**561**	**100**
Job Type Handled by their Firms	Building Construction	264	47
	Civil Engineering Construction	74	13
	Both Building and Civil Engineering	221	39
	Others	2	0
	Total	**561**	**100**
Designation	Safety Manager	32	6
	Construction Manager	226	40
	Workers	303	54
	Total	**561**	**100**
Profession	Roof Work	177	32
	Steel Work	62	11
	Excavation work	65	12
	Professionals	257	46
	Total	**561**	**100**

a large portion of the respondents possess at least a diploma, the approach to education in promoting safety practices is deficient. The educational approach has been noted to be reliant on lectures (Albert et al., 2020), with researchers calling for a more self-directed, active approach (Bhandari and Hallowell, 2017). Uddin et al. (2023) suggested tapping the potential of advanced technologies like large language models, specifically ChatGPT, to support hazard recognition education and training.

The study also analysed the differences in the types of jobs handled by the respondents. The study found only six hazard recognition factors to be significantly different, whereas 47 factors had no significant difference. This indicates that the types of jobs handled by the respondents do not influence their hazard recognition capability. This is supported by the fact that the analysis revealed, overall, no significant differences in the hazard recognition capability of the respondents based on their jobs. However, on designation of the respondents, all 53 factors show no significant difference. This is an indication that the hazard recognition capability of tradesmen and professionals can be treated as a whole.

Based on the profession of the respondents, 25 factors show a statistically significant difference in the hazard recognition capability of the respondents. On the other hand, 28 factors show no significant difference. This shows that the overall hazard recognition capability of the respondents across various professions is not significantly different.

5. Conclusion

This study assessed the hazard recognition factors of construction workers in construction projects. The mean score analysis revealed that 52 of 53 analysed hazard recognition factors are significant. The study found 'Level of experience in the job', 'Knowledge of the job', and 'Good visual ability' to be the leading factors in the hazard recognition capability of construction workers. The study further used inferential statistics, specifically the Kruskal-Wallis H-test, to analyse differences in the responses of the workers based on their demographic attributes. The analysis found that there is a significant overall difference in the hazard recognition capability of the respondents based on their years of experience and educational qualifications. However, the study found no significant differences in the hazard recognition capabilities of the respondents based on their job type, designation and various professions. The paper recommends the development of the capacity of construction workers in their experience and education for hazard recognition. The study also recommends leveraging advanced technologies to enhance hazard recognition education and training efforts and improve construction safety. Nevertheless, it is essential to recognise certain limitations of this study. The hazard recognition factors analysed were derived from empirical studies documented in the existing literature. Researchers, practitioners, and stakeholders must be aware of the sensitivity of these hazard recognition factors to various project types, geographical locations, objectives, and national contexts.

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Appendix 1

Table 1: Mean score ranking of the hazard recognition factors for construction projects

Factors	Mean	SD	Rank	Shapiro-Wilk
Level of experience in the job	3.92	0.963	1	0.000
Knowledge of the job	3.90	1.041	2	0.000
Good visual ability	3.85	0.960	3	0.000
Prior knowledge of the hazards	3.73	1.037	4	0.000
Safety training to recognise hazards	3.71	1.121	5	0.000
Organisational safety policy	3.69	1.101	6	0.000
Sound auditory ability	3.68	1.021	7	0.000
Attitude towards safety	3.68	0.982	7	0.000
Project characteristics (size, scope, materials, height, etc)	3.68	0.990	7	0.000
Hazardous nature/tendencies of equipment used in projects	3.65	1.036	10	0.000
Supervisory environment	3.65	1.009	10	0.000
The layout plan of the construction site	3.64	0.985	12	0.000
Safety Training Programs in the organisation	3.63	1.104	13	0.000
The productivity and delivery pressure of the project	3.63	1.021	13	0.000
Hazard recognition practices employed in the project	3.61	2.384	15	0.000
Job-specific safety training was provided for workers in the project	3.61	1.087	15	0.000
The site condition (e.g. elements of weather)	3.60	1.015	17	0.000
Employee involvement in hazard recognition and safety planning	3.59	1.026	18	0.000
Organisational campaign to promote hazard recognition	3.59	1.057	18	0.000
The site configuration (e.g. topography, soil condition, access, space, etc.)	3.59	1.004	18	0.000
Organisational communication system for managing hazard info. at work	3.57	1.122	21	0.000
The use of mechanical plants and equipment in the project	3.57	1.005	21	0.000
Project scope and schedule change	3.56	0.964	23	0.000
Hazard recognition method/tool adopted	3.56	1.123	23	0.000
Safety complacency	3.55	1.036	25	0.000
A large number of construction tasks on site	3.55	1.010	25	0.000
The size and composition of the work crew	3.55	0.925	25	0.000
Organisational structure with responsibilities for HR and management	3.55	1.096	25	0.000
The project site's house-keeping practices	3.55	1.010	25	0.000
Co-workers' hazard recognition and safety practices	3.53	0.998	30	0.000
Supportive environment for hazard recognition and management	3.53	1.011	30	0.000
Project safety climate	3.52	1.023	32	0.000
Hazard recognition ability and motivation of peers	3.51	1.020	33	0.000
Noise level at the project site	3.50	1.089	34	0.000
Work group norms	3.48	0.978	35	0.000
Use of incentive programs to motivate employees for HR	3.47	1.103	36	0.000
Use of hazard (both manual and automated) identification techniques	3.47	1.108	36	0.000

Appreciation of the risks associated with the job	3.46	1.015	38	0.000
Traffic on the project site	3.46	1.040	38	0.000
Knowledge of risks (consequences) associated with a hazard	3.45	1.056	40	0.000
Co-workers' and superiors' support for hazard recognition at work	3.45	1.024	40	0.000
Experience in using hazard recognition techniques	3.44	1.041	42	0.000
Stable emotional disposition	3.44	1.002	42	0.000
Hazard recognition ability of peers at work	3.44	1.011	42	0.000
Organisational policy on the use of psychoactive substances by workers	3.43	1.126	45	0.000
Risk-taking ability	3.39	1.059	46	0.000
Location of hazards	3.38	1.047	47	0.000
The project owner and community support for HR and management	3.38	1.102	47	0.000
Involvement in a previous construction accident	3.36	1.144	49	0.000
Fatigue and depletion	3.32	1.120	50	0.000
Belief system	3.20	1.194	51	0.000
Use of Substances (like drugs, alcohol and so on) at work	3.00	1.486	52	0.000
Race and ethnicity	2.86	1.233	53	0.000

Table 3: Kruskal-Wallis test in the hazard recognition capability of the workers based on their demographic attributes

Factors	**Exp**	**Educ**	**Job**	**Design**	**Profession**
Level of experience in the job	0.000	0.002	0.138	0.599	0.000
Knowledge of the job	0.006	0.081	0.197	0.519	0.000
Good visual ability	0.349	0.998	0.882	0.235	0.000
Prior knowledge of the hazards	0.002	0.000	0.287	0.757	0.114
Safety training to recognise hazards	0.002	0.003	0.373	0.246	0.979
Organisational safety policy	0.084	0.001	0.276	0.867	0.000
Sound auditory ability	0.066	0.005	0.057	0.881	0.105
Attitude towards safety	0.218	0.364	0.202	0.126	0.348
Project characteristics (e.g. size, scope, materials, height, etc)	0.034	0.015	0.430	0.401	0.001
Hazardous nature/tendencies of equipment used in projects	0.307	0.041	0.010	0.913	0.000
Supervisory environment	0.005	0.077	0.642	0.088	0.570
The layout plan of the construction site	0.216	0.003	0.131	0.901	0.012
Safety Training Programs in the organisation	0.000	0.000	0.868	0.890	0.157
The productivity and delivery pressure of the project	0.010	0.413	0.083	0.640	0.125
Hazard recognition practices employed in the project	0.001	0.003	0.152	0.470	0.194
Job-specific safety training was provided for workers in the project	0.000	0.001	0.322	0.753	0.001
The site condition (e.g. elements of weather)	0.054	0.156	0.032	0.080	0.001
Employee involvement in hazard recognition and safety planning	0.000	0.228	0.313	0.962	0.105
Organisational campaign to promote hazard recognition	0.012	0.368	0.023	0.965	0.000
The site configuration (e.g. topography, soil condition, access, space, etc.)	0.050	0.071	0.170	0.842	0.001

Organisational communication system for managing hazard info. at work	0.007	0.000	0.090	0.916	0.000
The use of mechanical plants and equipment in the project	0.108	0.099	0.257	0.087	0.021
Project scope and schedule change	0.009	0.070	0.138	0.664	0.015
Hazard recognition method/tool adopted	0.000	0.006	0.158	0.180	0.002
Safety complacency	0.024	0.889	0.119	0.837	0.022
A large number of construction tasks on site	0.012	0.272	0.297	0.346	0.203
The size and composition of the work crew	0.125	0.004	0.786	0.121	0.215
Organisational structure with responsibilities for HR and management	0.186	0.013	0.630	0.240	0.100
The project site's house-keeping practices	0.000	0.000	0.926	0.171	0.189
Co-workers' hazard recognition and safety practices	0.219	0.023	0.052	0.210	0.350
Supportive environment for hazard recognition and management	0.186	0.005	0.043	0.646	0.824
Project safety climate	0.000	0.000	0.417	0.766	0.476
Hazard recognition ability and motivation of peers	0.136	0.003	0.609	0.663	0.492
Noise level at the project site	0.034	0.156	0.220	0.976	0.004
Work group norms	0.221	0.046	0.146	0.127	0.693
Use of incentive programs to motivate employees for HR	0.000	0.006	0.331	0.797	0.006
Use of hazard (both manual and automated) identification techniques	0.006	0.152	0.146	0.653	0.004
Appreciation of the risks associated with the job	0.395	0.081	0.129	0.687	0.266
Traffic on the project site	0.018	0.056	0.203	0.567	0.100
Knowledge of risks (consequences) associated with a hazard	0.000	0.000	0.133	0.979	0.404
Co-workers' and superiors' support for hazard recognition at work	0.013	0.015	0.348	0.780	0.027
Experience in using hazard recognition techniques	0.004	0.143	0.119	0.358	0.459
Stable emotional disposition	0.000	0.025	0.388	0.481	0.758
Hazard recognition ability of peers at work	0.023	0.115	0.519	0.069	0.410
Organisational policy on the use of psychoactive substances by workers	0.297	0.000	0.002	0.818	0.002
Risk-taking ability	0.136	0.053	0.335	0.514	0.321
Location of hazards	0.000	0.547	0.940	0.778	0.060
The project owner and community support for HR and management	0.055	0.019	0.429	0.358	0.002
Involvement in a previous construction accident	0.002	0.534	0.807	0.435	0.000
Fatigue and depletion	0.048	0.030	0.016	0.480	0.003
Belief system	0.005	0.090	0.096	0.272	0.451
Use of Substances (like drugs, alcohol and so on) at work	0.139	0.004	0.887	0.057	0.000
Race and ethnicity	0.165	0.028	0.481	0.102	0.054

Impact of Barriers to Implementing Health and Safety Practices for Construction Workers' Productivity in SMMES

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Abstract

Health and safety (H&S) practices play a crucial role in improving efficiency, reducing costs, and ensuring the success of construction projects. However, small, medium, and micro enterprises (SMMEs) often experience low worker productivity, partly due to barriers to implementing H&S practices. This study investigates the barriers to the implementation of H&S practices affecting workers' productivity in construction SMMEs, addressing a research gap in construction management. A quantitative research approach was adopted, employing a structured questionnaire distributed to 530 Construction Industry Development Board (CIDB) contractors registered from grades 1-6 as general building contractors and civil engineering contractors in Gauteng Province. Descriptive statistics were applied for data analysis and interpretation. The findings indicate that barriers to implementing H&S practices are not widely perceived as major factors affecting workers' productivity in the study area. This challenges the prevailing assumption that such barriers significantly impact workers' productivity. The study highlights the need for policymakers and industry stakeholders in the study area to explore additional H&S barriers and their implications for worker productivity. This research provides new insights and lays the foundation for further investigation into broader barriers to H&S implementation and their potential effects on construction workers' productivity.

Keywords: Construction sector, contractors, health and safety practices, SMMEs, workers' productivity

1. Introduction

The construction industry is a critical sector in South Africa, employing over 536,000 workers as of March 2022, with small, medium, and micro enterprises (SMMEs) playing an essential role (Stats SA, 2022). The National Development Plan (NDP) 2030 underscores the importance of infrastructure investment to stimulate economic growth (National Planning Commission, 2013). Given the labour-intensive nature of the construction industry and the significant role of SMMEs, workers' productivity is crucial for the sustainability of construction businesses (Adebowale & Smallwood, 2020). Existing literature highlights the importance of health and safety (H&S) practices in enhancing workers' productivity in SMMEs (Agumba & Haupt, 2018). However, construction SMMEs often face significant barriers in implementing effective H&S practices, which reportedly hinder productivity (Agumba, 2013). Non-compliance with the Occupational Health and Safety Act (OHSA) 85 of 1993 and the Construction Regulations of 2014 can result in legal penalties, project delays, and operational inefficiencies (Mashwama *et al.*, 2018).

While some studies emphasise the benefits of H&S practices, others suggest that financial constraints, technological limitations, and worker attitudes are major factors influencing their successful implementation (Choudhry, 2017; Setiani & Abd Majid, 2019). This study examines the barriers to implementing H&S practices that affect workers' productivity in South African construction SMMEs. The primary objective is to identify the barriers to H&S practices implementation through a literature review and to determine their significance for workers' productivity using primary research data. A limitation of the study is the narrow scope of barriers identified in the existing literature. A more comprehensive literature review is required to explore a broader range of barriers to implementing H&S practices that may influence workers' productivity. The findings contribute to the ongoing discourse on improving H&S practices and productivity in SMMEs, offering potential benefits for policymakers, industry professionals, and construction SMMEs.

2. Literature Review

Health and safety practices present significant challenges for many SMMEs, particularly in the construction sector. The International Labour Organisation (ILO, 2020) highlights that SMMEs constitute most businesses worldwide, with many operating under informal conditions characterised by weak occupational safety and health (OSH) standards. These conditions increase workplace hazards, raising the risk of accidents and injuries. The extent to which SMMEs face barriers in implementing H&S practices varies based on financial resources, managerial commitment, and regulatory awareness. For many, limited financial capacity and knowledge hinder their ability to establish safer working environments (ILO, 2020). In some cases, SMMEs do not perceive H&S

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compliance as a primary concern, leading to inconsistent safety practices. However, inadequate H&S measures can directly impact worker productivity by increasing absenteeism, accident rates, and workflow disruptions (Tremblay & Badri, 2018).

Agumba and Haupt (2018) argue that construction SMMEs often underperform in H&S compliance due to financial and managerial limitations, weakening their safety culture and regulatory adherence. This negligence has direct consequences on worker productivity, as accidents lead to downtime, reduced morale, and skill shortages due to employee turnover (Ammad et al., 2021). While some studies emphasise that neglecting safety results in workplace incidents and regulatory penalties (Tremblay & Badri, 2018), others suggest that SMMEs may not always recognise the productivity benefits of H&S compliance. For instance, some construction firms perceive H&S regulations as bureaucratic and financially burdensome rather than necessary, leading to varying levels of commitment (Mashwama *et al.*, 2018). This lack of commitment contributes to unsafe working conditions, reducing workers' efficiency and increasing operational disruptions (Kaynak *et al.*, 2016).

Tremblay and Badri (2018) state that SMMEs' occupational health and safety (OHS) standards fall short of those of larger companies and that SMME enterprises have up to 50% more non-fatal injuries and up to eight times as many fatal accidents. Tremblay and Badri (2018) identify financial and human resource limitations, lack of OSH expertise, and negative perceptions of compliance as key barriers to adopting comprehensive H&S measures. These barriers have direct implications for worker productivity (Mashwama *et al.*, 2018). Unsafe conditions can cause frequent work stoppages due to incidents, illnesses, or injuries, affecting overall project timelines and efficiency (Choudhry, 2017). SMMEs that lack access to external safety programs often struggle with maintaining safety standards, leading to increased absenteeism and higher employee turnover (Mashwama *et al.,* 2018). The lack of proper H&S training exacerbates these challenges, as workers may fail to recognise hazards, resulting in more workplace accidents that reduce productivity levels (Adebowale & Smallwood, 2020).

Training and awareness gaps among employees further hinder the effective implementation of H&S practices, directly impacting productivity (Setiani & Abd Majid, 2019). Many construction SMMEs fail to provide comprehensive H&S training, leaving workers with limited knowledge of safety protocols (Ammad *et al.*, 2021). Insufficient training leads to increased workplace accidents, prolonged recovery times, and diminished worker efficiency (Mashwama et al., 2018). Without proper training, employees may be unaware of best practices, leading to higher rates of non-compliance and reduced overall workflow efficiency (Al Mawli *et al.*, 2021).

In many SMMEs, only a few individuals handle H&S responsibilities, making it difficult to enforce safety measures across all operations (Mashwama et al., 2018). The shortage of dedicated H&S personnel means that risk assessments, incident reporting, and compliance monitoring may be overlooked, further increasing workplace hazards and productivity losses (Kaynak *et al.*, 2016). Advances in technology may close the accessibility gaps regarding quality H&S training. According to Xu et al. (2023), the prevalence of technology has led to advances in digital learning platforms to the extent that workers can be trained on demand using mobile devices without the limitation of time and location. The efficacy of such training in H&S is yet to be proven, given the need for practice-based training to ensure that learning results are achieved.

Employee attitudes also play a crucial role in determining the success of H&S implementation and its effect on productivity. Some workers perceive H&S measures as time-consuming or unnecessary, leading to resistance to training programs and non-compliance with safety procedures (Tremblay & Badri, 2018). A lack of worker engagement in H&S initiatives weakens the integration of safety practices into daily operations, increasing the likelihood of accidents that disrupt productivity. When employees are not actively involved in safety decision-making, there is often a disconnect between management policies and on-site practices, reducing the overall effectiveness of H&S programs (Choudhry, 2017). Conversely, firms that foster strong safety cultures tend to experience improved productivity, as workers feel more secure and motivated, leading to higher efficiency levels and reduced absenteeism (ILO, 2020).

Financial constraints further impede the implementation of effective H&S practices and, by extension, productivity (Tremblay & Badri, 2018). Many construction firms operate on tight budgets and view safety investments as non-essential expenditures with no immediate returns (Setiani & Abd Majid, 2019). The cost of training programs, personal protective equipment (PPE), and compliance measures discourages many SMMEs from prioritising H&S initiatives. However, this short-term cost-cutting approach often leads to long-term productivity losses due to increased workplace accidents, reduced worker morale, and operational inefficiencies (Mashwama *et al.*, 2018).

The rapid pace of technological advancements in the construction industry further complicates safety compliance. Many SMMEs struggle to keep pace with evolving safety standards and digital tools designed to enhance workplace safety, leading to inconsistent safety enforcement and decreased productivity levels

(ILO, 2020). Ultimately, existing literature indicates that the barriers to implementing H&S practices in construction SMMEs not only impact compliance but also significantly affect worker productivity.

3. Research Methodology

This study adopted a quantitative approach, analysing numerical data to achieve its objectives. The study population was 22,429, which comprised CIDB-registered SMMEs (Grades 1-6) in the General Building and Civil Engineering Class of Works in the Gauteng Province. Respondents included construction site foremen, supervisors, labourers, and H&S officials, selected based on their knowledge of workplace H&S management and productivity. A structured questionnaire was distributed electronically to 530 respondents via Google Forms, with hard copies provided to those unfamiliar with digital platforms using a simple random sampling technique. A pilot study involving 10 respondents was conducted, which guided the refinement of the questionnaire.

Respondents were asked to rate their level of agreement with the barriers to implementing H&S practices for improving worker productivity using a 5-point Likert scale, where 1 = Strongly Disagree, 2 = Disagree, 3 = Neutral, 4 = Agree, and 5 = Strongly Agree. Data analysis involved descriptive statistics, including mean, frequency, and standard deviation. The construct validity was achieved using factor loading, and the internal reliability was assessed using Cronbach's alpha. SPSS Version 29 was used for statistical analysis. For result interpretation, the mean score value range was calculated as follows: 5 – 1 = 4; 4 ÷ 5 = 0.8. Thus, responses were categorised as follows: strongly disagree (>1.00 to ≤1.80); disagree (>1.80 to ≤2.60); neutral (>2.60 to ≤3.40); agree (>3.40 to ≤4.20); strongly agree (>4.20 to 5.00).

4. Findings and Discussion

4.1. Findings

Table 1 presents the significance of barriers to implementing H&S practices for construction workers' productivity in SMMEs, ranked by their perceived severity. However, before the ranking of the variables, the validity and the reliability of the data were determined. The results indicate the construct was valid and reliable. The factor loadings of the variables were greater than 0.4, suggesting the validity of the data (Yong & Pearce, 2013). In addition, the Cronbach alpha was 0.95, indicating strong reliability, which is greater than the acceptable value of 0.70 (Nunnally, 1978). In achieving the reliability and the validity of the construct, the mean values were interpreted.

The cost of H&S programs achieved a mean score of 2.31, categorising it as disagree. This is closely followed by rapid technological changes (mean = 2.30), which also fall within the disagree category. The failure to involve employees in H&S policy implementation ranks next (mean = 2.17), supporting the disagree classification. Other notable barriers include inadequate staffing for H&S responsibilities (mean = 2.00) and negative employee attitudes towards safety measures (mean = 1.96), both of which remain within the disagree category. A lack of understanding of H&S matters (mean = 1.77), inadequate training on H&S issues (mean = 1.75), and the perception that H&S programs are a waste of time and money (mean = 1.60) are categorised under strongly disagree. The standard deviation values indicate varying levels of agreement among respondents, with higher values suggesting greater dispersion in responses.

4.2. Discussion

This study aimed to determine the perceived significance of barriers to implementing H&S practices for construction workers' productivity in SMMEs in Gauteng Province. The findings challenge prevailing assumptions, as all identified barriers fell within the "disagree" or "strongly disagree" categories. This suggests that respondents do not perceive these factors as significant obstacles to worker productivity, diverging from prior research that has highlighted these barriers as critical challenges. However, while respondents downplayed these barriers, literature suggests that when such challenges exist, they can have detrimental effects on worker productivity by increasing accident rates, reducing worker morale, and causing workflow disruptions (Lingard & Rowlinson, 2005; Tam *et al.*, 2004).

For instance, the "cost of H&S programs" (mean = 2.31), while ranked relatively higher, remains within the "disagree" range. This contradicts studies by Agumba and Haupt (2018) and Tremblay and Badri (2018), which emphasise financial limitations as a key constraint for SMMEs in establishing safer working environments. Studies have shown that inadequate H&S investment can lead to higher accident rates, increased absenteeism, and decreased worker efficiency (Zhou *et al.*, 2015). The findings suggest that SMMEs in Gauteng may have developed adaptive strategies, such as leveraging cost-effective safety measures, integrating H&S into existing workflows, or accessing external support mechanisms. Alternatively, there may be a reluctance to acknowledge financial constraints due to social desirability bias or concerns about regulatory scrutiny.

Similarly, the "rapid change of technology" (mean = 2.30) was not perceived as a significant barrier, contradicting concerns raised by the ILO (2020) regarding the difficulties SMMEs face in keeping pace with evolving safety standards. In contrast, previous research suggests that failure to adopt new safety technologies can lead to inefficient work practices, increased exposure to hazards, and reduced overall

Table 1: Barriers Hindering H&S Practices to enhance workers' productivity

Cronbach alpha=0.95										
Item		**Strongly Disagree**	**Disagree**	**Neutral**	**Agree**	**Strongly Agree**	**Factor loading**	**Mean**	**SD**	**Rank**
C-2	H&S programmes are expensive, and our company cannot implement them due to a lack of funds.	26%	45%	12%	7%	11%	0.85	2.31	1.24	1
C-7	Rapid change of technology.	11%	66%	10%	10%	4%	0.83	2.30	0.93	2
C-8	Failure to involve employees in the implementation of the H&S policy.	35%	41%	7%	8%	10%	0.80	2.17	1.26	3
C-3	Our company has a few staff members responsible for H&S matters, which affects our performance in this area.	39%	45%	3%	5%	9%	0.93	2.00	1.19	4
C-6	Employees in our company have a negative attitude towards H&S practices.	48%	31%	8%	5%	9%	0.87	1.96	1.24	5
C-5	Very few people understand H&S in our company.	52%	33%	4%	7%	4%	0.93	1.77	1.07	6
C-4	Our staff are not properly trained on H&S matters.	55%	30%	4%	6%	5%	0.95	1.75	1.10	7
C-1	H&S programmes in our company are seen as a waste of time and money because they are viewed as yielding no results.	71%	14%	6%	4%	6%	0.83	1.60	1.14	8
							Average	**1.98**	**1.15**	

(Source: Authors' field data, 2024)

worker output (Haslam *et al.*, 2005). The results may indicate that SMMEs in Gauteng are gradually integrating new technologies without perceiving them as disruptive, or that the rate of technological change in their specific industry segment is manageable.

Other barriers, including "failure to involve employees in H&S policy implementation" (mean = 2.17), "inadequate staffing for H&S responsibilities" (mean = 2.00), "negative employee attitudes" (mean = 1.96), "lack of understanding of H&S" (mean = 1.77), "inadequate training" (mean = 1.75), and "H&S programs as a waste of time" (mean = 1.60), also fell within the "disagree" or "strongly disagree" categories. These findings diverge from Setiani and Abd Majid (2019), Ammad *et al.* (2021), and Mashwama *et al.* (2018), who emphasise training gaps, attitudinal barriers, and resource limitations as critical impediments. Studies indicate that inadequate H&S training and lack of worker involvement in H&S policies can contribute to poor hazard awareness, increased accident rates, and reduced productivity (Gibb *et al.*, 2014). The strong disagreement with these factors may indicate that SMMEs in Gauteng have effective internal practices, a well-established safety culture, or industry-specific H&S interventions that mitigate these concerns. However, it is also possible that respondents, influenced by social desirability bias, may have downplayed these issues.

The variability in responses, as indicated by standard deviation values, suggests that while the general trend is toward disagreement, perceptions are not uniform across all SMMEs. Differences in company size, industry sector, and management practices likely contribute to these variations. Furthermore, the study's reliance on a predefined set of barriers means that other potential impediments, such as regulatory enforcement challenges or industry-specific risks, were not explored. Future research should expand the range of examined barriers and employ mixed-method approaches, including qualitative investigations, to gain deeper insights into why SMMEs in Gauteng perceive these challenges differently from those in other contexts.

These findings have practical implications for policymakers and industry stakeholders. If cost and training are not perceived as significant barriers, safety initiatives should focus on reinforcing existing positive practices rather than solely addressing assumed deficiencies. However, literature suggests that even when SMMEs believe barriers are minimal, ongoing H&S improvements can enhance worker productivity by reducing downtime due to injuries, improving worker morale, and fostering a more efficient work environment (Hinze, 2002; Fernández-Muñiz *et al.*, 2007). Additionally, the findings suggest that targeted interventions may be more effective than broad, one-

size-fits-all safety policies, given the heterogeneity in perceptions among SMMEs.

5. Conclusion and Further Research

The findings of this study indicate that the identified barriers to implementing H&S practices are not perceived as significant impediments to construction workers' productivity in SMMEs. While some respondents acknowledged the existence of these barriers, the overall mean scores suggest that they do not substantially hinder work progress on construction sites. This challenges assumptions in existing literature that such barriers necessarily obstruct productivity. Instead, the results highlight the need for a better understanding of workplace safety dynamics, recognising that while barriers may influence worker productivity in some projects and regions, their impact varies across different organisational and regional contexts.

Generally, the findings suggest that the investigated barriers do not significantly affect construction workers' productivity in SMMEs. To build on this study, future research should explore additional barriers to implementing H&S practices, employing more advanced inferential statistical analyses to determine whether these barriers have a measurable impact on construction workers' productivity. A broader methodological approach, incorporating qualitative insights and case studies, could further enhance the understanding of this research area.

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Why I Registered for Construction Management

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Abstract

This research aimed to determine the reasons BSc undergraduate construction management (CM) students registered at Nelson Mandela University (NMU), including related issues, to inform career promotion interventions and increase registrations for the programme. The quantitative method was adopted, and the data were collected through the distribution of a structured questionnaire to BSc undergraduate CM students at NMU. The data was analysed using MS Excel to generate descriptive statistics in the form of frequencies and means. The study is based on a sample from a single university, which may affect the generalisation of the findings. Potential students consider a range of programmes and apply to several universities; however, both the programme and university are important factors in terms of their final decision. The CM programme is attractive due it being a vocational qualification, a business qualification, and the potential job opportunities. Although there is a general interest in the built environment among potential students, registered students envisage a career primarily in Construction Project Management and contracting in the capacity of CMs. CM programmes compete primarily with Construction Economics and Civil Engineering programmes, and therefore the difference between the programmes should be made clear. A multi-pronged approach is required to promote CM programmes, and a range of stakeholders need to contribute. A university should use the achievements of CM graduates and their career paths to promote its CM programme(s).

Keywords: Career, Construction Management, Registration

1. Introduction

A range of interconnected factors, including personal interests and aspirations, family occupations, societal perceptions, and remuneration prospects, influence the decision to register for an academic programme in tertiary education and pursue a related career. Research conducted by Robinson & Bornholt (2007) within the Australian tertiary higher education system determined that familial backgrounds, demographic factors, and transitions between various educational settings largely influence student registration decisions.

Given the competitive tertiary education environment, universities need to understand and appreciate the factors that influence potential students' decision-making with respect to programmes and the university of choice. Consequently, marketing and recruitment strategies must be enhanced to realise registrations (Agrey & Lampadan, 2014).

The research aimed to determine the reasons BSc undergraduate CM students registered at NMU, including related issues, in an endeavour to improve career promotion interventions and increase registrations for the programme, which constitutes the 'research gap'. The objectives were to determine the motivations, deterrents, and patterns associated with student registrations for the BSc CM programmes at the NMU.

2. Literature Review

To ensure the sustainability of a CM programme, students must be attracted to the CM programme, be compatible with the education process, integrated into the construction industry, and their continued participation in construction and the broader built environment engendered (Bigelow, Saseendran, & Elliott, 2017).

Jepsen and Dilley (1974) in Stead and Watson (2017) state that career decision making (CDM) strategies include a: decision maker; the necessity to decide; appropriate information internal and external to the individual; at least two choices; several outcomes and the related value or utility to the decisionmaker; a strategy based on organised information, and a commitment to make the decision.

2.1. Factors influencing students' career choices

According to John Holland's theory of career choice, most people fit into one of six personality types: realistic; investigative; artistic; social; enterprising, and conventional (Careers New Zealand, 2024). The interest areas, key skills, occupations with practical components, and subjects to develop the skills relative to each personality type are notable. Of the six, realistic, social, enterprising, and conventional relate more closely to CM than the other two. Table 1 describes the activities and skills related to these four personality types.

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Table 1: Holland's theory of career choice

Type	Description	Key skills
Realistic	• Likes to work mainly with hands, making, fixing, assembling or building things • Using and operating equipment, tools or machines • Often likes to work outdoors	• Using and operating tools, equipment, and machinery • Designing • Building • Repairing and maintaining • Working manually • Measuring • Working in detail
Social	• Likes to work with people to teach, train, and inform • Concerned for the well-being and welfare of others	• Communicating orally or in writing • Caring and supporting • Training and teaching • Meeting • Assisting • Informing • Interviewing • Coaching
Enterprising	• Likes meeting people • Leading • Talking to and influencing others • Encouraging others • Working in business	• Selling and promoting • Persuading • Developing ideas • Public speaking • Managing • Computing
Conventional	• Likes working indoors • Organising • Being accurate • Following procedures • Working with data or numbers • Planning work and events	• Computing • Record keeping • Paying attention to detail • Meeting • Doing calculations • Handling money • Organising • Arranging • Working independently

(adapted from Careers New Zealand, 2024)

A study conducted by Ajayi *et al.* (2023) among South African grade 12 learners sought to determine the relationship between career interest and career decision-making. The findings support Holland's (1959) theoretical assertion that individuals prefer to choose vocations that allow them to be around others and relate with people of like minds. Individuals look for environments that support their skills and knowledge, where they can express personal principles and values, while engaging in pleasurable activities to solve problems. Similarly, Holland (1992) also argues that an individual's behaviour is a result of their personality and environment in which they live, which informs their values and interests through personal experiences and career choices.

Abe and Chikoko (2020) conducted a study among 1st, 2nd, 3rd, and 4th year Science, Technology, Engineering, and Mathematics (STEM) students in a South African university to determine the factors that influence career decision-making. Students reported, *inter alia*, that their families, personality, and expectations influenced their career decision-making. Three key themes emerged, namely interpersonal factors, intrapersonal factors, and career outcomes expectancy. Interpersonal influences include family influence and teacher influence. Intra-personal influences include 'champion' mentality (save or change the world), career interest in STEM, personality, personal development, self-efficacy, spirituality and morality. Career outcomes expectancy includes financial matters, and career opportunities and prospects.

A study conducted by Siddiky and Akter (2021) among 120 students selected from 14 academic departments of a university in Bangladesh investigated the factors that determine students' career choice to determine their job preparedness strategies. Furthermore, the study sought to propose a theory which could explain the students' career choices from a social environmental perspective. The students' career choice and career preferences are determined by the interplay of several social and cultural, educational and training, and economic and

occupational forces. Social and cultural factors include: family influence in the form of preferences, and parents' occupations; teachers' advice; job prestige/dignity, and job security. Educational and training factors include: academic majors; educational achievements, and career development training. Economic and occupational factors include: remuneration; pension; scope of promotion, and scope of professional development.

2.2. Factors influencing female students' career choices

Construction is perceived as a masculine and hostile environment, physically demanding, and dirty (Francis, 2017). Numerous studies have identified the challenges in terms of attracting women to professional roles within construction, including enticing women to register for programmes in architecture, engineering, and construction (AEC), and thereafter, their retention in the industry (Rosa *et al.*, 2017). Furthermore, Powell *et al.* (2011) contend that the limited number of women who do register for construction programmes often encounter an educational journey deeply influenced by a predominantly masculine ethos, characterised by specific beliefs, actions, and presumptions.

A key recommendation arising from research conducted in New Zealand, which entailed surveying female AEC students, was the introduction of female professionals as guest speakers in secondary schools to promote construction-related careers for women. Further findings include: enhanced female representation in the construction sector to counter prevailing biases; career advisers' pivotal role in directing students towards AEC programmes, and for more interactive university day open-day events (MacDonald & Durdyev, 2020).

2.3. Factors influencing the selection of CM

Sparkling *et al.* (2019) conducted a study among CM technology students registered for an undergraduate programme in the United States of America. 49% of the students indicated they progressed to CM from high school; however, 34% migrated to CM from another programme in the university. Most of these students commenced exploratory studies or engineering before migrating to CM. In the case of male students, 32% learned about CM from their peers already undertaking the programme, while 35% of female students gained insights from their academic advisors or other academic counselling. In terms of prior work experiences during high school, 89% did not participate in vocational / career training work prior to entering the CM programme. However, 50% of the students participated in paid construction-related work, while 44% had been involved in volunteer construction work such as Habitat for Humanity. 'The hands-on experience' offered by CM was cited by 74% and 62% of female and male students, respectively.

2.4. Factors influencing students' university choices

Penceliah *et al.* (2016) conducted a study to identify factors that influenced university registration in South Africa. The top five of 17 factors were: the quality of teaching (1); availability of financial aid (2); ease of securing employment during and post-study (3); globally recognised qualifications (4), and sports and recreational programmes (5).

A study conducted among students registered at a university in South Africa by Fourie (2015) determined that students use social media as an information source to some extent when deciding whether to register at a university. It should be noted that social media was found to be a credible source of information, although it only has a slight influence on their decision-making process. Therefore, universities should take note of the role that social media plays in the lives of potential students and market their institutions accordingly.

3. Research Methodology

Due to the nature and extent of the data required, the quantitative method was adopted, which entailed the use of a self-administered questionnaire consisting of eleven questions, ten of which were closed-ended, and one open-ended. Five of the closed-ended questions pertained to the study and included a further five sub-questions. The remaining five closed-ended questions were demographically related and included a further sub-question.

The data has been presented in the form of two cohorts, namely < 2024 and 2024. The < 2024 cohort included two first-year CM cohorts over two academic years during first-year orientation at the commencement of the respective academic years, and a further cohort consisted of second-year students from an academic year. The 2024 cohort consisted solely of first-year students.

A total of 48 (< 2024) and 22 (2024) responses were included in the analysis of the data, utilising Microsoft Excel to produce descriptive statistics in the form of frequencies and means.

4. Findings and Discussion

Table 2 presents the gender and nationality of the respondents, and the form of funding. Notably, females constitute 50.7% and males 49.4% of the respondents, which bodes well in transforming the construction industry, which features limited female representation. In terms of the mean, South Africans (89.1%) predominate in terms of the nationality of students; international students only constitute 10.9% of the respondents. 59.6% of students are funded, 44.3% by NSFAS, 15.4% by others, and 40.4% are not funded.

Table 2: Gender and nationality of the respondents, and form of funding

emographic	es (%)		
	2024	24	ean
ender			
male	46.8	54.5	50.7
ale	53.2	45.5	49.4
Nationality			
uth Africa	83.0	95.2	89.1
ternational	17.0	4.8	10.9
Form of Funding			
nded by NSFAS	34.0	54.5	44.3
nded (Other)	17.0	13.7	15.4
ot funded	49.0	31.8	40.4

The mean age, which is not presented in Table 2, is 20 years for females and 21 years for males.

Table 3 indicates the respondents' source of awareness of the CM programme. It is notable that in terms of the mean, no source was identified by > 41.7% of the respondents, > 45.5% (2024), and > 37.8% (< 2024). The internet (41.7%) predominates, followed by family (24.8%) and career guidance (17.9%).

9.0%) indicate limited influence. The influence of the case of the 'career fair' and 'professional association' amplify the need for interrogation relative thereto.

Table 4 indicates that on average, 30.3% of respondents' family work in the built environment: 33.3% (< 2024), and 27.3% (2024). In terms of the capacity in which they do so, Civil Engineers predominated in terms of the mean (35.4%) and the <

Table 3: Respondents' source of awareness of the CM programme

Source	<2024	2024	Mean
Internet	37.8	45.5	41.7
Family	22.2	27.3	24.8
Career guidance	22.2	13.6	17.9
Professional association	8.9	9.1	9.0
Friends	8.9	4.5	6.7
Career fair	0.0	0.0	0.0

Table 4: The occupations of respondents' family members working in the built environment

Occupation	< 2024	2024	Mean
Civil Engineer (CE)	37.5	33.3	35.4
Quantity Surveyor (QS)	12.5	16.7	14.6
Construction Manager	25.0	0.0	12.5
QS & CE	0.0	16.7	8.4
Construction firm	0.0	16.7	8.4
Construction Project Manager	0.0	16.7	8.4
CAD Technician	6.3	0.0	3.2
Interior Designer	6.3	0.0	3.2
Plant Operator	6.3	0.0	3.2
Town Planner	6.3	0.0	3.2

Notable differences include: 22.2% (< 2024) vis-à-vis 13.6% (2024) relative to 'career guidance', and 37.8% (< 2024) vis-à-vis 45.5% (2024) relative to 'internet'.

'Career fair' was not identified by any respondents relative to both cohorts of respondents, and 'friends' (mean = 6.7%), and 'professional association' (mean =

2024 and 2024 cohorts, followed by Quantity Surveyors (14.6%), and Construction Managers (12.5%). The remaining seven occupations were identified by less than 10.0% of respondents. 83.3% of the < 2024 cohort of respondents considered another or other programmes, and 72.7% of the 2024 cohort did, which equates to a mean of 69.7%.

Table 5 indicates the number of other programmes the respondents applied for. It is notable that the majority of the respondents only applied for one programme, as indicated by the mean, and both cohorts. Thereafter, 15.0% (< 2024) and 25.0% (2024) applied for two programmes, and then only one applied for three programmes relative to both cohorts.

Table 5: No. of other programmes respondents applied to

No	< 2024		2024		Mean
	No.	%	No.	%	%
1	33	82.5	11	68.8	75.7
2	6	15.0	4	25.0	20.0
3	1	2.5	1	6.2	4.4
Total	40	100.0	16	100.0	

In terms of other programmes considered by respondents, the < 2024 respondents considered a total of 25, and the 2024 cohort, 16. Only eight programmes were identified by both cohorts. In terms of the mean, BSc Construction Economics (15.6%) predominates, followed by Civil Engineering (15.0%), which are 'close' sister disciplines of CM. Then, they both predominate in terms of the < 2024 cohort. Of the 32 (66.7%) of students who considered other programmes, 30 / 32 (93.8%) applied to another university. Table 6 presents an overview of the respondents who applied to another university. In summary, there is no significant disparity between females and males.

Table 6: Respondents who applied to another university

Nationality	Female				Male				Total			
	Yes		No		Yes		No		Yes		No	
	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
South African	12	26.7	5	11.1	14	31.1	7	15.6	26	57.8	12	26.7
International	2	4.4	2	4.4	2	4.4	1	2.2	4	8.9	3	6.7
Total	14	31.1	7	15.6	16	35.6	8	17.8	30	66.7	15	33.3

A total of 14 male (56.0%) students applied to eight universities, NMU (24.0%) included, and 11 female (44.0%) students applied to seven universities, NMU (16.0%) included.

Table 7 indicates the factors that resulted in respondents who considered other programmes finally registering for CM at the NMU. In terms of the mean, three factors predominate, namely 'first choice (programme)' (29.6%), followed by 'changed my mind' (25.4%), and 'first choice (university)' (23.6%). Notable differences include: 44.4% (< 2024) vis-à-vis 6.3% (2024) relative to 'changed my mind', and 2.8% (< 2024) vis-à-vis 18.8% (2024) relative to 'was not accepted elsewhere'.

Table 8 indicates the extent to which factors contributed to respondents registering for the CM programme. Respondents were presented with ten factors and an 'other' option.

In terms of the mean responses, 'wish to pursue a career in construction' (39.8%) is followed closely by 'wish to pursue a career in the built environment' (39.5%), and 'wish to pursue a career in CM' (38.9%). 'Potential income' (23.7%), 'job opportunities' (23.5%), 'business qualification' (14.0%), and vocational qualification (12.8%) follow. The remaining four factors were identified by between 0.0% to 5.6% on average.

Table 7: Factors that resulted in respondents finally registering for CM at the NMU

Factor	Yes (%)		
	< 2024	2024	Mean
First choice (Programme)	27.8	31.3	29.6
Changed my mind	44.4	6.3	25.4
First choice (University)	22.2	25.0	23.6
Was not accepted elsewhere	2.8	18.8	10.8
Other	2.8	0.0	1.4

Table 8: Extent to which factors contributed to respondents registering for the CM programme

Factor	Yes (%)		
	< 2024	2024	Mean
Wish to pursue a career in construction	34.0	45.5	39.8
Wish to pursue a career in the built environment	42.6	36.4	39.5
Wish to pursue a career in CM	59.6	18.2	38.9
Potential income	6.4	40.9	23.7
Job opportunities	10.6	36.4	23.5
Business qualification	23.4	4.5	14.0
Vocational qualification	25.5	0.0	12.8
Variety of subjects (Programme)	2.1	9.1	5.6
Types of subjects (Programme)	0.0	9.1	4.6
Manage the family business	4.3	4.5	4.4

Notable differences include: 59.6% (< 2024) vis-à-vis 18.2% (2024) relative to 'wish to pursue a career in CM'; 6.4% (< 2024) vis-à-vis 40.9% (2024) relative to 'potential income'; 10.6% (< 2024) vis-à-vis 36.4% (2024) relative to 'job opportunities'; 23.4% (< 2024) vis-à-vis 4.5% (2024) relative to 'business qualification', and 25.5% (< 2024) vis-à-vis 0.0% (2024) relative to 'vocational qualification'.

Table 9 indicates the respondents' medium to long term desired career in terms of the built environment. Respondents were presented five careers and an 'other' option. In terms of the mean responses, Construction Project Management (63.8%) predominates, followed by contracting (CM) (34.5%), and CM consulting (13.3%). A notable difference between the cohorts is the percentage of respondents relative to Construction Project Management in 2024 (81.8%) vis-à-vis < 2024 (45.7%).

of CM as a career. The CM programme faces competition from other built environment programmes and those leading to non-built environment careers - 69.7% of respondents considered another or other programmes. However, the notable percentage responses relative to BSc Construction Economics and Civil Engineering pinpoint them as the principal competitor programmes.

Potential students tend to apply to various universities, suggesting a non-exclusive preference for any single institution. However, the CM programme and NMU are key factors in terms of students registering for the CM programme at NMU. The extent to which ten factors contributed to respondents registering for the CM programme informs in terms of the approach and issues that must be addressed when promoting CM as a career. However, potential students must wish to pursue a career in construction, the built environment, or CM.

Table 9: Respondents' medium to long-term desired career in terms of the built environment

Career	Yes (%)		
	< 2024	2024	Mean
Construction Project Management	45.7	81.8	63.8
Contracting (CM)	32.6	36.4	34.5
CM consulting	13.0	13.6	13.3
Materials manufacturing / Supply	0.0	13.6	6.8
Other	4.3	9.1	6.7
Research & Development	4.3	0.0	2.2

5. Conclusions

The gender composition of respondents indicates that the construction industry and the Department of Construction Management are making progress in terms of enhancing female representation. The degree of response relative to the six sources of awareness of the CM programme indicates that there is potential to intensify awareness through the respective channels, especially career guidance, professional association, and career fairs. Given that on average, 30.3% of respondents' family members work in the built environment, this can be seen as influencing the choice

Construction Project Management predominates in terms of the respondents' medium to long term desired career followed by contracting in the capacity as a Construction Manager. This underscores the recognition of CM programmes as the foundation programme for Construction Project Management. Although the CM programme offered at the NMU is recognised and valued, the competitive environment must be acknowledged. The programme must evolve to respond to the changing nature of the construction industry and the aspirations of potential students, and marketing strategies must be revisited.

6. Recommendations

A multi-pronged approach is required to promote CM programmes. Furthermore, a range of stakeholders need to contribute, which includes employer associations, government departments, primary and secondary schools, professional associations, statutory councils, and tertiary institutions. However, a pre-requisite in many cases is the development and provision of suitable material for, inter alia: the internet, including social media; career fairs; career guidance, and distribution. CM career promotion should differentiate itself from other built environment programmes and highlight the multiple career paths that graduates can pursue. Given that students consider other programmes and apply to a range of universities, the achievements of CM graduates and their career paths, especially non-standard career paths, should be used by a university to promote its CM programme(s).

The inherent aspects of CM programmes, namely being a vocational qualification, a business qualification, and the potential job opportunities or career paths, should be emphasised during career promotion interventions.

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ACADEMIC PAPERS: THEME 7 - CONSTRUCTION EDUCATION/WOMEN IN CONSTRUCTION/ MENTAL HEALTH AND WELLBEING

Assessing the Barriers to Online Learning in the Built Environment Post-graduate Programmes

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Abstract

The rapid and ongoing advancement of technology, hardware, and software has significantly impacted and enhanced online learning and education. Universities globally are investing huge sums of money in online courses and degree programs. Some of the universities are offering these programs at all levels of study, anging from bachelor's to doctoral degrees. Nonetheless, despite the swift expansion, growth and adoption of online learning, there is a lack of understanding of the unique challenges faced by students in these disciplines. Consequently, this research aims to identify barriers to online learning in the built environment programme. A quantitative research approach was adopted, which informed the use of questionnaire survey administered to 115 postgraduate students from the departments Quantity Surveying, Architecture, Building, and Engineering. Descriptive statistics, including the calculation of mean and standard deviation, was used to analyze the collected data. Findings show that the most commonly agreed upon barriers include lack of time to study, financial constraints, and resistance to change. This study offers a valuable contribution by identifying these key factors; however, further research can explore the drivers to online learning among undergraduate students and professionals undertaking continuing education.

Keywords: Barriers, Online, learning, Education

1. Introduction

Technological developments have encroached upon university/higher education and gradually shaping and changing how learners engage with content, course facilitators, and classmates, especially in online learning environments (Gillett-Swan, 2017). Online learning is defined as the deployment of technological tools to deliver learning content and promote interactive and collaborative learning regardless of geographical distance from the classroom (Cheng, 2012; Wu *et al.,* 2012). Rapid technological changes, along with hardware and software advancements, have propelled online education (Cook and Sonnenberg, 2014).The rapid growth of Information and Communication Technologies (ICTs) in the recent decades has reshaped the forms of teaching and learning in higher education (Sife, Lwoga, & Sanga, 2007). Although many forms of ICT innovations have been employed for educational purposes including "computers, the Internet, broadcasting technologies (radio and television), and telephony". Efforts have been made to identify drivers and barriers to online learning globally (Alshwiah, 2021; Parmley, 2022). Through advancements in communications and digital devices, online education has been evolved with the potential to scale education, making it more affordable and accessible. Statistics indicate that between 0.7 to 52.1% of enrolled individuals complete online learning courses (Jordan, 2015). While there are many barriers to learning, these can become more pronounced in online setting (Parmley, 2022). Authors have reported on drivers and barriers to online learning in computer science, nursing education during the COVID-19 pandemic, and English education in Wuhan (Wen *et al.*, 2021; Zou, Ping, Li, 2021; Talbert, 2020; Achebo *et al.,* 2019). Little to no research exists in the literature identifying barriers to online learning in the built environment. Therefore, this study examines these barriers to online learning in built environment programmes.

2. Literature Review

2.1. Overview of Online Learning

Online learning has emerged as a pivotal mode of education, offering flexibility and accessibility to a diverse student population. It enables learners to engage with course materials asynchronously, accommodating various schedules and commitments (Dhawan, 2020). The digital environment fosters self-paced learning, enhancing students' self-regulation and time management skills (Broadbent, 2021). However, the efficacy of online learning is contingent upon learners' digital literacy, motivation, and the availability of institutional support systems (Rapanta et al., 2021).

2.2. Barriers to Online Learning

Despite its advantages, online learning presents several challenges that can impede student success. These barriers can be categorized into technological, institutional, and learner-related factors as shown in Table 1.

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Table 1: Barriers to Online learning

Parmley (2022)	Alshwiah (2021)	Gawish, and Main (2021)	Srichanyachon (2014)	Ndzibah, Agbejule, Lotchi (2014).
1 Lack of confidence.	1 Financial problem.	1 Lack of access to learning materials.	1 Decreased live, face-to-face interaction between students and instructors.	1 Learning-teaching process.
2 Self-doubt and difficulty adapting to change.	2 Poor skills.	2 Fear of failure.	2 Lack of Internet connection.	2 Participation and attention.
3 Fear of failure.	3 Lack of resources.	3 Lack of purpose.	3 Lack of money.	3 Inadequate online learning environments.
4 Lack of goals and purpose.	4 Lack of time to study.	4 Language barriers.	4 Connection problems.	4 Lack of Technical infrastructures.
5 Lack of Technical Skills.	5 Poor quality content.	5 Low self-esteem.	5 Lack of technical skills.	5 Time management.
6 Trainer Incompetence.	6 Irrelevant course material.	6 Boredom.	6 Impairments.	6 Language barriers.
7 Noisy environments.	7 Connection problems			
8 Not paying attention.	8 Lack of technical support.			
9 Lack of internet	9 Limited feedback.			
10 Lack of resources.	10 Information overload.			
11 Disability	11 Lack of student/teacher interaction.			
12 Poverty	12 Registration issues.			
13 Lack of financial stability.	13 Time management.			
14 computers.	14 Resistance to change.			

Technological Barriers: Limited access to reliable internet connectivity, inadequate digital infrastructure, and insufficient technical support are prevalent issues, particularly in developing countries (Mairal-Llebot et al., 2024). Students often face difficulties in accessing necessary hardware and software, which hampers their ability to participate effectively in online courses (Maina, 2015).

Institutional Barriers: The rapid transition to online learning has exposed gaps in institutional readiness, including the lack of comprehensive training for educators, inadequate online pedagogical strategies, and insufficient support services for students (Mosier et al., 2024). These shortcomings can lead to suboptimal learning experiences and outcomes.

Learner-Related Barriers: Students may encounter challenges such as decreased motivation, feelings of isolation, and difficulties in self-regulation within the online learning environment (Tandon et al., 2022). The absence of face-to-face interaction can exacerbate these issues, leading to reduced engagement and academic performance.

2.3. Barriers Specific to Built Environment Education

Built environment programs, including architecture, construction management, and quantity surveying, have unique educational requirements that pose additional challenges in the online learning context. These disciplines often rely on studio-based learning, hands-on experiences, and collaborative projects, which are difficult to replicate virtually (Asfour & Alkharoubi, 2023). A study by Altıntaş Kaptan *et al.* (2021) highlighted that architecture students

encountered significant obstacles in synchronous online learning, such as reduced interaction with instructors and peers, limited feedback on design work, and challenges in maintaining motivation. Similarly, Tandon et al. (2022) identified that the absence of physical studio environments impeded the development of critical design skills and peer learning opportunities. Furthermore, in the Nigerian context, Maina (2015) reported that the effective use of Computer-Aided Design (CAD) and Building Information Modeling (BIM) tools in architecture education is hindered by inadequate infrastructure, limited access to technology, and insufficient training. These factors contribute to a gap between academic instruction and industry requirements.

The COVID-19 pandemic has further exacerbated these challenges, necessitating a reevaluation of pedagogical approaches in built environment education. There is a pressing need for blended learning models that integrate online and face-to-face instruction to accommodate the practical components of these programs effectively (Asfour & Alkharoubi, 2023).

The literature reveals that while online learning offers flexibility and accessibility, it is often hindered by various challenges categorized as technological, institutional, and learner-related. These barriers include poor internet access, lack of digital infrastructure, inadequate support systems, and diminished student motivation. Although these challenges have been widely studied across disciplines like healthcare and computer science, limited attention has been given to how they affect built environment education programs that typically rely on hands-on, collaborative, and studio-based learning.

This study addresses that gap by examining the specific barriers faced by students in built environment programs within the Nigerian context. Given the practical and design-oriented nature of these disciplines, the shift to online learning presents unique challenges that have not been adequately explored in existing literature. By focusing on this under-researched area, the study provides insights that can inform more targeted pedagogical and institutional strategies for improving online learning in technical and design-intensive fields

3. Research Methodology

A quantitative research approach was adopted for this study because it is a successful method for achieving objectivity and quantifiability (Fellows and Liu, 2015). Furthermore, the lack of understanding of the unique challenges faced by students necessitated a wider coverage of students' perceptions of the unique barriers to their online learning. That is, the nature of barriers being studied is better suited for quantitative method which requires objective measurement rather than exploratory. A similar study (Qifu, 2013) has used quantitative approach. A questionnaire administered manually was used to collect data. Several barriers were identified from literature, synthesized and used as variables in designing the questionnaire, which was administered using stratified sampling technique to postgraduate students of built environment programmes in Ahmadu Bello University (ABU) Zaria. The postgraduate students considered are from Quantity Surveying, Architecture, Building and Civil Engineering departments. A total of 375 postgraduate students were identified from the various departments' registers, and a sample size of 270 was computed using the formula by Yamane (1967). Data was analysed using descriptive statistics through the Statistical Package for the Social Sciences (SPSS) version 20.

4. Findings and Discussion

This section presents the results of the analysis, starting from the demographic information to the descriptive results of the barriers to online learning as responded by the students. Table 2 shows that of the 270 questionnaires were distributed, only 115 were retrieved, and 155 were not retrieved, 42.59% and 57.41%, respectively. Survey results with return rates lower than 30% may be considered biased, unreliable, and of little significance. However, the number of questionnaires completed and returned for this research is 42.59%, and so it is considered adequate for analysis.

Table 2: Response Rate

Item	Frequency	Percentage (%)
Not Retrieved	155	57.41%
Retrieved	115	42.59%
Distributed	270	100.00%

Source: Field Survey (2023)

Table 3 presents the demographic information of the respondents, showing the degree category, program of study, profession, and their years of online experience. In terms of degree category, 76.5% of the respondents are master 's students, while 23.5% are PhD students. Of the respondents , 33% are registered in the Quantity Surveying department, 20.8% in Architecture, 18.3% in Building, and 27.8% in the Civil Engineering department. Regarding years of online experience,

18.26% of the respondents have 1- 5 years , 20% have 6- 10 years , 22.6% have 11-15 years, and 39% have 16- 20 years of online experience.

Table 3: Demographic Information

Respondent Information	**Frequency**	**Percentage (%)**
Degree Category		
MSc	88	76.52
PhD	27	23.48
Programme of Study		
Quantity Surveying	38	33.04
Architecture	24	20.87
Building	21	18.26
Civil Engineering	32	27.83
Years of Oline Experience	**Frequency**	**Percentage (%)**
1-5 years	21	18.26%
6-10 years	23	20.00%
11-15 years	26	22.61%
16-20 years	45	39.13%
TOTAL	**115**	**100.00%**

Source: Field Survey (2023)

Table 4 (see Appendix 1) presents the results of the analysis from SPSS, showing the ranked barriers to online learning within the built environment. "Lack of time to study, financial problems , and resistance to change" are the top three ranked barriers to online learning, with mean scores of 3.71, 3.68, and 3.66, respectively. The least ranked barriers to online learning are an unproductive or noisy environment, registration issues, and information overload, with mean scores of 3.11, 3.04, and 2.97, respectively. These results contradict the works of Roslan and Halim (2021), who found that while all students owned at least one learning device, 22.5% of the students did not have a learning space at home. Additionally, 21.9% of students lacked Wi-Fi access, and 11.2% did not have mobile broadband coverage at home. Similarly, Muilenburg and Berge (2005) suggested that students' barriers to online learning include time interruptions, a lack of motivation to use technology, infrastructure issues, perceived skills, and technical and social skills. Results show that postgraduate students are more concerned with time management and financial issues than with technical constraints such as internet access and teachers' technical skills. However, these barriers to online learning will vary from one institution to another, depending on the level of advancement in technology. Hence, technologically advanced institutions may have overcome barriers like internet access, focusing on affordability and self-discipline as more pressing issues. While unproductive or noisy environments , registration issues, and information overload were ranked as the least impactful barriers, their presence indicates the diversity of these challenges . Institutions can adopt flexible learning approaches to accommodate more constrained learners and support these learners financially by providing scholarships and/or installment payments .

5. Conclusion and Further Research

Technological advancement has encroached upon universities and higher education, gradually shaping and changing how learners engage with content, course facilitators, and classmates , especially in online learning environments. However, while online learning has the potential to make education more accessible and affordable, many barriers still hinder its effectiveness. Therefore, this study assessed the barriers to online learning within built environment programs , identifying key barriers, including a lack of time to study, financial problems, and resistance to change. Although the findings did not align with some previous studies, it can be understood that these barriers to online learning are context-specific. That is, the level of technological advancement within institutions may play a key role in determining the nature of barriers hindering online learning.

To address these challenges, the study recommends the following:

I. Institutions should introduce trainings on time and change management to enable students better manage their time and struggle less in transitioning to online learning.
II. In addition, awareness campaigns, and the use of digital platforms can ease the transitioning.
III. Scholarships or grants can be granted by institutions to lessen the financial burden on students.

Further studies can focus on context specific mitigating measures to the barriers hindering online learning. Particularly, focusing on

institutional policies, and technological tools.

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Appendix 1

Table 4: Barriers to online learning.

BARRIERS	MEAN	STANDARD DEVIATION	RANK
Lack of time to study	3.71	0.934	1
Financial problems	3.68	0.923	2
Resistance to change	3.66	1.067	3
Lack of focus	3.47	1.029	4
Connection problems	3.45	0.957	5
Time management	3.42	1.221	6
Irrelevant course materials	3.41	0.954	7
Limited feedback	3.37	1.188	8
Lack of purpose	3.35	1.093	9
Low self-esteem	3.34	0.990	10
Fear of failure	3.33	0.989	11
Teachers' technical skills	3.33	1.024	12
Lack of access to internet	3.32	1.031	13
Boredom	3.30	0.955	14
Lack of student/teacher interaction	3.23	1.029	15
Impairment	3.20	1.070	16
Language barriers	3.16	1.031	17
Unproductive or noisy environment	3.11	1.058	18
Registration issues	3.04	1.150	19
Information overload	2.97	1.184	20

Enhancing Gender Equality Policies for Promoting Women's Participation in the Zimbabwean Construction Sector

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Abstract

Gender equality is a fundamental human right woven within the Sustainable Development Goals as a blueprint for progress across all areas of life. However, sectors such as the construction industry remain segregated and characterised by unequal opportunities for women. Therefore, the study explored how gender equality policies can be enhanced in the construction sector to improve the participation of women. The concomitant objective was to identify the key strategies that be incorporated in policies promoting women's participation in the Zimbabwean construction sector. Through an interpretive philosophy, qualitative data were collected through in-depth interviews of purposively sampled key informants from construction consultancy firms, government departments and construction professional bodies. Thematic analysis of data was conducted to unveil the prominent strategies for improving gender equality policies. The findings include the need to promulgate construction-specific legislation through improved and well-resourced quota systems for women, effective gender protection policies, and support of work-life balance policies for women. Although adequate policies may be in place, their implementation is lacklustre. A top-down approach may be a significant step toward promoting women's participation in the construction industry. The determined policy enhancement strategies, through analysing views of key professionals and informants, for enhancing gender equality are a significant step in promoting women's participation. A limitation of the study was the exclusion of most female construction professionals and operatives, yet they possess valuable experience and perspectives of work in the construction sector.

Keywords: Construction sector, Gender equality policy, Women, Workplace diversity, Zimbabwe

1. Introduction

Zimbabwe's construction industry is generally characterised by several challenges regarding the implementation of the intertwined Sustainable Development Goals (SDGs) (Machingura and Nicolai, 2018). However, this paper focuses mainly on the aspects of SDG Number 5 and Number 8 on achieving gender equality and decent work, respectively. According to the United Nations Global Goals, achieving these is an approach to alleviating the tremendous waste of the world's human potential, especially in the construction industry (Brueckner et al., 2022). Inequality continues in various offices and workplaces across the globe (Mukhija, 2019). The construction industry remains a heavily male-dominated sector where the representation of female workers is insignificant despite the benefits derived from the construction sector (Moyo et al., 2023). Little has been achieved in this sector, and according to the Infrastructure Development Bank of Zimbabwe (IDBZ) (2019), the statistics of female construction workers was 3,5% in 2019, and it has remained at the same level over the years.

Therefore, this study sought to interrogate ways to enhance gender equality policies for the Zimbabwean construction sector. Zimbabwe has ratified the most fundamental conventions to achieve gender justice. Zimbabwe has ratified the most fundamental conventions to achieve gender justice across its economic sectors (Machingura and Nicolai, 2018). In support, the Women Research Institute (2023) asserts that protecting workers is not just a matter of legality. However, it should refer to the international legislation for the development of legal protection on the grounds of equal employment opportunities for men and women. The following section considers the theoretical framework proposed to shape and understand gender equality in society and the working environment. There is also a literature review on policies and legislation that supports gender equality. After that, the study's methodology was presented together with the discussion of the findings, and then the conclusions were presented.

2. Literature Review

2.1. Theoretical framework

There are numerous theories, but for this study, an extensive literature review identified two main sociological theories relevant to the study of gender equality in the working environment, as supported by Basmechi (2018). These are the 'gendered organization theory' and the 'hegemonic masculinity theory.' The

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theories aim to shape and understand gender equality in society and the working environment. The Gendered Organization Theory claims that organizational structures are not gender-neutral and that gendered characteristics are embedded in organizations and obscured by the nature of work (Basmechi, 2018). The Hegemonic Masculinity Theory legitimizes male dominance in society, while female subordination is justified through that legitimacy. Connell and Messerschmitt (2005) assert that culture, institutions, and persuasion are the tools that aid the attainment of hegemonic masculinity, benefiting men who participate in the complicit subordination of women. This perpetuates harmful stereotypes and creates unfavorable working environments for women (Ellemers, 2018). The theories provide an understanding of gender perceptions, gender role assignments, and the status of women in society and the workplace.

2.2. Zimbabwean gender-related policies and legislation

The Committee of Experts on the Application of Conventions and Recommendations (CEACR) made notable observations on the progress regarding the position of women at work (Mutangi, 2016). However, continued progress is still necessary to achieve a positive future of work for women, and this begins with a proper rectification of appropriate legislation and public policies (Mushayavanhu and Mutangi, 2013), especially in male-dominated trades. In this section, the legislation that governs gender equality and related issues was reviewed with a specific focus on the construction industry, as shown in Table 1. The relevance was determined from a semantic point of view and the associations among them, highlighting the avenues through which gender inequalities have found ways to creep into the world of work for female construction workers. The literature presents gender equality, social inclusion, and diversity policies as foundations for creating environments that enable equality (United States Agency for International Development , 2018). Despite legislation that Zimbabwe enacted in support of women in workplaces, female workers continue to suffer from structural barriers, especially in industries predominantly dominated by men (Ibid). Strategies for enhancing the efficacy of the existing gender equality policies can be deduced from the identified concerns within the study area and literature.

The main areas of concern gathered from this review include challenges associated with work-life balance, sexual harassment, and leadership and decision-making. According to Kalysh (2016) and Tijani et al. (2020), work-life balance is a common struggle that has

Table 1: Zimbabwean Policies and legislation reviewed

Source	Challenges
Constitution of Zimbabwe 2013-2017	It does not criminalise certain acts of violence, such as verbal offences, or psychological and economic abuse (Domestic Violence Act (5:16); International Federation of Red Cross and Crescent Societies, 2018), yet verbal offences are a form of sexual harassment. Contradictory sections of the Labour Act (28:01) on maternity leave are in contradiction with the International Labour Organisation (ILO) convention on maternity rights (Mutangi, 2016). Zimbabwe has yet to ratify the Maternity Leave Convention No. 183 of 2000 Inconsistencies with other laws (Sibanda,2023).
Labour Act (28:01)	Cumbersome and lengthy processes of the court systems to victims (Marimo et al., 2021). Female entrants of the reproductive age are often side-lined in preference for a male employee, and these firm stereotypes can be extremely harmful, automatically influencing conscious and unconscious presumptions about people based on gender and age (Machingura and Nicole, 2018). Mushayavanhu and Mutangi (2013) state the need to interrogate disciplinary hearings and decisions of sexual harassment in workplaces. The chain of reporting needs to be improved.
National Gender policy	Limited publication regarding the impact of the intended goals on the nation (Fombard, 2016) Culture and tradition hindered the implementation process (CARE International, 2014), Need more support and resources to implement the strategies at the company level (Mwangi, 2018); hence, women remain disadvantaged in workplaces. ILO (2020) states that legislative solutions need meaningful and proactive action from social partners such as employers to yield meaningful progress.
Gender Commission Act (10:31)	There needs to be more clarity on the actual roles of the established commissions, yet there is a need for a more holistic approach to deal with the systematic barriers against women, especially in leadership positions (Mwangi, 2018). The Commission is disappointing as it limits clarity on the actual responsibilities it is to deal with, and it only adds a little to the Commission's Constitutional powers (Machingura and Nicolai, 2018).
National Quota System	Criticised for tokenism (Ip et al., 2020), glass ceilings and downplay of the meritocracy of the selected female construction workers.

induced growing attention in the construction industry due to its effects on the mental health of female construction workers, turnover , and project performance. This was also echoed by Muthambi and Agumba (2022) when they highlighted the challenges of long working hours and work-life balance. Nyanga and Chindanya (2020) cite sexual harassment elimination through legislation as an essential action towards accelerating progress towards gender equality in the world of work.

In leadership and decision-making, executive leadership in the construction industry remains repeatedly constituted by masculine domination where women are silenced (Hill, 2016). Therefore, diverse voices must be included in drafting policies with input from multiple stakeholders at all levels, ensuring that women are included (ILO, 2020). Public consultation is critical to effective policymaking (Sibanda, 2023). Hanke (2017) and Wade (2015) point out inadequate support from the national government with resources to effectively implement the strategies at company levels. Therefore, effective legislative instruments and practices in line with international labor standards help industries promote transparent, accountable actions on gender equality (ILO, 2020), which positively impacts the participation of women in the construction industry.

3. Research Methodology

The study employed an interpretivist philosophy and implemented a qualitative method to collect data through in-depth interviews. Babbie and Mouton (2015) suggest that such approaches allow the data to determine the researcher's themes. In-depth interviews were conducted to uncover the detailed support for gender equality required from policies and legislation for the Zimbabwean construction industry. The first section of the interview guide addressed demographic issues, namely gender, profession, and experience in the relevant fields. The second section requested strategies for policy enhancement. According to the Clayman Institute of Gender Research (2016), to achieve gender equality, the culture of masculinity must be dismantled through essential alliances with men to amplify new voices and advance gender equality. The purposive sampling technique was employed to select key informants, preferably females with expert knowledge , to create a more robust understanding of the research topic (Babbie and Mouton, 2015).

As suggested by Saunders et al. (2016), four to twelve interviews are acceptable to reach saturation. Therefore, the sample for the study targeted seven participants and consisted of both genders and registered construction professionals (five), legal practitioners of Labour Law, civil litigation, and estate administration (one), as well as a District Development Officer from the Ministry of Women's Affairs, Gender and Community Development (one). Data saturation was achieved after the seventh interview. Thematic analysis was used to analyze the qualitative data, and it was the most suitable approach to apply to the transcribed interviews . According to Saunders et al. (2016), the researcher needs to scrutinize the data to develop patterns of meaning that repeatedly appear. The thematic analysis included various approaches, and it followed a six-step process that included familiarization , coding, categorization, and the generation of themes

4. Findings and Discussion

4.1. Profile of Respondents

The interviewees, shown in Table 2, were drawn from selected government ministries, professional bodies, and construction firms with extensive experience in the construction industry. They provided first-hand information and knowledge, thereby offering recommendations for solutions .

The interviewees included five (5) females and two (2) males; thus , the responses obtained from the interview were broadly representative of the gender under study,

Table 2: Profile of the Interviewees

Participant	Gender	Profession	Position	Years of experience
P1	Male	Civil/Structural Engineer	Director	20
P2	Female	Labour and civil litigation lawyer	Chief legal adviser and Consultant	15
P3	Female	Quantity surveyor	Director	12
P4	Male	Civil/ Structural Engineer	Professional body- General Secretary	22
P5	Female	Sociologist	District Development Officer for Gender Empowerment	18
P6	Female	Architect	Professional body executive member and consultant	10
P7	Female	Quantity Surveyor	Professional body executive member	7

and the presence of males mitigates bias in the study. The various designations of the interviewees also validate the data collected. Data saturation was achieved after the seventh interview.

4.2. Strategies for enhancing gender equality policies

Generally, the seven respondents offered strategies for good practices and programmes for enactment at the company and national levels. Themes were extracted from the data analysis. These included the need to promulgate construction-specific legislation through improved quota systems for women, effective gender protection policies and work-life balance support for women. They are discussed hereafter.

4.2.1. Generation of legislation specific to the construction industry

Apart from acknowledging efforts by the Zimbabwean government to achieve gender equality through legislation, some respondents inferred the need for legislation that deals specifically with the construction industry because of its manifest masculine culture, which is a significant barrier to the participation of women (Mwangi, 2018). P1 and P6's narratives describe the need for specific legislation concerning gender equality.

P1: "...there is effort in the construction industry to have their act in which they have been pushing through the Zimbabwe Construction Industry Association… which addresses specific issues within engineering''.

P6: ''…. laws need to be enacted that directly penalise discrimination and incentivise inclusion to create healthy working environments for women''.

In tandem with the literature, the labour laws that govern the construction industry universally apply to all economic sectors. Yet, unlike other sectors, female construction workers face more hardships in their work environment. ILO (2020)), also support this notion. Based on all the forms of discrimination experienced by women in the sector, undoubtedly, there is a need for more prescriptive policies and legislation through policy refinement and enactment enforcement. Furthermore, the legislation should be consistent with current trends, as Sibanda (2023) argued. The views shared by P1 and P6 are in tandem with the efforts by the Australian government to disrupt gender stereotypes in the construction industry through the enactment of the Building Equality Policy. Jones (2021) notes that the government mandated a percentage of females in each trade role. This aligns with arguments by Sibanda (2023), who states that legislation must be consistent with industry trends. Gender quotas are some of the suggested methods to increase the number of female leaders in the construction industry, as alluded to by P1, P2, and P5.

P1: '' There is a need to push forward for a quota system to ensure a balance as of now to address deliberately previous imbalances ...".

P2: "Maybe introducing a temporary quota can certainly be effective as was done with the cabinet".

P5: ''We want to reach a stage whereby women are not selected by quota system only…".

All respondents acknowledged the need for quota systems in leadership because the construction industry has been male-privileged for a long time. Nevertheless, the economy and society are interested in tapping into all talent in their midst, per Manzini (2020). Using the phrases 'as of now' by P1 and 'temporary quota' by P2 reveals that it is a desired policy in the short run to eradicate the inequalities until women are fairly or equally represented in management positions in the construction sector. Response by P5 shows that quotas are a starting point towards the maximum utilisation of female talents, but they downplay the meritocracy of female leadership versus men. P5 and P7 had this to say.

P5: "...because we want to be selected based on merit just like men…''

P7: "...we deserve and are capable of functioning in our workplaces…"

P5 and P7's responses align with Ip et al.'s (2020). Nonetheless, quota systems work better alongside measures that address biases against females in the workplace. However, they are a starting point to signify the end of women's exclusion from decision-making positions in the construction sector.

4.2.2. Establishing effective gender protection policies for women.

Findings from the research study show that some female construction workers endure harassment on construction sites, which can cause mental health effects such as depression, and sometimes they leave the industry too early. Mutangi (2016) and Marimo et al. (2021) cite inadequate and inconsistent support from legislation against harassment at workplaces can also trigger unethical behaviours such as drug addiction and alcohol intake on sites to cope. The responses from P1, P2 and P7 demonstrate the importance of support and immense psychological safety in the working environment.

P1: "Employers and managers who are senior on-site must make sure that construction sites are comfortable for both genders as one of their key result areas."

P2: " As a constitutionalist, I believe there is a need for remedying injustice. Women should be encouraged to report injustices at workplaces".

P7: "…women seldom respond to discriminatory practices due to a lack of guaranteed protections…"

Employers and workplaces such as construction sites must address violence against female operatives and professionals in all its forms by setting up practical interventions that encourage equal and respectful relationships between female and male workers. This also entails assigning adequate resources towards creating policies that encourage the minority voice to speak out against unfair treatment practices. There is a need for an integrated approach rather than individual mandates to support victimised women from the courts of law, the sectors, ministries, and departments (International Federation of Red Cross and Red Crescent Societies, 2017).

4.2.3. Support for work-life balance.

Women face increased pressures and frustrations in their desire to balance work and life domains, and quite often, the relationship between work-life balance and female leadership is complex.

P2: "The law should work on that...there is no paternity leave in Zimbabwe, yet it significantly affects how work and life are later balanced ...".

P3: "Of course, introducing flexible working would do, but it is easier within advanced technology spaces."

P4: "The existing labour statutes have improved working conditions in the construction industry even for the female employees, especially on balancing work and life…".

P2 is a female, aware of the struggles of the work-life balance of female professionals with family responsibilities. Motherhood and fatherhood differences stem from the cultural expectations and gendered societal roles of family responsibility prevalent in patriarchal societies like Zimbabwe. P2's proposed social support from paternal leave enables women to combine their reproductive and productive roles successfully. ILO (2020) supports this notion, stating that well-managed maternity and paternity leave policies encourage women to return to work after childbirth, thus closing the leaky pipeline of female talent. Kalysh (2016) suggested that social support relieves the work-life pressure in studying female leadership in the construction industry, especially when supported by legislation. In addition, P3, in line with P4, expressed concern about the need for flexible work policies that support work-life balance to encourage female construction workers to stay in the industry. Tijani et al. (2020) emphasised that this continuous struggle for work-life balance has effects on job satisfaction, which causes women to either leave or stay in the industry. Therefore, there is a need for flexible working policies supported by legislation which enable female construction workers to manage the coexistence of family and work responsibilities.

5. Conclusion and Further Research

Gender inequality exists in the Zimbabwean construction industry; the industry can improve with appropriate strategies. Zimbabwe has progressed in promoting gender equality and protecting women's rights in the workplace. However, significant impediments to achieving diversity remain within the legal stipulations under which the policies are devised. The provisions of the law should clearly define what constitutes a gender-inclusive work environment. Consequently, there is a need for gender equality legislation and policies specific to the construction industry that support work-life balance for female construction workers. Additionally , a well-supported quota system is needed as a measure to enhance the representation of women.

These findings contribute context-specific strategies that can be incorporated into gender equality policies to address their identified shortcomings. They have substantial implications for policymakers and leaders in the construction industry who design policies and legislation that support gender equality and the effective functioning of female labor in the traditionally male-dominated construction sector. As proposed by gendered organization theory, workplaces must be gender-neutral. Furthermore , the hegemonic masculinity theory within workplaces that legitimizes male dominance must help identify variances. Future studies should consider the experiences and insights on gender equality from female operatives and professionals on construction sites. The major limitation of the study was its exclusive qualitative nature.

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Initiatives for Improving Physical Well-Being for Construction Workers in Zimbabwe

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Abstract

The hazardous working conditions associated with the construction industry have led to increased poor health and work disability among construction workers. Although workplace physical health promotion programs for construction workers are present in developed countries, developing countries still need to identify applicable programs. Therefore, this study sought to uncover initiatives to improve the physical well-being of construction workers in Zimbabwe. Quantitative data were collected from project/site managers and skilled workers through Google Forms and interviewer-administered questionnaires, respectively. Statistical analysis was conducted using the relative importance index and the T-test. The findings indicate that exercise programs, health risk assessments, nutrition education, weight loss programs, and Safety, Health, and Environment (SHE) workshops are critical for improving the physical well-being of skilled construction workers in Zimbabwe. There is consensus between both respondent groups on the initiatives required. The study recommends that employers and other stakeholders invest in proactive and preventative measures for physical well-being and health promotion that include exercise equipment and nutritionists to assist with meal planning. Additionally, workers should be encouraged to participate in workshops on Safety, Health, and Environment promotion programs offered by internal or external organisations. The main limitation of the study was the inclusion of only five residential and commercial construction sites for the skilled workers. Including civil construction sites could yield more insights. Identifying physical well-being initiatives is important for improving the health and safety of construction workers. This paper is valuable for enhancing human-centred occupational health and safety policies within the construction industry.

Keywords: Construction, construction skilled workers, initiatives, physical well-being, Zimbabwe

1. Introduction

Across various sectors, the construction industry is regarded as having the highest rates of work-related illnesses (Lingard & Turner, 2015). Adams (2019) argued that workplace conditions can affect employees physically, mentally, or emotionally and enhance or harm their well-being. Lette et al. (2018) reported that work-related injuries and illnesses constituted 41.4% in Ethiopia, and Yang et al. (2020) recorded an average injury rate of 2.21 per 100 workers in the state of Oregon, the United States of America, indicating workers' well-being challenges within the construction industries of both developing and developed countries. Samanta and Gochhayat (2022) attributed 80-95% of accidents to poor well-being. Construction workers are at the lowest on the socio-economic power gradient among blue-collar workers. They are associated with poor health, increased rates of disability, chronic disease, and mortality (Du Plessis et al., 2013), with at least 70% suffering from mental health issues (Powell et al., 2018). Moreover, the tough nature of the construction industry poses significant health risks to construction workers (Liang & Shi, 2022). Loudoun and Townsend (2017) pointed out that poor health among construction workers is often due to the predominance of musculoskeletal conditions, such as fall injuries, fractures, back injuries, or arthritis, as well as respiratory issues. The construction industry is a male-dominated sector (Hanna et al., 2020). Because men rarely seek medical attention for health issues, they are associated with poor health (Stergiou-Kita et al., 2016). Moreso, construction is an occupation highly related to elevated stress levels, which impact workers' psychological and physical well-being (Fenton et al., 2014). Due to the poor health associated with the construction industry, working lives are significantly shortened (Ajslev et al., 2013). For example, poor nutrition among construction workers has been linked to chronic diseases that later affect the performance of workers and result in injuries and accidents (Okoro et al., 2019).

The construction industry is facing serious problems regarding the management of occupational health, safety, and wellness issues. The cost of claims related to occupational injuries, including construction-related claims, in Zimbabwe translates to 0.05% of the Gross Domestic Product (Magada, 2024). Chipato et al. (2019) established that the existence of a negative health and safety culture significantly affects the construction industry. The problem is intensified by poor conditions of machines and equipment, lack of attention to ergonomic factors, poor hygiene

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conditions, a severe lack of functional occupational safety and health management policy, insufficient personal protective equipment, lack of training programs, and pollution (Chazireni & Chagonda, 2018). The failure to facilitate employees' well-being programs has led to challenges such as depression, stress, musculoskeletal disorders, drug abuse, high blood pressure, and respiratory diseases, among others (Ganster & Rosen, 2013; Fenton et al., 2014; Quick et al., 2014; Carmichael et al., 2016; Salvagioni et al., 2017).

Notwithstanding these shortcomings, inadequate research on physical wellness initiatives exists in developing countries like Zimbabwe. Therefore, initiatives aimed at improving the physical health and well-being of Zimbabwean construction workers were sought. Addressing the employee wellness challenges will enhance employees' physical and mental well-being, and the industry will enjoy improved productivity. The following sections will consider the theoretical foundation of the study and review physical health and well-being initiatives from previous studies. The methodology is expanded, and the results are presented and discussed. Finally, conclusions and recommendations are derived from the results.

2. Literature Review

The study's theoretical framework and physical well-being initiatives are reviewed in this section.

2.1. Theoretical framework

This study is based on the motivational theory by Henry Maslow, where physiological, safety and self-actualisation needs are emphasised (Leonard & Trusty, 2015). These needs relate to the physical well-being initiatives for skilled construction workers. Moyo et al. (2022) reported that activating health and well-being initiatives substantially advances the profitability and satisfaction of both the employer and skilled construction workers, respectively.

2.2. Initiatives for physical well-being improvement

The workers in the construction industry are affected by poor mental and physical health (Kaluarachchi et al., 2022). To improve the physical well-being of construction workers, Lingard and Turner (2017) developed a qualitative causal loop diagram that shows a relationship of factors operating at and between individual, family, workplace, and industry levels as affecting the adoption of healthy behaviour. This highlights the importance of these factors for future health promotion interventions. Table 1 presents initiatives for physical well-being improvement from previous studies.

Table 1: Initiatives for physical well-being improvement from previous studies

Initiatives	Sources
Exercise programs	Lingard and Turner (2015), Ganu et al. (2017), Loudon and Townsend (2017)
Health Risk Assessments	Mattke et al. (2015), Lawami et al. (2023)
Mental health policies	Viester et al. (2014), Campbell and Gunning (2020), Greiner et al. (2022), Kaluarachchi et al. (2022), Lawami et al. (2023)
Nutrition Education (Diet)	Viester et al. (2014), Lingard and Turner (2015), Maes et al. (2015), Anger et al. (2018), Chung, et al. (2019)
Safety, Health, and Environment (SHE) workshops (Team cohesion and training)	Lingard and Turner (2015), Maes et al. (2015), Loudon and Townsend (2017), Lawami et al. (2023)
Weight loss programmes	Viester et al. (2014), Lingard and Turner (2015), Anger et al. (2018)

Due to the highly demanding and stressful work environment in the construction sector, characterised by long working hours and high rates of safety incidents, employers should be encouraged to get involved in workplace health promotion programs (WHPPs) by creating a healthy work environment (Loudoun & Townsend, 2017). The hazardous working conditions associated with the construction industry have led to poor health and work disability among construction workers. This has resulted in the popularity of workplace health campaign plans within the construction industry (Maes et al., 2015). According to Lingard and Turner (2015), healthy eating, smoking cessation, and physical exercise are priority areas for intervention to achieve the physical well-being of construction workers. Therefore, several health campaign measures addressing these issues were implemented in Australia, including healthy eating and cooking workshops, an abstinence from smoking program, a "healthy options" menu in the canteen, and on-site yoga and stretching sessions, resulting in improvements in physical well-being.

The exercise programs have multiple positive effects, which are not only of a physical nature but are also psychological (Ganu et al., 2017). Moreover, the workers suggested the need to offer a work setting that encourages healthy habits for these health promotion

interventions to be effective (Lingard & Turner, 2017). However, these may not necessarily be implementable in a developing country due to differences in construction health and well-being structural policies. The continuous rise in chronic diseases amongst construction workers suggests the need for lifestyle behavioural changes. This is because unhealthy lifestyle behaviours affect productivity, safety, and interpersonal relations among workers (Loudoun & Townsend, 2017). In agreement, Lingard and Turner (2015) highlight that lifestyle factors are critical in shaping the health outcomes of construction workers; hence, the introduction of numerous individual behaviour change programs. Sorensen et al. (2011) observed significant benefits from individual information campaigns encouraging the consumption of fruit and vegetables amongst US construction labourers. Chung et al. (2019) also observed a substantial change in the intake of fruit and vegetables after implementing nutrition education for construction site workers. Therefore, this may be a viable solution in developing countries, as fruits and vegetables are readily available and can be provided to site workers at a minimum cost to the employer.

Loudoun and Townsend (2017) opined that productivity decreases after meals on construction sites due to poor food choices. This is due to food choices, lack of fluids, meal skipping, and excessive use of energy drinks that affect performance, attentiveness, and increase site tensions. In addition, it is characterised by mood swings, tiredness, and high irritability, thereby affecting morale and interpersonal relationships amongst construction site workers. Viester et al. (2014) developed a feasible worksite intervention aiming at the prevention and reduction of overweight and musculoskeletal disorders (MSDs) among construction workers. Therefore, health promotion programs within the construction industry are fundamental and can succeed if employers recognise that it is within their short-medium- and long-term interests to have a workforce that is both safe and healthy (Loudoun & Townsend, 2017). According to Nwaogu et al. (2020), the rise in depression, stress disorders, anxiety, and suicidality among construction workers has resulted in numerous studies on the psychological dangers to health (Hsu et al., 2016; Liang et al., 2018; Langdon & Sawang, 2018).

Assessment of occupational safety and health risks on construction sites is done through risk assessment matrices based on experience and knowledge (Al-Anbari et al., 2015). Mattke et al. (2015) also remarked that wellness programs frequently assess employees for health risks through health risk surveys and biometric assessments, which offer intervention for addressing health risks and evident diseases as well as endorsing healthy routines. Lawami et al. (2023) identified that the lack of transparency in reporting the well-being of construction workers, stemming from a lack of engagement from employers and inadequate genuine leadership commitment to addressing mental health, has resulted in increased cases of poor health of workers. Issues such as lack of job security, long working hours, long commutes to and from work, and complex work activities are among the high-stress factors experienced by construction workers (Laidler, 2019).

To tackle health literacy, strategies such as health first aiders, health and safety executives' "Talking Toolkit" action plan/policy/strategy, modular emotional training for managers, and webinar sessions about mental health and well-being audits can be implemented in construction organisations (Lawani et al., 2023). Mattke et al. (2015) highlight that despite being somewhat costly and difficult to implement at times, wellness programs always yield positive results. Although these strategies can effectively tackle health concerns in construction, some may be difficult to implement in developing countries due to inadequate financial resources.

3. Research Methodology

A quantitative research design method was adopted, like a study by Lawami et al. (2023). A quantitative methodology contributes to the collection of varied insights from a considerable number of respondents to enable the generalisability of results (Leedy & Ormrod, 2016), as was required by the study. Additionally, the aim of identifying initiatives to improve physical well-being varies and is best identified through a broader survey. Skilled workers from construction sites and site managers were targeted because they possess the required knowledge in the study area. Construction companies were drawn from the Construction Industry Federation of Zimbabwe (CIFOZ) 2023 list, specifically those registered under categories A, B, and C, due to the structures in these organisations. The construction sites were purposively sampled in Harare and Bulawayo in 2023. The application of the Taro Yamane formula (Umar & Wachiko, 2021), resulted in a sample size of 88 from the population of 113 construction companies registered in categories A, B, and C. Skilled workers were selected through census sampling to eliminate bias (Saunders et al., 2016) on purposively identified construction sites (2 residential and three commercial). Online and self-administered questionnaires were used for data collection. Google Forms were used to create the online questionnaire to collect data from project/ site managers, and links were distributed through Emails, WhatsApp, and LinkedIn platforms. According to Saunders et al. (2016), online questionnaires have the merit of promoting effortless data collection in real time. Interviewer-administered structured questionnaires collected data from the skilled workers, which allowed the researcher to counter any ambiguity concerns (Leedy & Ormrod, 2016).

Data analysis was conducted using the Statistical Package for Social Sciences (SPSS). The Relative Importance Index (RII) evaluated the significance of physical well-being initiatives with: 'not important' < 0.2; 0.2 < 'of little importance' ≤ 0.4; 0.4 < 'somewhat important' ≤ 0.6; 0.6 < 'important' ≤ 0.8; 0.8 < 'very important' ≤ 1 (Moyo & Chigara, 2023). The reliability of the questionnaire instrument was confirmed by a Cronbach's coefficient alpha of 0.787, which was acceptable as it exceeded 0.7 (Field, 2014). The Shapiro-Wilk (SW) test assessed normality (Razali & Wah, 2011), and a value of 0.072, being > 0.05, confirmed a normal distribution. Furthermore, the t-test assessed whether there was a significant difference between the insights of managers and skilled workers, with $p \leq 0.05$ indicating statistically significant differences. A low-risk ethics clearance was undertaken and approved by the Department of Construction Economics and Management at The National University of Science and Technology before data collection commenced.

4. Findings and Discussion

4.1. Response rate and Profile of respondents

Questionnaires were distributed to all construction companies and all managers. This was after a pilot test with five conveniently selected participants was implemented. The views from the pilot test were used to improve the questionnaire. Adequately completed questionnaires (51 managers; 82 skilled workers) represented a response rate of 45.13% and 73.2% from populations of 113 and 112, respectively. The mean response rate of 59.11% is above the expected minimum. Chigara and Moyo (2021) highlighted that an acceptable response rate for a survey questionnaire in the study area is at least 30%.

Table 2 shows that most respondents, 76.7%, were male. All managers held at least a bachelor's degree, while most skilled workers (32.3%) were trade-tested. Most respondents (68.4%) had more than 10 years of experience. Overall, the respondents exhibited characteristics that upheld the validity of the study.

4.2. Initiatives for improving the physical well-being of construction workers in Zimbabwe

Table 2: Demographic Profile of respondents

Characteristic	Description	Frequency	Percentage (%)
Gender	Male	102	76.7
	Female	31	23.3
Designation	Managers	51	38.3
	Skilled workers	82	61.7
Educational background	Trade test	43	32,3
	National Certificate and Diploma	39	29.3
	Bachelor's degree	36	27.1
	Post Grad	15	11.3
Number of years working in the construction industry	0-5 years	30	22.6
	6-10 years	12	9
	Above 10 years	91	68.4
	Total	133	100

Table 3 indicates the various initiatives that can be implemented to improve the physical well-being of construction workers with construction skills, rated on a scale of 1 (not important) to 5 (very important).

The results show that respondents consider all the wellness programs listed to be important in enhancing

Table 3: Initiatives for physical well-being for construction workers in Zimbabwe

	Skilled workers			Project/site managers			T-Test of means results
Initiative	RII	Evaluation	Rank	RII	Evaluation	Rank	
Exercise Programs	0.898	Very important	1	0.878	Very important	3	0.058
SHE Workshops	0.874	Important	2	0.908	Very Important	1	0.050
Health Risk Assessments	0.862	Very important	3	0.738	Important	5	0.099
Weight Loss Programs	0.822	Very important	4	0.890	Very important	2	0.070
Nutritional Education	0.748	Important	5	0.794	Important	4	0.052

employees ' well-being. The findings support Mattke et al. (2015), who pointed out that although costly and difficult to implement at times, wellness programs are effective in improving the physical well-being of workers. All the programs scored above average; hence, all are considered effective. From the results in Table 3, employees perceived exercise as the most effective wellness program with an RII of 0.898, while management ranked it third with an RII of 0.878. Exercise programs have proven to be effective, supported by several scholars (Lingard & Turner, 2015; Ganu et al., 2017; Louden & Townsend, 2017). As part of the wellness programs, employees can offer moderate fitness classes that combine yoga, low-impact aerobics, and relaxation methods, potentially attracting first-timers and individuals with special physical needs or limitations (Lingard & Turner, 2015).

As part of the wellness programs, employees can offer moderate fitness classes that combine yoga, low-impact aerobics, and relaxation methods; these may attract first timers and those with special physical needs or limitations (Lingard & Turner, 2015). In addition, investing at least 30 minutes of exercise each day resulted in more than 80% of the employees reporting fewer medical problems and sound mental well-being (Lingard & Turner, 2017). Conducting SHE Workshops with RII of 0.874 and 0.908 for employees and management, respectively, is the highest-ranked initiative by management, while it is the second-ranked initiative by the employees. Hosting seminars and inviting health and wellness experts into the program is one way to get employees actively engaged in the health and wellness discussion, thereby reviving health and wellness efforts (Lawani et al., 2023). It is from these workshops that the employees are taught about the importance of employee safety and that it is everyone's duty, not just the employers'. Once appreciation of each one's roles is increased, there is bound to be a marked improvement in the SHE performance of the companies.

Health risk assessment is the third-ranked initiative suggested by the employees with an RII of 0.862, while for the management, it is the fourth-ranked initiative with an RII of 0.738. The importance of health risk assessment is mainly attributed to the need to identify employees with underlying health conditions that might not be suitable for the physically demanding construction work. In Zimbabwe, workers working in mining areas are assessed for Tuberculosis, to protect those with respiratory challenges from further harm to their health. Also, assessment of mental health is very important, as outlined by Lawami et al. (2023), to ensure the safety of the workforce, as mental challenges may affect the concentration levels of workers, resulting in accidents on site. Weight loss programs are the fourth-ranked initiative by employees with an RII of 0.822, while the management ranked it second with an RII of 0.890. According to Viester et al. (2014), weight loss programs are very effective as they lead to a reduction of excessive body weight, thus minimising medical leave, increasing productivity, and reducing musculoskeletal symptoms through lowering the burden on the musculoskeletal system. Nutrition education is the fifth-ranked initiative with an RII of 0.748 as ranked by employees and an RII of 0.794 as ranked by management. Promoting nutrition knowledge results in improved dietary behaviours. This can be achieved through encouraging a diet composed of fruit and vegetables, which will lower the risk of diet-related diseases such as obesity, diabetes, and cardiovascular disease (Chung et al., 2019).

The t-tests of all the initiatives were above 0.05, which shows that there were no significant differences between the responses from employees and responses from managers. This highlights that managers understand the physical well-being needs of the workers, enabling them to craft the necessary policies to ensure that these initiatives are implemented. Moreover, the consensus also indicates that both managers and workers acknowledge the health hazards associated with construction work and are aware of what is required to safeguard their physical well-being. Therefore, this shows that all five initiatives discussed are critical to the improvement of the physical well-being of skilled construction workers in Zimbabwe. However, awareness and knowledge do not necessarily equate to adequate implementation. Managers may not implement these initiatives if they are not regulated within the construction industry.

5. Conclusion and Further Research

Due to the increased poor health and work disability among construction workers in Zimbabwe, this study aimed to identify initiatives that can be implemented to improve their physical well-being. Initiatives such as exercise programs, S.H.E. workshops, health risk assessments, weight loss programs, and nutrition education were rated as important by both the employees and management. These programs need to be created in close consultation with the employees and ensure that they are of high quality through employing counsellors and team-building professionals who are accredited by renowned bodies or institutions. Consultation with the employees also helps in improving the chances of broader acceptability. Therefore, there is a need for employers to develop measures or programs that are effective and acceptable to the intended users to circumvent the adverse effects being faced by their employees, who are valuable resources within organisations. This study contributes context-specific initiatives that can be used on construction sites to enhance the physical well-being of workers. This study recommends employers take it upon themselves to invest more in preventative measures, such as investing in exercise equipment, introducing on-site yoga, and hiring nutritionists to

assist with meal plans on-site, rather than reacting when problems have arisen. As is the case, employers tend to save more in implementing preventative measures as compared to the costs incurred when resolving problems. Additionally, workers should be consulted extensively for continuous improvement of the implemented initiatives on SHE issues, and their labour unions must be involved. Employees must be encouraged to participate in workshops on health and well-being. Implementing these initiatives is predicated on evolving the construction organisation's strategic policy on occupational health and safety. Further, the broader policies must encourage such proactive strategies to reduce accidents and preserve the safety and health of construction workers. Further studies can measure how these initiatives improve physical well-being. The main limitation of the study was the inclusion of only five residential and commercial construction sites for the skilled workers. The inclusion of civil construction sites could reveal more insights.

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The Challenges to Women's Career Progression in the Construction Industry: An Investigative Study

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Abstract

The construction industry, a traditionally male-dominated sector, has seen gradual changes in female representation over recent decades. However, substantial barriers persist, influencing the rate and degree of women's career progression. This paper investigates the challenges to women's progression and trends in the construction industry, focusing on the South African context. This study employed a mixed-methods approach, combining quantitative data from a questionnaire survey and qualitative insights from focus group discussions in obtaine the data required to answer the research objective. The questionnaire was emailed/self-administered to 259 randomly selected construction workers and professionals listed in the Professional Construction Register, Housing Development Association, and Informal Builders Group. A total of 199 completed questionnaires were collected yielding a response rate of approximately 77%. The data collected were analysed using descriptive and thematic analysis. The study found that the key challenges to women progression in the construction industry include the cost of education, gender bias and a few female mentors. Based on these findings, the study concludes that positive changes in the organisational culture of construction companies, educational support, mentorship, and networking will foster an equitable work environment that enables women to thrive and contribute effectively to the construction industry. The study recommends that construction companies implement policies to close gender pay gaps and introduce quotas for women in leadership positions.

Keywords: Career Progression, Diversity, Gender Equality, Mentorship, Organizational Culture

1. Introduction

The global construction industry is a cornerstone of economic development, playing a vital role in employment creation, investment stimulation, and infrastructure provision. However, it remains predominantly male-dominated, with minimal representation of women in leadership roles (Hasan et al., 2021). In South Africa, this disparity is particularly stark, with women constituting only 9% of the workforce and mainly occupying non-managerial positions (Stats SA, 2022).

Previous studies have identified various barriers to women's career progression in the construction sector. For example, Afolabi et al. (2019) highlight that barriers often stem from societal influences, personal beliefs, and contextual factors that disproportionately affect women from marginalized groups. Research by Liem et al. (2021) and Zhang et al. (2021) emphasizes the necessity for gender-focused initiatives to boost female representation while addressing the qualitative experiences of women within the industry. Despite governmental efforts in South Africa - such as affirmative action policies and targeted training programs - significant obstacles to women's progression persist (Ndweni and Ozumba, 2021; Windapo, 2024).

However, existing literature often lacks empirical depth, particularly regarding the distinct challenges women face in navigating their careers in construction. Many studies have either generalized the issues of gender inequality or failed to explore specific barriers especially within the South African context. While the conversation around gender diversity acknowledges its importance for innovation and enhanced organizational performance, it often overlooks the unique challenges women encounter, particularly in male-dominated environments.

This study seeks to fill that knowledge gap by offering empirical data specifically focused on the South African construction industry. Utilizing a mixed-methods approach allows for the identification and ranking of barriers, while capturing the nuanced experiences of women in the industry, thereby contributing valuable insights that can guide policy and practice. The literature review in the following section analyses existing studies on gender disparities and women's participation in the construction industry, followed by a mixed-method research approach employing questionnaires targeting randomly selected

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construction workers and professionals, as well as focus group discussions with industry stakeholders to obtaine quantitative and qualitative data respectively.

2. Literature Review

2.1. Historical Context and Trends in Female Progression

The construction industry has historically exhibited a pronounced gender imbalance, primarily characterized by a male-dominated workforce that often limits women's participation and advancement in various roles (Hirschi & Läge, 2007). In the United Kingdom, for instance, females represent less than 5% of the construction sector's employees, and their underrepresentation becomes even more evident in managerial roles, where less than 6% of leadership positions are held by women (Seidu et al., 2022). In contrast, South Africa's construction industry has made commendable strides toward addressing these gender imbalances through initiatives like the Broad-Based Black Economic Empowerment (BBBEE) Act, which aims to promote equality and improve women's representation in the workforce (Windapo, 2024). Noxolo Kuviet, a former Deputy Minister of Public Works and Infrastructure in South Africa, highlighted the importance of equitable participation, noting that women, comprising more than half the population, deserve a fair share of economic activities.

Women's representation in the South African construction industry shows positive trends, with 51% of registered contractor enterprises owned by women, while female enrolment in higher education in architecture and building programs has reached 29.4%, signalling progress toward bridging the gender gap (Stats SA, 2022). The differences in gender representation between South Africa and the United Kingdom highlight the ongoing challenges women face globally. For example, while women in South Africa are incrementally gaining ground in company ownership and educational participation, the situation in the UK illustrates a deeply embedded culture of gender imbalance that is resistant to change.

Statistics South Africa data reveal a diversification of women's participation in various construction roles, with women's involvement in site preparation increasing by 9.9% from 2017 to 2022, and participation in building construction rising from 10.4% to 16% during the same period (Stats SA, 2022). These developments signify that while the journey toward gender parity remains complex, progress is tangible and indicative of changing dynamics within the construction workforce. Despite these positive advancements, this period also saw a decrease in women's representation in civil engineering, where female participation dropped by 20.1%, resulting in only 14.5% of the workforce (Stats SA, 2022), highlighting persistent challenges that warrant further examination and intervention.

2.2. Overview of the Challenges to Female Career Progression in the Construction Industry

The challenges to female progression is discussed in the following sub-sections:

2.2.1. The Underrepresentation of Women in the Construction Industry

Studies indicate a significant disconnect between the entry of women into the workforce and their representation in decision-making positions (Kodagoda and Jayawardhana, 2022). According to Naoum et al. (2020), women are confronted by ingrained organizational and societal barriers that challenge their success in high-ranking positions that require demonstrated competence. Oyewobi et al. (2019) note that the scarcity of women in leadership positions often reflects broader organizational structures that fail to promote inclusivity. The organizational culture skews towards males because of their dominance in decision-making positions. Moreover, insufficient mentorship, support networks and female role models further exacerbate these challenges, limiting their access to leadership opportunities (Ndweni and Ozumba, 2021). The introduction of interventions and affirmative action policies, such as gender quotas in leadership positions, has been suggested to enhance female representation and facilitate progress within the construction sector (Liem et al., 2021).

*2.2.2. **Gender Discrimination***

Norberg and Johansson (2021) highlighted the prevalence of biases that favor male employees, resulting in wage disparities and reduced opportunities for women to secure promotions. Reports illustrate that women receive lower wages than their male counterparts, further embedding gender stratification in career advancement (Park et al., 2019). This discrimination is often exacerbated by traditional societal norms that perceive women as unsuitable for roles in construction, thereby reinforcing gender stereotypes and discouraging female participation in the sector (Afolabi et al., 2019).

2.2.3. Unwelcoming or Hostile Workplace Culture Towards Women

Male-dominated environments and inflexible work practices are substantial barriers to women's advancement in the construction industry (Naoum et al., 2020). Furthermore, women often face various forms of hostility—including bullying and harassment—that create an unwelcoming environment, contributing to lower retention rates within the industry (Osei et al., 2023).

2.2.4. Work-life Balance Factors that impact Women working in Construction

According to Lefrançois and Trottier (2022), male-dominated organizational cultures often fail to accommodate flexible work arrangements that support women in balancing professional and familial responsibilities. The lack of family-friendly policies can lead to increased stress and dissatisfaction among female employees, further complicating their career trajectories.

2.2.5. Traditional Stereotypes About Women

Traditional gender roles and societal expectations significantly influence women's career choices and aspirations in construction. According to Mbukanma and Strydom (2022) cultural perceptions that view construction as a male domain diminish the likelihood of women aspiring to or succeeding in these careers.

The literature review outlines the historical context and current trends regarding women's progression in the construction industry, particularly highlighting the deep-rooted gender imbalance characterized by a predominantly male workforce that limits women's participation and advancement. The barriers identified in the literature were further broken down into 46 barriers used in the questionnaire to provide granularity. These barriers 20 of which are presented in Table 2 (see Appendix 1) suggest the need for further investigation towards proposing effective interventions and support mechanisms to promote women's advancement in the construction sector. The following section describes the research methodology used in collecting the data required to answer the study objectives.

3. Research Methodology

The study employed a mixed-methods approach by combining primary data from structured questionnaires circulated among workers in various construction roles in South Africa and from Focus Group Discussions. The quantitative research approach allowed for objective analysis of perceptions of barriers and trends in women's career progression (Kothari, 2004; Creswell & Creswell, 2017), while the qualitative strand provided a more nuanced approach to understanding of the barriers to women progression in the industry (Kamberelis & Dimitriadis, 2013).

Sampling for the quantitative strand was conducted via a random sampling approach of 259 workers and professionals in the construction industry listed in the Professional Construction Register, Housing Development Association and Informal Builders Group via emails and self-administered questionnaires. A total of 199 completed surveys were obtained at the end of the survey period. The questionnaire featured closed-ended, open-ended, and contingency questions to facilitate data collection on perceived barriers, workplace culture, and professional experiences, while allowing for generating actionable insights. The data collected was analysed using descriptive statistics including Mean Item Score. The barriers are then ranked in descending order of their MIS to indicate their impact on adopting the technology. Mbachu and Cross (2015) illustrate the interpretation of the MIS and the rating of the various impact levels. This paper adopts this impact rating used by Mbachu and Cross (2015), highlighted in Table 1, in interpreting the MIS values obtained.

Table 1: Mean Impact Ratings – The interpretation of the MIS values as ordinal scale rating point (adopted from Mbachu & Cross, 2015)

Mean Impact Score	**Level of Impact of the Barrier in the Subscale**
MIS > 4.2 (0.84)	Very high impact; very significant barrier
3.4 < MIS < 4.2 (0.68 – 0.84)	High impact; significant barrier
2.6 < MIS < 3.4 (0.52 – 0.68)	Moderate impact; moderate barrier
1.8 < MIS < 2.6 (0.36 – 0.52)	Low impact; insignificant barrier
MIS < 1.8 (0.36)	Very low impact; very insignificant barrier

The focus group (see Cresswell & Poth, 2016) comprised a diverse mix of 25 participants, including 14 construction professionals, five CEOs of construction companies, three students, two educators and a media consultant who registered for a capacity building workshop in August 2024. The gender distribution featured 18 female and seven male participants. The discussions followed a presentation of the findings from the quantitative data collection and two other presentations titled Gender Equality and Education, and Employment in the Construction Industry. The discussions were collated and analysed thematically to identify the key trends and barriers.

Ethical considerations were paramount throughout the research, emphasizing informed consent, confidentiality, and participant rights. Ethics approval was received before data collection commenced. The next section presents the data obtained and the results of the data analysis, as well as a discussion of the implications of the findings.

4. Findings and Discussion

4.1. Background Details of the Survey Respondents

There was a predominance of female participation in the quantitative study: 125 females (62.81%) and 73

males (36.67%) participated. In terms of age distribution, the majority of respondents fell within the 35 to 44 age range, accounting for 84 individuals (41.38%); this was followed by the 45 to 54 age group comprised of 56 respondents (27.59%), suggesting that the sample is predominantly composed of middle-aged individuals. Geographically, the respondents were spread across various provinces, with KwaZulu-Natal having the highest representation of 53 participants (26.63%), followed by the Western Cape with 46 respondents (23.12%), indicating a diverse provincial representation.

Regarding academic qualifications, the largest group was comprised of individuals with diplomas, with 68 respondents (34.17%). This was followed by those with other qualifications, such as Matric Certificates (55, 27.64%) and vocational qualifications (20, 10.05%). Notably, 22 participants (11.06%) reported having no formal education, while 16 (8.04%) were apprentices. A few respondents held advanced degrees, including 17 with master's degrees (8.54%) and one with a PhD (0.50%). The data on years of experience indicated that 68 respondents (34.17%) had 0 to 5 years of experience, making this the largest group. This was followed by those with 6 to 10 years (51, 25.63%) and 11 to 15 years (48, 24.12%), suggesting a relatively young workforce. Regarding job positions, most respondents identified as directors (93, 46.73%), indicating a significant representation of senior-level professionals with adequate insights into the study problem.

The types of organizations represented in the survey varied, with micro-enterprises comprising the largest group of 69 respondents (34.67%), followed by small enterprises with 56 participants (28.14%), medium-sized enterprises with 25 (12.56%), large enterprises with 16 (8.04%), and 33 participants (16.58%) identified as "other," suggesting a diverse organizational landscape. Lastly, professional affiliations showed that a significant number of the respondents (78, 39.20%) did not belong to any professional organization. Among those who did, the most common affiliations were with the Association of Construction and Project Managers (ACPM) (15, 7.54%) and the South African Council for the Project and Construction Management Professions (SACPCMP) (14, 7.04%). It can be inferred from Table 2 that the data collected is obtained from a sample of predominantly female, middle-aged, and well-educated participants, with a significant representation of directors and individuals from micro and small enterprises with diverse experiences.

4.2. Barriers to Progression

The study sought to find out the perception of the respondents on the barriers impacting women's progression in the construction industry on a scale of 1 to 5, where 1 is very insignificant and 5 is very significant. The ten top and least ranked barriers out of the 46 proposed are presented in Table 2.

Table 2 shows that while all the top ten barriers were significant and that from a ranking perspective, Educational Expenses and Costs ranked as the most significant barrier with an MIS score of 0.76, followed by Male Domination and Lack of Representation, Ineffective Recruitment Programs, and Lack of Encouragement from Male Colleagues with the same MIS score of 0.75. Workplace Culture and Support Systems ranked equally at fifth place with an MIS score of 0.74. The responses also indicate that traditional views regarding women's societal roles hinder their career progression, and issues such as gender pay gaps (0.72), and the insecurity associated with short-term contracts (0.71) ranked lower but are perceived as significant barriers that affect long-term planning and stability for women in the construction industry.

4.3. Findings from the Focus Group Discussion

The following themes emerged from the Focus Group Discussion:

4.3.1. Gender Biases

Gender biases affecting women's advancement were a prevalent discussion point. A female CEO of a construction company noted that, "Women are often overlooked for projects simply because of gender biases; these norms need to be challenged." A male professional manager also stated that "women generally find it difficult to access construction due to gender biases, whether it is in business or in the office." According to him, it is rare to find new entrants in the construction industry, those those who have made it continue growing while those like us remain stagnant and in the same place."

4.3.2. Work-Life Balance Challenges

Several participants highlighted women's difficulties in juggling professional duties and family responsibilities. According to a male academic, "The construction industry is demanding, and for women, managing home life alongside work is a real struggle. Women need supported from the men in their lives." A female professional noted that "there is no counselling for women to motivate them, women can also do men's work."

4.3.3. Educational Gaps and Opportunities

There was a consensus for improved educational initiatives in construction-related fields to encourage female participation. A female Health and Safety practitioner noted that, "We need training, master classes and short courses." Another female professional stated, "In construction and building courses, there is no funding for people, especially women, to empower themselves and improve their living conditions,"

supporting the view that there is inadequate educational training and courses available for women.

4.3.4. Advocacy and Policy Changes

The group discussed the need for advocacy to promote women's representation at higher organization levels. According to a Male Media Consultant, "We need to build a space for force that accommodates women and helps them to demand their rights." The female CEO of an advocacy group noted that "Gender inclusivity in the industry should be non-negotiable" and "that the lack of policy implementers is a concern."

4.3.5. Utilization of Technology

Participants noted the importance of leveraging technology to enhance participation. "Creating a database of resources for women in construction could help in networking and connect them to jobs and opportunities (Female member of the South African Women in Construction). The Focus Group Discussion revealed a multifaceted overview of the barriers to female career progression in the South African construction industry. Key issues that surfaced include gender biases, work-life challenges, educational gaps and opportunities, advocacy and policy changes, and the utilization of technology.

4.4. Discussion of Findings

The study sought to identify the barriers women face regarding career progression in the South African construction industry. Findings indicate that while progress has been made in engaging women in the construction sector , barriers such as financial constraints, gender biases, work-life balance issues, and insufficient educational opportunities persist . The survey data reveals that educational-related expenses and costs are perceived as the most significant barrier to women's career progression in construction, with an MIS of 0.76. This indicates a pressing need for financial support systems that can alleviate the economic burdens women encounter when pursuing careers in construction. Additionally , male domination in supervisory and managerial roles is seen as a significant barrier to female career progression, reflected in the responses indicating an MIS score of 0.75 for the combined barriers and lack of encouragement from male colleagues. This aligns with the findings of the FGD and previous research by Kodagoda and Jayawardhana (2022), who identified a considerable disconnect between women entering the workforce and their representation in decision-making positions. This systemic undervaluation of women's contributions aligns with the documented gender discrimination in the literature, reinforcing that societal norms influence organizational behaviors and decisions (Norberg & Johansson, 2021)..

Barriers such as a highly competitive environment and institutional discrimination, each scoring an MIS of 0.74, indicate not only a hostile workplace culture but also reflect larger issues of gender inequality that persist in the industry. The survey findings are aligned with previous studies indicating that male-dominated organizational cultures often foster environments that make it difficult for women to thrive (Naoum et al., 2020). Work-life balance emerged as another key barrier during the FGD. Participants articulated the struggles of managing professional responsibilities alongside family duties, which aligns with previous studies by Oyewobi et al. (2019). The findings highlight the need for more flexible work arrangements and family-friendly policies in an industry known for its demanding schedules and rigid work environments (Lefrançois & Trottier, 2022).

The synthesis across all sources of data used reveals a narrative that highlights both progress and persistent barriers to the career progression of women in the South African construction industry. The intersection of these issues – rooted in gender bias, cultural expectation, finance and organization culture – shows that women's progress is inhibited by both structural (gender inequalities, educational access, organizational culture) and societal factors. For instance, traditional stereotypes, as observed in the literature and survey, significantly diminish women's aspirations and reinforces cultural biases against them.

5. Conclusion and Further Research

This paper investigates the barriers to female progression and trends in the construction industry using a mixed-method research approach. The study found that there are improvements in female representation and ownership in the South African construction industry. Despite these improvements , significant barriers-including financial constraints, gender biases, organizational structure, and work-life balance issues-persist and hinder female career progression. Based on these findings, the study concludes that positive changes in the organizational culture of construction companies, educational support, mentorship, and networking will foster an equitable work environment that enables women to thrive and contribute effectively to the construction industry.

The study recommends that construction companies implement policies to close gender pay gaps and introduce quotas for women in leadership positions; develop and support mentorship initiatives to guide women in career development and leadership competencies; and increase exposure for young women to construction career paths through funded educational initiatives and outreach programs in schools. The study fills a gap in the literature by providing empirical data on the key challenges women encounter, such as the cost of education, particularly in the South African context, where the representation of women in leadership roles remains low. Further research could investigate how technology can be leveraged to enhance female participation and career progression in the construction industry.

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Appendix 1

Table 2: Ranking of the Barriers to Female Career Progression

Barrier	Response %					MIS	RANK
	Insignificant…….……Very Significant						
	1	2	3	4	5		
Educational related-expenses and costs	8.18	6.36	20.91	27.27	37.27	0.76	1
Male domination in construction industry careers. Few female peers, supervisors and managers	9.01	10.81	17.12	20.72	42.34	0.75	2
Ineffective programs to attract women to challenging and competitive jobs and positions	9.26	8.33	18.52	24.07	39.81	0.75	2
Lack of encouragement from men	4.59	10.09	25.69	26.61	33.03	0.75	2
Highly competitive environment, being unwelcoming and lacking support	8.93	9.82	20.54	22.32	38.39	0.74	5
Explicit and implicit gender bias favouring men. Institutional discrimination	8.93	11.61	18.75	22.32	38.39	0.74	5
Lack of support networks, including career sponsors and professional groups	9.73	10.62	16.81	23.89	38.94	0.74	5
Lack of female mentors/role models, career counselling and supervision opportunities	9.73	10.62	18.58	21.24	39.82	0.74	5
Lack of strategies and policies for gender balance in construction-related fields	10.00	7.27	20.00	28.18	34.55	0.74	5
Lack of access to vocational construction-related training and development opportunities	10.00	8.18	20.00	26.36	35.45	0.74	5
Difficulty in finding work-life balance. Lack of flexible work conditions	14.04	8.77	21.05	32.46	23.68	0.69	40
Lack of encouragement and support from family members and friends/peers	12.73	10.91	22.73	23.64	30.00	0.69	40
Queen bee syndrome in the workplace: women competing and hindering other women	7.89	15.79	32.46	17.54	26.32	0.68	42
Women are perceived with lower physical and mental abilities	19.30	8.77	15.79	24.56	31.58	0.68	42
Women being discourages or dismissed from managerial and leadership positions	14.29	16.07	17.86	23.21	28.57	0.67	44
Lack of personal interest in construction-related fields	16.81	9.73	21.24	24.78	27.43	0.67	44
Lack of self-confidence about skills and abilities	16.96	8.93	25.00	21.43	27.68	0.67	44
Lack of supportive facilities I the working environment (e.g. creche, single-sex toilets)	12.17	14.78	23.48	25.22	24.35	0.67	44
Lack of confidence to apply for positions and promotions	18.02	9.01	21.62	25.23	26.13	0.66	45
Construction-related courses are difficult	18.92	9.91	28.83	21.62	20.72	0.63	46

ACADEMIC PAPERS: THEME 8 - INFRASTRUCTURE DEVELOPMENT

Investigating Underutilization of the Municipal Water Infrastructure Grant (MWIG) in Leekwa-Teemane Local Municipality (LTLM)

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Abstract

Access to potable water and sanitation remains a pressing issue in South Africa, where 3 million people lack clean water and 14 million lack adequate sanitation. Informal settlements and rural areas are disproportionately affected due to ageing infrastructure, insufficient investment, and poor governance. This study aims to investigate the challenges hindering Leekwa Teemane Local Municipality (LTLM) from leveraging the Municipal Water Infrastructure Grant (MWIG) to address water infrastructure backlogs. Using a qualitative methodology, the research analyses documents, conducts stakeholder semi-structured interviews, and explores a case study to identify institutional, financial, and operational constraints. Interviews were conducted with key stakeholders who are involved in infrastructure grant spending, with questions addressing expenditure, rate of project completion, and other significant challenges faced by the municipality. The findings indicate that inadequate planning, limited technical capacity, and complex grant application processes are the primary obstacles faced by LTLM. The study concludes with actionable recommendations to streamline grant processes by enhancing technical capacity and improving accountability mechanisms. These insights provide strategies for LTLM and similar municipalities to overcome barriers, ensuring the delivery of essential water infrastructure.

Keywords: Basic services, Government, Infrastructure Funding, Municipal Grants, Service delivery

1. Introduction

In South Africa, the provision of basic services like water, electricity, and sewerage remains a critical challenge, essential for realising fundamental human rights (Maluleke, 2024). Poor municipal service delivery, often due to inadequate infrastructure caused by limited maintenance and slow development of new systems, contributes to this failure (Maluleke, 2024). Funding constraints have been identified as a significant barrier to improving infrastructure (Mazele & Amoah, 2022). To address these challenges, the South African government introduced Conditional Infrastructure Grants to support municipalities in delivering the infrastructure needed for basic services. However, the ineffective utilisation of these grants has been reported (Mazele & Amoah, 2022).

A thriving economy relies on municipalities creating environments conducive to business operations. Without this, opportunities for residents diminish, leaving municipalities with indigent populations reliant on public support rather than contributing to the municipal fiscus (Balie, 2020).

This research focuses on the underutilisation of the Municipal Water Infrastructure Grant (MWIG) in the Lekwa-Teemane Local Municipality (LTLM). Building on existing knowledge is fundamental to academic research (Snyder, 2019). This literature review examines South Africa's infrastructure landscape to identify gaps and explore solutions to improve the use of conditional infrastructure grants, particularly MWIG.

By synthesising studies, the review aims to provide insights into technical, social, and environmental factors influencing water access, quality, and management in the country. It seeks to propose strategies for increasing grant utilisation and addressing infrastructure challenges in municipalities like LTLM. Assistance in maintaining and developing water infrastructure is critical to improving service delivery and economic opportunities in the municipality.

LTLM is identified as a good municipality to conduct the case study to determine what barriers are preventing the municipality and similar municipalities from utilising conditional infrastructure grants, particularly the Municipal Water Infrastructure Grant (MWIG), to supplement the income required to outlay water infrastructure projects. These conditional infrastructure grant funding targets service delivery priorities.

2. Literature Review

Previous studies on the MIG indicate the types of challenges faced by municipalities. A study that addresses the barriers preventing the Ba-Phalaborwa municipalities from receiving and effectively utilising conditional infrastructure grants, with a specific focus on the Municipal Infrastructure Grant (MIG) in South

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Africa. It aims to identify the challenges and factors hindering the receipt and utilisation of these grants by municipalities, contributing to gaps in infrastructure development and service delivery (Rangwato, Mukonza & Molepo, 2022). The study focuses on understanding the dynamics and complexities surrounding the utilisation of these funds within municipalities, with implications for infrastructure development and service delivery, utilising a mixed-methodology approach, combining qualitative and quantitative data collection methods (Rangwato et al., 2022).

Further studies by Hostetter, Bolding and van Koppen in 2020 address the failure of water infrastructure delivery in low-income rural South Africa. Despite progressive policies and a legal framework from the Government, ensuring the right to sufficient water, significant problems with water service delivery in these areas, highlighting a gap between policy intent and actual implementation. The study provides an understanding of water service delivery challenges in low-income rural areas of South Africa. Researchers analysed the implementation of policies to examine the four phases of public water services delivery: identification, planning, construction, and operation, to understand the challenges and shortcomings in infrastructure delivery and the underlying factors contributing to these challenges (Hofstetter, Bolding & Van Koppen, 2020). The Authors analysed the four phases of public water services delivery (identification, planning, construction, and operation) in the Sekhukhune District. They conducted a thorough analysis of accountability relations between service delivery agencies and end users, focusing on factors such as gatekeeping and patronage that undermine accountability. The study found that practices often deviate from stipulated policies during the various phases of water service delivery (Hofstetter, Bolding & Van Koppen, 2020). Accountability relations between service delivery agencies and end users were undermined by gatekeeping and patronage, contributing to infrastructure delivery failures (Hofstetter, Bolding & Van Koppen, 2020). The study contributes to the existing research on water infrastructure challenges in South Africa. It provides insights into potential strategies for improving service delivery and addressing barriers preventing municipalities from effectively utilising conditional infrastructure grants.

Another article by O'Brien, O'Neill, and Pike in 2019 seeks to understand further and explain the funding, governance, and financing of urban infrastructure**.** Contributing to the knowledge on the funding, governing and financing of urban infrastructure in a contemporary period of financialisation internationally. Empirical data were collected from case studies conducted worldwide, including Europe, Africa, Asia, and North America, with Policies surrounding infrastructure funding not addressed in the paper being a limitation (O'Brien, O'Neil and Pike, 2019). This article allows the authors to identify the relationship between infrastructure funding, finance and governance and where the shortfall may lie in ensuring infrastructure projects are delivered effectively.

Studies by the Development Bank of Southern Africa (DBSA, 2024) identified key challenges in municipalities, including inadequate infrastructure, limited resources, and poor maintenance, which hinder basic service delivery and halt progress. Research on municipal infrastructure grant spending in Ba-Phalaborwa Municipality highlights barriers such as poor municipal governance and inefficiencies in utilising conditional grants, offering strategies to enhance fund utilisation and improve service delivery outcomes (Rangwato et al., 2022). Hofstetter et al. (2020) revealed that deviations from policy during water service delivery phases undermine accountability through gatekeeping and patronage, further contributing to infrastructure failures. Ramokgopa (2021) identified a funding and technical gap in South Africa's infrastructure delivery. Key findings included reduced infrastructure budgets to manage rising national debt and the government's reluctance to use Development Finance Institutions due to loan conditions. The study stressed the need for a larger role for DBSA and IDC in project execution while concluding that Public-Private Partnerships (PPPs) are ineffective. Future avenues that need further investigation were identified, namely, identifying exactly how revenues are generated from infrastructure assets, specifying the relations of financialisation with other processes such as "assetisation", marketisation and privatisation (O'Brien, O'Neil and Pike, 2019)

3. Research Methodology

This paper employs a case study to determine the findings. It employs an interpretivist research philosophical approach, which emphasises understanding social phenomena through subjective experiences such as interviews, context such as journal articles, audit reports, and conference papers, and meanings. Interpretivism recognises that knowledge is socially constructed and influenced by cultural norms, historical context, and personal experiences. Researchers actively engage with participants, valuing their insights and allowing for flexible research design (Pervin and Mokhtar 2022).

Qualitative research methodology is used in this study, where specific content and data are collected and analysed through a purposive sampling methodology through semi-structured interviews conducted on the targeted population, i.e., key municipal employees with exposure to conditional grant information within the LTLM. The data and content collected will be analysed to identify patterns in the responses. The aim is to

uncover the nature of conditional infrastructure grants, water infrastructure failures in South Africa, Government infrastructure maintenance programs, municipal employees' understanding and knowledge of conditional grants and the allocation of conditional grants in South Africa. Understanding the factors contributing to the under-utilisation of the MWIG in LTLM is crucial to understanding how stakeholders in the LTLM interpret the MWIG funding process and uncovering the underlying issues.

Data collection and research were conducted with a focus on ensuring consent, confidentiality, voluntary participation, agreed access, and the sharing of accurate, plagiarism-free, and ethically sound results. While participants did not specifically request anonymity, it was also respected. The methods of collecting data in this study can be separated into two parts. The first step was the collection of data in the form of document analysis, which included journal articles, policy documents, legislation, government gazettes, etc., on municipal water infrastructure funding and conditional infrastructure funding were purposely selected and analysed to understand the reasons for municipal underutilisation of grant funds when there is a clear need. Secondly, data was collected through semi-structured interviews conducted with municipal employees from various levels within the structures on funding policies and procedures. The interview was designed to determine the barriers preventing the municipality from utilising the MWIG grant. The questions were formulated and targeted at the key stakeholders within the LTLM who deal with infrastructure grant funding.

Interview data were collected from eight participants at the LTLM office based in Bloemhof.

I. Two participants from Technical Services.
II. Two participants from IDP (Integrated Development Plan).
III. Two participants from Finance.
IV. Two participants from the Office of the Municipal Manager.

This research has a cross-sectional time horizon, as we are limited to collecting data at a single point in time. The research will provide information on the current state of utilisation of the municipal water infrastructure grant in the Leekwa-Teemane Local Municipality. The approach involves collecting data from the municipality to determine their understanding of the municipal water infrastructure grant through conducting interviews with identified stakeholders. Key activities in our time horizon include literature review, research scoping and design, stakeholder identification, data collection and data analysis.

The research covers municipal expenditure and finances, which may be linked to political influence in the day-to-day running of the municipal finances. Due to this, the research involves ethical considerations such as ensuring confidentiality of sensitive information, obtaining informed consent from participants, and maintaining objectivity and transparency in data collection and analysis, after all "all researchers have good intentions, but if they are not careful, their studies can place individuals in situations that involve risk." (Gall, 1996). Ethical risks also include potential conflicts of interest and ensuring that recommendations prioritise the well-being of communities. The researchers applied for ethical clearance from the university's ethics committee. The application outlined our intended approach to obtain the data, including, amongst others, the inclusion of presenting consent forms to the participants, ensuring anonymity and that the answers would only be used for academic purposes for this research.

4. Findings and Discussion

Empirical research involves the case study conducted in the Leekwa-Teemane Local Municipality in the Northwest Province. The research focused on the municipality's current water infrastructure challenges. Notably, during the period of the interviews conducted, the municipality was experiencing water issues. The sample size was eight participants, and we received eight respondents, as there is a limited number of employees dealing with the administration of infrastructure grants in the municipality.

The research established that Lekwa-Teemane Local Municipality currently relies on the district municipality for all its funding, which includes infrastructure funding. LTLM falls under the Dr Ruth Segomotsi Mompati District Municipality, and the district municipality facilitates all funding received by LTLM on behalf of the local municipality. The process starts with LTLM, together with four other local municipalities within the district municipality, submitting an application in the form of a business plan to the district municipality for funding. The district municipality then makes a consolidated application to the treasury department. Each application is dealt with on a case-by-case basis. In terms of priority, this means that not all the applications will be approved, and the district municipality will allocate funds based on priority. Further to that, the district municipality will deduct an administration fee from the funds, meaning the local municipality will receive less than what they originally applied for.

Additionally, LTLM has never applied for MWIG grants, as it is not aware of any such grant. LTLM, however, does have experience in applying for MIG funding through the district municipality, where there have been no recorded technical or administrative challenges in applying for this grant. This is due to the

existing cordial relationship between the municipality and the application agents it utilises.

With regards to the current state of water infrastructure, much of the reticulation water infrastructure is obsolete. It consists of the old asbestos piping, which has been banned as a building material for its harmful properties and effects on human beings. LTLM needs funds to replace these old asbestos pipes with safer, newer pipes. LTLM, like the rest of the country, is facing population growth, which further puts strain on the existing water infrastructure, so it needs additional funds for expansion and maintenance.

LTLM does not engage the national government directly and relies on Dr Ruth Segomotsi District Municipality to communicate any issues they are experiencing. This has been raised as a challenge by LTLM, as they feel the brunt of the restless community members, even though the failures to deliver on basic services can be attributed to the district municipalities.

The local municipality employs traditional procurement strategies for all its infrastructure projects, which means that an engineering consultant company will be appointed to provide stages 1 to 6 engineering services, and the contractor will be appointed through an open bid process.

Lastly, like any other government institution, the LTLM faces high employee turnover for reasons such as low-income family and living environment, local employment quotas, career growth prospects and political interference in certain positions, to name a few.

5. Conclusion and Further Research

The study identifies several factors contributing to the underutilisation of the Municipal Water Infrastructure Grant (MWIG) in LTLM. Municipal staff lack awareness of MWIG and conditional infrastructure grants, while high staff turnover in the Technical Services department and significant vacancies in the IDP unit exacerbate the issue. Additionally, the responsibility for initiating projects and applying for grant funding lies with the District Municipality, limiting local action. Provincial funding to local municipalities is reduced by administrative fees imposed by the District Municipality. These challenges, coupled with the dire state of water infrastructure and ongoing water shedding, highlight the urgent need for improved staffing, awareness, and funding mechanisms.

Based on the study's findings, it is recommended that the municipality prioritise filling vacancies in Integrated Development Planning (IDP) units and focus on retaining technical staff to ensure continuity and expertise. The Municipal Infrastructure Support Agency (MISA) should increase awareness about available infrastructure grants to help municipalities access these funds. Continuous professional development (CPD) and training on infrastructure grant funding must be provided to municipal staff. Additionally, responsibilities for project initiation, funding applications, and implementation should be assigned to local municipalities rather than district municipalities, enabling faster decision-making and better responsiveness to community needs.

The study has several limitations, which include time constraints. There was limited time to interview the different departments within the municipality, and only focused on the government departments related to the infrastructure project plan, which are the IDP department and the technical services department. The study also did not investigate the role of other spheres of government in the utilisation of the infrastructure grants. Additionally, this research faces time limitations in conducting comprehensive public interviews. Engaging with residents is crucial to understanding the on-the-ground impacts of water infrastructure, but time constraints have restricted public engagement. This limitation could result in a narrower perspective on community concerns and satisfaction with current water services, potentially omitting valuable insights from residents in more remote or underserved areas.

There are also time constraints on thoroughly investigating the current condition of LTLM's water infrastructure. A detailed examination of existing facilities would provide insights into maintenance needs, structural issues, and areas requiring urgent upgrades. The investigation would assist in determining the extent of the infrastructure funding required. Political priorities, pressures, and agendas can directly impact how funds are allocated, potentially favouring specific priorities or areas based on political affiliations or electoral considerations rather than objective need. The study has not investigated the role of politics in the funding application process.

By investigating the barriers hindering the effective and efficient utilisation of MWIG, the researchers aim to provide valuable insights to municipalities. The findings can help educate municipalities about the availability of conditional grants, such as MWIG, which can supplement existing funds required to complete water infrastructure projects. Once informed, municipalities can apply for and access these grants, enabling them to develop or maintain essential water infrastructure and enhance service delivery to their communities.

Future research stemming from this study has the potential to address critical gaps in understanding and implementation related to infrastructure grant utilisation. These studies could focus on building staff

capacity within municipalities, comparative analyses of grant allocation models, and the broader socio-economic impacts of infrastructure improvements. Such research would not only contribute to academic knowledge but also provide actionable insights to policymakers and practitioners, fostering more efficient and equitable infrastructure development and service delivery.

6. Acknowledgement

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Critical Review of the Challenges of Financing Renewable Energy Development in Sub-Saharan Africa

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Abstract

There is an acute shortage of electricity supply in Sub-Saharan Africa (SSA), and electricity blackouts are a common occurrence. Climate change and carbon dioxide gas emissions from conventional power-generating systems are also of great concern. Africa has vast renewable energy resources, including hydropower, solar, wind, biomass and geothermal, which are relatively unexploited. Based on a literature review, this study aims to identify the factors that hinder investment in renewable energy development in SSA. The review finds that barriers to renewable energy development include fragmented electricity markets, utilities with poor balance sheets and low credit ratings, high energy transmission losses, political risks, high initial capital costs, poorly directed subsidies, insufficiently developed money markets, and a poor regulatory framework, The study also finds that the global utility-scale levelized costs of electricity from renewable energy resources compare favourably with that of conventional sources. Countries in SSA need to draw up a clear policy framework with legally binding targets for the contribution of renewable energy to the energy supply portfolio. In addition, subsidies currently enjoyed by conventional energy generators need to be restructured to target low-income groups. SSA countries should identify pipelines of suitable renewable energy projects, complete feasibility studies and invite potential developers. Risks faced by international investors in renewable energy projects, including political, commercial and financial risks, are insurable. An important consequence of this work is that it is possible to accelerate innovative financing solutions to ramp up investment to deliver energy for all.

Keywords: Finance, Renewable Energy Development, Risk Management

1. Introduction

The United Nations Paris Agreement seeks to limit global warming to well below 2 degrees Celsius compared to pre-industrial levels. Achieving this goal requires all countries to take action to reduce greenhouse gas emissions (GHG). In Sub-Saharan Africa (SSA), there is also emphasis on climate-related capacity building to enable these countries to address these challenges. Since the Paris Agreement came into force, there is now a whole range of low-carbon technology solutions and new markets, particularly in the energy and transportation sectors. Zero-carbon solutions are now competitive with traditional technologies in many sectors. Renewable energy technologies have reached sufficient maturity and constitute sound investment opportunities that provide nations with the opportunity to reduce global warming. Africa's contribution to greenhouse gases on a per capita basis is much smaller than that of developed countries. However, African countries are more likely to be disproportionately affected by the impacts of climate change (Agyekum et al., 2021). The United Nations Sustainable Development Goal 7 calls for universal access to modern energy services for all by 2030.

Furthermore, Agenda 2063 of the African Union seeks to create a prosperous Africa with renewable energy development as one of the priority areas (African Union, 2015). At present, 789 million people in the world do not have access to electricity. Of these 648 million (or 69%) live in Sub-Saharan Africa. Over 900 million people in Sub-Saharan Africa do not have access to clean cooking (Ireri and Shirley, 2021). Most families rely on biomass in the form of charcoal for cooking. This leads to land degradation, indoor pollution and respiratory diseases. Forty per cent of the population in Sub-Saharan Africa lives on less than USD 1.90 per day, which approximates to 433 million people. Excluding South Africa, the energy consumption per capita in Africa is 180 kWh annually compared to 6,500 kWh in the EU and 11,500 kWh in the USA. It is estimated that Africa needs a capital investment of USD 100 billion annually until 2040 (KfW Development Bank, 2020) in the energy sector. Africa has seen low levels of investment in the energy sector compared to other parts of the world because of the higher levels of risks perceived by international investors (Bashir et al, 2024). Meeting this financing challenge requires contributions from all possible sources. This paper provides an overview of the renewable energy resources in Sub-Saharan Africa. It outlines the barriers and challenges of financing renewable energy expansion in Sub-Saharan Africa, followed by a policy framework that can help to de-risk renewable energy projects and scale up investment.

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2. Research Method

The overall aim of the study is to identify the factors that hinder public and private sector investment in renewable energy development in SSA. Furthermore, the study aims to develop effective intervention strategies to improve energy access. The study seeks to highlight the options available for countries in SSA to improve the investment climate to attract investment into renewable energy projects. Six research questions, namely, guide the study:

1. What is the overall economic case for renewable energy in the context of SSA?
2. What are the current attitudes of the multitude of actors in SSA, including policy makers, homeowners, industry, market operators and investors, towards renewable energy development?
3. What are the biggest challenges to scaling up renewable energy investment in SSA?
4. What are the most challenging risks and uncertainties faced by investors and developers for renewable energy investments?
5. What lessons can we draw from countries that have successfully upscaled investment in solar energy?
6. What package of policies and incentives could make a significant impact and breakthrough to stimulate widespread adoption and investment in renewable energy in SSA?

This paper reports preliminary findings from the literature. A systematic review was undertaken starting with the identification of peer-reviewed journals and conference papers, books, theses, dissertations and academic reports. The literature was identified through electronic search engines, including Google Scholar, Scopus, Science Direct, and ProQuest. The search terms used were finance, Sub-Saharan Africa, and renewable energy. The search terms were combined with the terms challenges, barriers, and potential solutions to narrow down and identify relevant academic literature. Non-academic literature, such as social media reports, newspaper articles, and unpublished reports, was excluded from the study. Other non-scholarly literature, such as blogs, wikis, tweets or other social media content, was excluded.

3. Renewable Energy Resources in Africa

Africa has vast renewable energy resources that remain untapped. This includes solar, geothermal, hydropower, biomass, and wind. The share of renewable energy in power generation in Sub-Saharan Africa was 29% in 2019. This is comprised of 24% hydropower and 5% other renewable energy sources (IRENA and AfDB, 2022). Therefore, the role played by non-hydro renewable energy resources in electricity supply in Africa has been at best marginal.

3.1. Solar Energy

Africa, as a region, has excellent solar energy potential. It is estimated that many parts of Africa receive a daily solar radiation of 4-6 kWh/m^2. Solar power can also be deployed in a decentralised manner, even in rural and remote areas of Africa. The two technologies currently employed for solar energy are solar PV and concentrated solar power (CSP). Over 95% of solar energy that is currently generated utilises solar PV technology. Only 5% of the power is based on CSP. The potential for solar PV technology is widely distributed across Africa. The potential for CSP is found mainly in the desert areas as dry air is required (Komendantova et al, 2012). If African countries could develop the right policies, the learning curve and the associated reductions in cost could see solar energy play a pivotal role in their energy supply. The only challenge that solar PV energy supply faces, particularly in off-grid solutions, is the cost of batteries, which remains high. In desert areas of North Africa, solar PV and CSP systems could play a bigger role in water desalination because the intermittency of energy supply is not an issue. Solar energy in Africa has great potential and a vast positive impact on all elements of sustainability, including social, economic, technical and environmental dimensions (Maqbool and Akubo, 2022).

3.2. Wind Energy

The potential for wind energy in Africa is enormous. In terms of distribution, wind energy resources are found mainly in the coastal areas of Northern, Eastern and Southern Africa. In these areas, wind is the cheapest form of energy in the absence of hydropower. One of the most significant challenges facing the development of wind power in Africa is the operations and maintenance of wind turbines. There is a lack of technical expertise and sufficient financial resources to ensure regular maintenance. By their nature, wind turbines require higher levels of maintenance compared to other forms of renewable energy generation. The countries with the most significant potential for wind power generation include Chad, Cape Verde, Sudan, Kenya, Madagascar and Mauritania. Countries with the most considerable installed wind power at present include Egypt, Morocco, Tunisia and South Africa. Wind energy development in Africa faces technical, economic, competition, and policy challenges. Provided suitable policies are developed, wind power in Africa can transition from a small-scale industry to large-scale commercial developments (Boadu and Otoo, 2024).

3.3. Geothermal Energy

Geothermal energy originates from the Earth's volcanic activity. Underground temperatures generally increase with increasing depth at a rate of 30 degrees centigrade per kilometre. The advantages of geothermal energy are that electricity production is continuous and can therefore serve as a baseload technology. It is reliable,

cost-effective and renewable. The most significant potential of Africa's geothermal resources is mainly found in the East African rift valley. The Western Rift Valley extends from Uganda to Mozambique, and the Eastern Rift Valley, where volcanic activity is most intense, extends from Ethiopia to Kenya, where fluid temperatures above 200 degrees centigrade can be found. In this region, the direct use of steam to produce electricity is possible. Only Kenya and Ethiopia have made some efforts to exploit geothermal energy. In Kenya, one IPP has been constructed with a capacity of 250 MW (Oluoch et al., 2024). More geothermal plants are planned, and by 2050, Kenya expects to generate 5,000 MW of electricity from geothermal energy (Olando et al, 2024). The total technical potential of geothermal energy in Africa is 105 TWh/year, and it is all located in East Africa (IRENA, 2020). Development of geothermal energy in Africa will depend not only on adequate heat resources but also on adequate finances (Moore et al., 2025).

3.4. Biomass

Biomass is an important source of energy in Africa. Biofuel in the form of charcoal is widely used for cooking and heating in many parts of Africa. It is easier to store; it has a high energy content and low levels of smoke emissions. It is the primary source of fuel for the urban and rural poor. Production of charcoal is a significant source of employment, but it is responsible for the destruction of trees and forests, unless fast-growing varieties of trees are used. Bioenergy is also an important source of renewable energy in the form of wood pulp residues and sugar cane bagasse. Bagasse accounts for the bulk of bioenergy installed capacity in Africa. The technical potential of bioenergy in Africa is currently estimated at 2,374 TWh/year, although the current electricity generation of biomass power projects in Africa is negligible (Namaswa et al, 2022). This potential is substantial, particularly in Central Africa, and represents the opportunity to provide a renewable electricity supply. The principal attractions are the low bioenergy feedstock costs compared to other parts of the world. However, the availability of feedstock in sufficient quantities to make electricity production attractive is a challenge, given that large-scale farming in Africa is rare.

4. Hydropower Potential in Sub-Saharan Africa

Africa has a huge hydropower potential, and estimates suggest that only 10% to 20% of it has been developed. Most countries in Eastern and Southern Africa depend heavily on hydropower. For example, the share of hydropower is Ethiopia (90%), the Democratic Republic of Congo (95%), Zambia (85%) and Uganda (83%). It is small in other countries such as South Africa, Zimbabwe and Mauritius, where electric power is generated mainly from thermal energy, including coal (IRENA, 2022). Hydropower is a clean and renewable, emissions-free electricity-generating technology. However, hydropower plants are capital-intensive. The silting of dams over time and periods of drought can reduce the available head and the amount of power generated.

Hydropower projects are divided into two categories, namely: large hydro (greater than 10 MW) and small hydro (Less than 10 MW). The typical cost structure of developing a hydro power plant includes hydro-technical construction (60%), turbines (25%), electrical equipment (10%), buildings (5%), and exploration and other costs (0.5%). Africa has the potential to generate 350,000 MW of electricity from hydropower alone. Hydropower will be an essential contributor to the future energy mix in Africa. It can be used to provide a base load and to smooth out the intermittency of other renewable energy sources. The main reason for the current low level of hydropower development is access to finance. The perceived levels of high risk by international investors have also driven low levels of investment. The other reason is that tariffs in many countries are political decisions and do not reflect the market costs of generation, transmission and distribution of electricity. There is an urgent need in many countries to develop regulations and a policy framework that is transparent and fair. An energy pricing system where charges reflect the production costs of electricity is necessary to attract private sector investment. As the technology of hydropower production is proven, raising private sector investment in hydropower should be straightforward, provided appropriate risk mitigation strategies are implemented.

5. Unit Costs of Renewable Energy Generation

The falling costs of renewable energy generation recorded in recent years present the opportunity to unlock this potential. Compared to other power generation sources such as nuclear or fossil fuels, the construction of solar and wind power generation has short construction lead times, and so implementing these technologies could fast-track access to an electricity supply. The estimated global levelized cost in USD/ KWh of utility-scale electricity power generation from various renewable energy sources is as follows: Bioenergy (0.067), Geothermal (0.068), Hydropower (0.048), Solar PV (0.048), Concentrating Solar Power (0.114), Onshore Wind (0.033), Offshore Wind (0.075) (IRENA, 2022).

This data indicates that the financial and economic viability of renewable energy generation is now well-established and competes with conventional technologies. Given the low costs of hydropower, solar PV and onshore wind technologies, African governments must focus on removing institutional barriers and developing a pipeline of renewable energy projects to make progress. The costs of renewable

energy generation depend on the technology employed. Power generation costs are also influenced by the quality and availability of the energy resources, the project details and the specific site. The costs of project implementation in Africa are also higher than in other countries because of additional transportation costs and import duties. Economies of scale are important in power projects. Large projects are generally cheaper per kWh. There are also skills gaps for operations and maintenance. In the next section, the barriers to renewable energy development in SSA and potential solutions are discussed.

6. Barriers to Renewable Energy Development in Africa and Potential Solutions

6.1. Structure of Electricity Markets in Sub-Saharan Africa

The economic case for the development and expansion of renewable energy in Africa is strong. Feasibility studies need to be conducted for specific locations, projects and technologies. For rural populations in Africa without access to electricity, grid extension to rural areas is encouraged. However, electricity markets in many countries in Africa are still relatively small, and so utility companies do not benefit from economies of scale. A significant proportion of people, particularly in rural areas in Africa, also live subsistence livelihoods. Thus, extending electricity to rural areas requires governments to address affordability concerns. This is part of the reason why many developing country governments in Africa have favoured rural electrification strategies rather than the development of renewable energy. Thus, providing access to electricity must be addressed in tandem with poverty eradication and other programs that seek to raise household incomes in rural areas (Sachs, 2015).

The other challenge in electricity supply, particularly in SSA, is the large gap between electricity demand and the available generating capacity. The overall state of the generation, transmission and distribution infrastructure is old and therefore requires investment and modernisation to improve efficiency and reduce power losses. Many countries in Africa suffer from electricity blackouts due to load shedding, particularly during peak demand periods. Generation of electricity from petrol or diesel generating plants is expensive but commonly employed to meet this shortfall. Electricity tariffs in many African countries do not reflect the market costs of production. Electricity markets have had to be liberalised in many countries in order to attract private investment. Market liberalisation has therefore necessitated an increase in prices to reflect market production costs. Unbundling of generation, transmission and distribution also means that terms of access to the transmission grid can be developed and provided to private Independent Power Producers (IPP) without conflicts of interest. Reforms of the energy market, including privatisation, can also be implemented to improve efficiency and competition in power generation. Removal of electricity subsidies can assist the general economy in delivering sound public finances.

Setting up an independent electricity regulatory agency is also an important step in the liberalisation of the electricity market. This means that regulatory policies can be developed, applied and enforced transparently, leaving the role of government to be policy development and execution. Development of broad energy strategies coupled with ease of access to the electricity transmission grid, competition in the generation and distribution of electricity can encourage Independent Power Production (IPP) companies to participate in renewable energy generation. Unfortunately, earlier reforms in the electricity market in SSA led to increased use of fossil-based generation rather than renewable energy generation because of the cost advantages of conventional energy. This needs to be addressed in energy reforms to encourage the uptake of renewable energy.

In summary, conventional energy-generating projects in the past have scored better than renewable energy projects based purely on the financial profile of such projects. This is no longer the case. Renewable energy projects are competitive in their own right. Their competitiveness improves further when their environmental and social benefits are factored in. Renewable energy projects can be developed in an off-grid and modular manner, particularly in rural areas, which should also prove attractive for improving energy access for the rural poor.

Finally, developing countries should develop the electricity market reforms and include a practical regulatory framework to encourage private sector IPP companies to invest in renewable energy. The market for the electricity generated can be guaranteed through feed-in tariffs, tax incentives, and subsidies. Provided that the private sector has guarantees of an adequate legal and regulatory framework coupled with sound, consistent policies, this will attract private sector funding to enable scale-up of investment into renewable energy projects.

6.2. Policy Reforms Required in Developing Countries

Renewable energy projects generally have high capital costs but low operating costs compared to conventional energy projects. Investing in Africa also attracts considerable country, regulatory, commercial and market risks. Capital markets in Africa are underdeveloped, and bond markets are illiquid. The perception of high risks in Africa increases the cost of capital required by investors in renewable energy projects. Renewable energy projects also tend to be smaller. Thus, transaction costs per kWh are much

higher than for conventional projects. The lack of data on wind speeds or solar insolation means that it takes much longer to complete feasibility studies. The lack of relevant data to inform economic feasibility, decision-making, siting, planning and financing decisions increases the risk and uncertainty faced by potential investors.

Fossil fuels attract considerable subsidies in developing countries, including tax breaks, research and development grants, fuel price guarantees, etc. This puts financing of renewable energy projects at a competitive disadvantage compared to conventional energy projects. Subsidies lower the costs of power generation from conventional means. Developing country governments in SSA should, as a matter of urgency, set out a clear vision for the contribution of renewable energy in the total energy mix, where this has not been done. Setting out clear and legally binding national targets demonstrates commitment, political will and determination. This assures private sector investors that the national authorities have a clear trajectory towards green electricity.

Developing country governments should also gradually phase out subsidies that are enjoyed by electric power-generating companies using fossil fuels. Switching fossil fuel subsidies to renewables is justifiable as renewable energy projects bring social and environmental benefits. Removal of subsidies needs to be implemented in a manner that does not disadvantage poor members of society (Menyeh et al., 2021). Removal of subsidies will also encourage energy efficiency in use and conservation. Removal of fossil-fuel subsidies can be controversial and poses a political challenge for most governments in SSA, as many stakeholders, including high-income groups, benefit from subsidised energy costs. Therefore, any reforms need effective planning, strong communications and civic engagement to ensure that they are gradual, socially and economically fair and are generally acceptable to the public.

Alongside renewable energy targets, governments should also set out clear feed-in-tariffs for renewable energy producers. Offering a guaranteed fixed price with a premium above the market production costs provides an output-based incentive for large-scale Independent Power Producers (IPPs). This can enhance the profitability of the project and increase returns on investment. The setting of feed-in-tariffs reduces the uncertainty associated with energy prices and revenues and improves project bankability. Although over 30 countries had feed-in-tariffs in 2010, only four of them were in sub-Saharan Africa and included Uganda, Kenya, Tanzania and Mauritius. By 2021, only fourteen countries in Africa had feed-in-tariffs. Even then, these had not been successful in delivering increased investment into renewable energy projects because of a weak regulatory framework.

Many electricity utility companies in developing countries are publicly owned. Governments should set out clear and mandatory targets for utility companies to supply a given proportion of their electricity from renewable sources as a regulatory requirement. Provided that there is transparency and competition in the awarding of contracts for renewable energy projects, auctions and feed-in-tariffs, together with efficient procurement systems, are an essential prerequisite for attracting private sector capital into renewable energy generation.

6.3. Financial Risks and Effective Mitigation Strategies

Investors in renewable energy projects in SSA face several risks, including political risks, currency risks, and commercial risks. Commercial risks arise from the fact that state-owned utilities often have poor balance sheets and credit ratings. Their credit payment obligations under power purchase agreements cannot be guaranteed. Poor balance sheets and credit ratings result from poor billing and payment collection systems, and prices that do not reflect the market production costs of energy. Country and political risks include the risks of government expropriation, war and civil disorder, and breach of contract. These risks feature highly when international investors are making location decisions for foreign investments. International investors also rank prevailing legal systems and independence of the judiciary highly, as they need confidence that commercial contracts will be enforceable in the event of default. Foreign investors in renewable energy projects also face currency risks, including fluctuations in interest rates and foreign exchange risks. If development capital is borrowed from international money markets and designated in hard currency, investors face risks if revenues are designated in local currency. Money markets are not well developed in SSA, implying that hedging instruments involving local currencies may not be readily available.

Other risks include expropriation of funds or nationalisation of assets by developing country governments. Governments may also fail to honour their contractual obligations. Clauses seeking dispute resolution through international arbitration tribunals should be incorporated in any contracts. Investors also need to protect their investment from losses arising from war, terrorism and civil disturbance. They also need guarantees against currency transfer restrictions and currency inconvertibility. Finally, governments may fail to honour their financial obligations or default on honouring guarantees provided to investors. Fortunately, all these risks are insurable through the Multilateral Insurance Guarantee Agency (MIGA) of the World Bank Group. The World Bank has operations in many developing countries, and it is therefore well diversified to mitigate the impacts of such risks.

7. Conclusion and Further Research

Africa has vast renewable energy resources. It has enough renewable energy resources to meet its demand and also be a net exporter. However, renewable energy at present contributes very little to the electricity consumed in Africa. In any case, most of the renewable energy at present is hydropower. Because of population growth and expansion of electricity connectivity, electricity demand is expected to grow by up to 10% per annum between now and 2030. Six hundred forty-eight million SSAs do not have access to electricity, and over 900 million do not have access to clean cooking. Universal access to electricity in SSA is possible with an enabling policy framework and increased investment in innovative financing.

International investors in renewable energy projects in sub-Saharan Africa face several risks, including country, political, currency and commercial risks. These risks are insurable. The cost of utility-scale power generation from renewable energy sources has declined substantially over the last few years. However, developing country governments need to implement policy reforms, including setting clear renewable energy targets, developing technical capacity, providing grants, implementing feed-in-tariffs, holding competitive auctions, removing subsidies from conventional energy generation, and identifying bankable projects and de-risking them to attract renewable energy investments.

Renewable energy expansion in SSA will require substantial financial resources from a range of sources, including public and private sources, grants and bilateral aid, and multilateral agency loans. To unlock these investments, further research is required at the country level to collate stakeholder views on the required government policy changes, public perceptions and acceptance of various renewable energy technologies, and public willingness to pay for these investments. Further research should also survey attitudes of international investors, energy companies and developers about the changes needed to make the renewable energy sector in SSA attractive for investment. Research on innovations in financing required to accelerate investment in renewable energy in SAA is urgently required.

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Navigating Formal Land Acquisition Channels for Construction Projects in Lagos: Issues and Challenges

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Abstract

Construction projects, like other activities, take place on land, thereby making land acquisition a crucial factor in construction ventures. This is because land acquisition is one of the important decisions that make or mar a construction venture, as other activities depend on getting a suitable site for the project. This paper examined the process of land acquisition from the various formal land delivery channels of Lagos, Nigeria. Primary and secondary data were employed for the study. Secondary data on the procedure of land allocation in the various channels of land delivery collected from Government Offices Providing Land Administration Services (GOPLAS) were analysed in addition to interviews with 19 senior officials of the GOPLDS. The result revealed that there were five different formal land delivery channels in the study area, which include Site and Service Scheme, Private Sector Developers' Programme, and Excision. Others included Regularisation and Joint Venture. The land delivery process in all the channels is a multi-stage procedure that takes between two and 14 months to complete. Also, challenges such as a lack of necessary infrastructure in some of the schemes, clientelistic practices, and the encroachment of land by indigenous landholding families and other bureaucratic challenges associated with GOPLAS make acquiring land through the formal land delivery channels problematic. The inefficiencies and delays in the formal land delivery process can deter investment and slow down urban development.

Keywords: land governance, land accessibility, project management, construction projects, Land acquisition

1. Introduction

Land is the platform of human existence. It is the foundation of the production of the three necessities of life – food, housing and clothing. Irrespective of the importance of land in meeting society's needs, it is limited in supply. The increasing population and urbanisation in many African cities are progressively reducing the supply of accessible land. In Lagos, Nigeria, rapid urbanisation and economic growth have created an unprecedented demand for land, especially for construction projects. As one of Africa's most populous cities, Lagos faces unique challenges in land acquisition, which are crucial for the success of construction ventures.

The land acquisition channels, also referred to as land delivery channels, are routes through which land is made available for development and could be categorised as formal and informal channels (Olapade & Aluko, 2022). While the informal/customary land delivery channels supply the majority of land for development in many African cities (Rakodi & Leduka, 2004), accessing land from this delivery system has been bedevilled with increasing tenure insecurity, land disputes, undocumented titles, environmental degradation, landlessness, unsustainable development, poor layout plans and a general lack of infrastructure facilities (Ige & Gbadegesin, 2022; Olapade & Aluko, 2023).

The lack of a formal title and other challenges associated with acquiring land from the informal land delivery system have led many people to turn to the formal land delivery channels. Meanwhile, the formal land delivery channels face their challenges. For instance, the formal land delivery system is usually not able to supply adequate plots of land for development (Rakodi & Leduka, 2004); the procedure of land allocation is cumbersome and costly (Olapade & Aluko, 2021); and land delivered is associated with clientelistic practices (Durand-Lasserve et. al., 2015). To address some of the challenges associated with the formal land delivery system and encourage its use, different channels of formal land delivery have been developed in many cities.

Despite the existence of different formal mechanisms designed to streamline land acquisition, developers often grapple with bureaucratic red tape, legal ambiguities, and other challenges. These challenges not only delay project timelines but also inflate costs, thereby impacting the overall feasibility and sustainability of construction projects (Husain, 2024; Olapade & Aluko, 2025). Against the foregoing, this paper examines formal land acquisition channels for construction projects in Lagos, Nigeria. This is to provide information that could enhance accessibility to land for construction projects. This study delves into the formal channels of accessing land for construction projects in Lagos, highlighting the procedural intricacies and the multifaceted challenges encountered by stakeholders.

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2. Literature Review

Acquisition of land by individuals or corporate bodies can either be from the government, which is often referred to as formal channels, or through the purchase of land through informal channels (Aluko et. al., 2004). The formal channels for land acquisition, however, differ from one country to another, and so are the processes relating to such acquisition. While many studies (Ige & Gbadegesin, 2022; Musyoka, 2005; Rakodi, 2005; Rakodi & Leduka, 2004; Nkuruziza, 2008, among others) have focused on the informal land delivery channels, few studies focus on formal land delivery channels. The few studies on formal land delivery channels are either not in the same institutional environment or are not comprehensive. For instance, Musyoka (2005) examines the formal land delivery processes in Eldoret, Kenya, focusing on a single channel of land delivery. The study discovered that acquiring land from the formal land delivery involves about fifteen stages, which take several months to complete. The processes were also discovered to be slow, expensive and inefficient. Similarly, Durand-Lasserve et al. (2015) examined the formal land delivery system in Mali. They discovered that there are various channels for accessing land for development, and each channel has its unique processes. The study also discovered that the formal land delivery system is associated with clientelistic practices and bureaucracy, which affect efficiency.

In Nigeria, Fabiyi (1984) examined the procedures for land allocation in the formal land delivery system in Ogun, Ondo and Oyo states of Nigeria. The study employed secondary data from the government offices providing land delivery services and interviews with government officials. The study discovered that the process of land allocation for the three states was similar. The procedures involve a four-stage process that takes several months to complete. Again, Aluko et. al. (2004) examined the formal and informal land delivery processes in Lagos State. The data for the study were obtained from the Lagos State Lands Bureau and interviews with some key informants. The study reported that the procedure for the allocation of a plot in a formal site and service scheme requires meeting stringent requirements and is subject to the approval of the State Government, and the process might take up to two years. The study did not provide information on other channels of accessing land in a formal land delivery system.

In another study, Butler (2009) assessed the procedures for the supply of business / commercial land in the cities of Kano and Lagos in Nigeria using desktop analysis and interviews of key informants. The study identified three different types of markets for land delivery with different procedures. The identified market includes the primary state market where direct state grants are allocated; the organised secondary market, which trades in Statutory Rights / Certificate of Occupancy; and the informal secondary market, which transacts in pre-1978 land rights or customary rights. The study also reported a high inefficiency in the allocation of direct state grants, which represents one of the formal channels of land delivery. Again, Yakubu (2014) examined the process of acquiring a direct grant of Statutory Right of Occupancy in Kaduna, Nigeria. The study discovered that while the stipulated time for the processing of a grant of Statutory Rights of Occupancy was 50 days, it takes about 400 days in practice.

Olapade and Aluko (2021) categorised channels of land delivery in Lagos into three, namely formal, semi-formal and informal channels. The study further categorised the six modes of acquiring land in the city under the three land delivery channels. For instance, the study categorised land allocation through the site and service scheme and allocation through the private developer scheme as formal. In contrast, land allocation through regularisation and excision was categorised as semi-formal and allocation of land through customary landholding authority, whether for members or non-members, as an informal channel. The study, however, does not cover the procedure of land allocation through the channel and the challenges associated with each of the channels.

On challenges confronting the formal land delivery channels, many studies have criticised them for bureaucracy and inefficiency (Rakodi & Leduka, 2004; Muyoka, 2007; Nkuruziza, 2008). Especially for the long duration it takes for the allocation of land through the formal channels. For instance, it involves fifteen stages and takes several months to complete in Kenya (Muyoka, 2007). Omirin (2003) observed similar challenges in Lagos, Nigeria. Bello et. al. (2014) focusing on site and service schemes in Nigeria criticised the land delivery channel for lack of available facilities and inefficiency in land allocation.

Most of the extant studies that have examined formal land delivery have either focused on a single channel of land delivery or were carried out in different institutional environments with distinct land governance. There is, therefore, a gap in the assessment of land allocation procedures in the land delivery channels of cities in developing countries such as Lagos. Earlier studies on the Formal Land delivery system are either dated (Fabiyi, 1984; Aluko, et. al., 2004) or were carried out in different institutional environments (Musyoka, 2005). Apart from these, earlier studies were limited to a channel within the formal land delivery system (Yakubu, 2014; Bello et al., 2014) and did not document challenges associated with each of the channels. There is therefore a need to holistically assess the different channels for land acquisition in Lagos, Nigeria, hence this study.

3. Research Methodology

The study adopted a descriptive survey design employing both primary and secondary data. Using a qualitative approach, secondary data on the procedure of land allocation in the various channels of land delivery were collected from Government Offices Providing Land Administration Services (GOPLAS). This includes schematic diagrams of procedures for each land delivery channel and their associated requirements. The information collected was corroborated by the Key Informants Interview (KII) of officials from the GOPLDS. There were a total of nine GOPLAS operating in Lagos State; seven were under the control of the State Government, while two were under the control of the Federal Government. The GOPLDS under the control of the Lagos State Government include the Lands Bureau, Ministries of Physical Planning and Urban Development, Justice, Agriculture and Cooperative; and Waterfront Infrastructure Development; other Lagos State GOPLAS include the Lagos State Property Development Corporation; New Towns Development Authority (NTDA), and the Office of the Surveyor General. The GOPLDS under the control of the Federal Government in Lagos State include the Lands Division of the Federal Ministry of Works and Housing and the Federal Housing Authority (FHA).

The head of each of the GOPLAS was contacted to serve as a key informant for the research. The heads or representatives of each of the GOPLAS were interviewed and acted as key informants. Meanwhile, in some GOPLAS, more than one officials were interviewed based on the structure of the Office, which required information from different departments. A form of purposive sampling was therefore adopted for the study. In all, interviews were conducted with 19 officials from GOPLAS, who served as key informants for the research. All the key informants are government officials with years of experience ranging from 14 to 30 years. Five of them were female, and all of them had at least a first degree qualification. The interviews were transcribed verbatim. The transcribed interviews, supplemented with secondary data, were analysed using thematic analysis. The themes generated from the quotations extracted from the interviews and desktop research were organised into a narrative to answer the research questions. To better illustrate the themes and provide evidence for interpretations and readability, some quotations were presented. The selected quotes are representative of the patterns observed in the data. Specifically, quotations from interviews with IGOPLAS 1, 2, 5, 10, 18 were presented. The background information of the IGOPLAS is presented in Table 1.

Table 1: Background Information of Informants from IGOPLAS

Respondents	Gender	Highest Academic qualification	Year of experience	Position/ Rank
IGOPLAS 1	Male	Second Degree	22	Assistant Director
IGOPLAS 2	Female	Second degree	17	Chief Land Officer
IGOPLAS 5	Male	First degree	18	Chief land officer
IGOPLAS 10	Male	First degree	15	Assistant Town Planner
IGOPLAS 18	Male	First degree	30	Assistant Director

4. Findings and Discussion

This section provides the results of the field study and the discussion based on them.

4.1. Formal Land Delivery Channels (FLDCs) for Land acquisition and their Challenges

From the review of secondary data collected and interviews conducted with key informants from GOPLAS, it was discovered that there were available in the study area. This includes Site and Service Scheme, Private Sector Developers' Programme (PSDP), Acquisition from Excised land, Regularisation and Joint Venture. Table 2 provides a list of formal land delivery channels, descriptions of each channel, procedures for land acquisition in each of the channels and their challenges.

As shown in Table 2, one of the FLDCs was the site and service schemes, which are purposely designed estates by the government that are provided with infrastructure such as roads, water, and electricity, and are laid out in plots of different sizes based on density. The site and service The scheme channel is usually employed to allocate land to individuals.

Table 2: Procedures of land allocation in the formal land delivery channels and their challenges

Land Delivery Channels	Description of channel	Procedure of land allocation	Challenges
Site and Service Scheme	purposely designed estates that are provided with infrastructure	A 15-stage process of land allocation, which could take several months to complete	Poorly conceived Schemes that lack the necessary infrastructure. Inefficient allocation of plots in prime locations. Land encroachment by a third party.
Private Sector Developers' Programme	The state government is allocating undeveloped/service land en bloc to prospective developers who, thereafter, provide it with infrastructure.	The allocation process involves 11 stages culminating in the issuance of a Certificate of Occupancy to the applicant.	Delay inland allocation as a result of lengthy procedures. It also requires meeting stringent conditions before land can be allocated.
Acquisition from Excised Land	The channel is a medium used by the government to return a particular portion of land to the indigenous landholding families from which it was initially acquired, and the family can sell it to interested members of the public.	After the land has been excised, the developer can approach the family that now owns the land allocated to the developer. The three stages involved in the land acquisition can be completed within a few days (2 to 3 days)	Double allocation and other problems associated with land delivery involving indigenous landholding families
Regularisation	Granting of title to people who erroneously purchased uncommitted government land.	The regularisation process involves 11 stages with a minimum duration of 33 days.	False claims by the applicant and other administrative issues.
Joint Venture	Partnership between the government and a private organisation in the land delivery system.	The government allocate land to the private organisation free of charge, which will provide the necessary infrastructure.	Bureaucratic nature of GOPLDS which delay granting approval for JV. Change in government.

[...]Site and Services Scheme that is they (government) will lay out land, put infrastructure like road, light (electricity) and all that, they allocate to individual [...] (IGOPLAS 18)

The analysis of information from key informants shows that acquiring land through this channel involves an 8-stage process, which could take several months to complete. This result supports earlier studies such as Omirin (2003) and Musyoka (2005) that land allocation through the site and service scheme involves multiple stages and takes considerable time. Apart from the long duration for acquiring land using the channel, the channel is bedevilled with other challenges, such as poorly conceived and managed schemes, which lack the necessary infrastructure. Others include inefficiency in land allocation, clientelistic practices similar to the findings in Durand-Lasserve et. al. (2015), and encroachment of allocated land by customary landholding families. Some of the comments of the key informants regarding the challenges of the site and scheme channel of land delivery include:

[…] we sometimes have issues with the cost of providing the infrastructure, maybe because of some people's negligence, that they did not give the government the right estimate […]. (IGOPLAS 1)

[…] Only those who are close to people in power get land from formal LDIs. Cost is also high and not affordable […] (IGOPLAS 1)

The corollary of the foregoing is that the process of land allocation through the Site and Service Scheme in the study area was not effective. The designs of the Schemes were not usually effective, and the process took a long time to complete; also, the cost of allocation was high. This result supports the finding in Bello et al. (2014) that the Site and Service Scheme in Nigeria was not effectively designed and managed.

Another channel of acquiring land in the study area was through the Private Sector Developers' Programme. This channel, which is specifically designed for private developers, is a corporate initiative where the government give virgin land to intending developers. The developers were expected to provide the necessary infrastructure, parcel the land into plots and sell the parcelled land to members of the public. The smallest size of land allocated by the government under this scheme is one hectare.

[…] Private developers scheme is a process where corporate organisations that need land for their business request land from the government; we give nothing less than 1 hectare and above… it is from 1 hectare to 5 hectares […] (IGOPLAS 2)

The channel is most suitable for construction ventures as it is designed for property developers who want to embark on large-scale development. Interviews with informants and secondary data collected reveal that the procedure for land allocation under the channel involves a 12-stage process that could take up to 12 months. The delay is usually associated with lengthy procedures and the time it takes for the governor of the State to endorse the Certificate of Occupancy (C of O). It also requires meeting stringent conditions before land can be allocated. For instance, one of the officials commented on the process of land allocation under the channel as follows:

[…] Some criteria they must meet, particularly their bank statement that shows that they have the funds, they must show the project they are about to embark on, they must show their track records of what they have done before [...] (IGOPLAS 2).

Apart from the issue of time duration to complete the process, other challenges associated with the process, as expressed by the informants, include land conflict with Indigenous land owners referred to as omo onile, who usually claim that they were not adequately compensated by the government when their land was compulsorily acquired. The *omo onile* usually prevents the applicants from taking possession until they make another round of payment to the omo onile. Some of the respondents commented as follows:

[...] we have challenges of the *omo onile*, it is something we have been battling with [...]. (IGOPLAS 10)

Another channel for acquiring land for construction ventures is through the excision channel. This channel, which Olapade and Aluko (2021) referred to as a semi-formal channel of land acquisition, involves acquiring excised land from the Indigenous customary landholding families. Sometimes the State Government embarks on massive land acquisitions of semi-urban / rural, undeveloped lands. This is to make land available to the State for future use. Excised lands are land previously acquired by the government and have now been returned to the original Indigenous customary landholding family. Unlike land acquired through informal channels, an excised land has a registered title, thereby categorised as a formal land delivery channel. One of the government officials commented as follows:

[...] It is under the Land Use Act to do an excision for the existing landholding family in that area, which is a form of compensation, and also not to extinguish their existence in their locality [...] (IGOPLAS 2)

When the land is excised and a formal title obtained, interested members of the public who need land for development can approach the family. The process of acquiring land through the channel is a simple three-stage process, which commences when the prospective purchaser obtains information on the availability of the plot. This stage is followed by an inspection of the available plot by the prospective purchaser to examine the physical condition of the site. The next stage is for the purchaser to investigate and confirm the authenticity of the ownership claims. The stage of price negotiation and payment would follow this. The acquisition of land through this channel is high-speed. The stages can be completed within a few days (2 to 3 days) compared to the process in the other formal channels, which will take several months. The challenges associated with land acquisition from excised land are similar to those of acquiring land through informal channels. This includes double allocation, tenure insecurity, and land conflict associated with land in the informal channel, as discovered in Olapade & Aluko (2023).

Another channel of land acquisition revealed in Table 2 is the regularisation channel. This channel provides formal title to land for those who have erroneously purchased uncommitted Government land (LASG, 2009). Regularisation is among the channels described by Olapade and Aluko (2021) as a semi-formal channel of land delivery. Land allocation in locations subjected to the regularisation policy is usually assigned by landholding families from whom the government acquired the land. The family will issue a deed of assignment, which is part of the requirement needed to obtain the formal registered title of a Certificate of Occupancy.

[...] when you encroach on government land and the land is not committed, instead of destroying your property, the government can say you should come and regularise, that is what we call regularisation […]. (IGOPLAS 18)

The process of land acquisition through regularisation after purchasing land from the customary landholding families involves a 10-stage process, which could be completed within 33 days (Lagos State Government, 2019). This is, however, contestable as delays in any of the stages can increase the duration of the period. Similarly, the process involves numerous inter-agency activities, which further escalates the complexity of the process.

From the analysis, the duration for regularisation is fast when compared with other channels of formal land delivery in the study area. This could be a result of the creation of a specific directorate that handles all issues relating to regularisation, thereby establishing a one-stop shop for the processing of regularisation. This therefore reduces the bureaucracy in the process. Despite the short processing time for regularisation, some challenges were identified with the regularisation process from the interview with the officials of

GOPLDS, including false claims by the applicants, such as submitting a survey plan that does not correspond with the actual location of their land and false ownership claims.

[…] Some of the challenges we encounter in regularisation are the issue of incorrect survey plans. On many occasions, the applicants present a survey plan that corresponds with the actual location of their land. There is also the problem of false claim of ownership by the applicant, which, when a counterclaim is presented, will disrupt the regularisation exercise […] (IGOPLAS 5)

One of the respondents, however, criticised the regularisation process on the claim that the process encourages people to encroach on government land and also results in the creation of slum settlements and suggested a general regularisation and upgrading of the area.

[…] What we are doing is not the best; we are directly or indirectly encouraging people to keep encroaching on government land. In my own opinion, I think what we should do is regularisation and upgrading. So when you get to slum areas, do infrastructure there, some plot will automatically go… You have regularised them by giving them the title, you have upgraded, some people will sell their land and move out if that place […] (IGOPLAS 1)

The last channel of land delivery presented in Table 2 is the Joint Venture channel. This is an arrangement where the government partners with a private body to deliver land. It is similar to the Private Sector Developers' Programme (PSDP), only that instead of the developer making an outright payment for the land, the land is allocated free of charge, but the proceeds of the development are shared between the government and the developer. Some of the respondents provided insights into what a Joint Venture Arrangement entails as follows:

[…] People seeing our (government) acquired land as underutilised or unused can apply to us to partner with us so that they can build some housing units.… So at the end of the day, it is a public-private partnership […]. (IGOPLAS 18)

The process of land allocation through the joint venture arrangement entails the developer approaching the appropriate GOPLDS for the allocation of their unused land. Interviews with some officials of GOPLDS provided insights into what the Joint Venture Arrangement entails as follows:

[…] the Government gives them the land as equity, then the developer uses his resources to build. So he parts with some units to the Government […] (I GOPLDS 18)

The joint venture provides a public-private arrangement which makes developable land available, thereby increasing the supply of serviced plots. The main challenge with that land supplied under this arrangement is that it is usually expensive and outside the reach of the poor. The challenge with the approach is the bureaucratic nature of government offices, which delays the approval of JV. Also, a change in government might disrupt any arrangement made with the previous government when a new government take over the reins of affairs.

The synthesis of the findings of this study reveals that the formal land delivery process in Lagos is characterised by multiple channels, each with its own set of procedures and challenges. Each of the five identified channels involves a multi-stage process that can be lengthy and complex. The findings also reveal that it takes considerable time to acquire land through the formal land delivery channels, except for acquisition from excised land, which is usually fast but very risky. This result is in tandem with the results from Musyoka (2005) and Durand-Lerserve et al. (2015) that the formal land allocation process is slow, expensive and inefficient. Some of the challenges plaguing the land delivery process include poorly conceived schemes, which lack the necessary infrastructure, limited allocation of plots in prime locations to government officials and their associates, and the encroachment of land by omo-onile. Others include the allottee not developing the land after obtaining the C of O, a highly politicised process, and other administrative issues. All these challenges connote a weak governance of the formal land delivery channels. This is a problem that needs to be addressed to make land accessible for construction projects. There is therefore a need for improvement in land governance to curb these challenges and improve access to formal land delivery.

5. Conclusion

This study examined the formal land acquisition channels for construction projects in Lagos, Nigeria, and identified the challenges associated with each channel. The findings reveal that the formal land delivery process is complex, involving multiple stages and significant delays. Key challenges include poorly conceived schemes, high costs, bureaucratic inefficiencies, and conflicts with indigenous landowners. All these challenges connote a weak governance of the formal land delivery channels.

While the availability of multiple formal land delivery channels creates different routes to access formal land for the public, the challenges associated with acquiring land through the formal channels will prevent their use. The implications of these findings are significant for policymakers, developers, and project managers. For instance, the inefficiencies and delays in the formal

land delivery process can deter investment and slow down urban development.

To address these issues, a holistic restructuring of the GOPLDS is recommended to reduce bureaucracy and improve efficiency. Implementing an Integrated Land Administration Automation System could streamline processes, enhance transparency, and reduce delays. Improving land governance is crucial to making formal land delivery channels more attractive and accessible. This will not only facilitate timely access to land for construction projects but also reduce the reliance on informal land acquisition methods, promoting sustainable urban development in Lagos.

In summary, this paper contributes to knowledge by identifying and categorising formal land delivery channels in Lagos, providing a detailed analysis of their procedures and challenges, and offering practical recommendations for improving land governance and accessibility.

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ACADEMIC PAPERS: THEME 9 - PROCUREMENT INNOVATION AND TRANSFORMATION

Client and Construction Machinery Related Factors Influencing the Selection of Contract Procurement Method in KwaZulu Natal Province in South Africa

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Abstract

The study aims to find the adequate client and construction machinery related factor influencing the selection of contract procurement method in Kwazulu Natal province in South Africa. The study population consists of Architects, Project managers, Quantity surveyors, and Builders. Simple random sampling techniques were used to select respondents. All in all, sixty-five professionals were surveyed, and data was analyzed using descriptive statistics. The Cronbach alpha value were greater than 0.70. Findings for this study are: Client's emphasis on timely project delivery, low construction cost, type of client's funding, poor maintenance of tools and machinery, and difficulties in hiring construction tools and machinery are the client and construction machinery related factors influencing the selection of contract procurement method. The study recommends that amongst the factors to be considered for the selection of a contract procurement method, timely project delivery, low construction cost, type of client's funding, poor maintenance and difficulty in hiring construction tools and machinery should be foremost.

Keywords: Contract procurement, Machinery management, Procurement, Project delivery, Project management

1. Introduction

Project procurements are merely sub-projects that must be properly handled instead of being assigned to an independent body to purchase for the project. Certain procurements, large complexity developments, or developing something new that does not exist, according to the project's unique requirements, must be managed by the project team and backed by the professional procurement group (Fleming 2019). The procurement process is important in construction projects and its activities spans from identifying requirements from start to the closeout of project. Construction procurement processes are complex with different options and direction (Ruparathna and Hewage 2015). The level of experience that a client has and project delivery time is very important in choosing a procurement method in construction processes. A client who has been involved in lots of construction works would be willing to give more into ensuring that the project is successfully executed while a client who is new or has been involved in few projects would want most responsibility to be shouldered by the construction team (Plunkett 2021).

The identification of machinery required for the construction of a project is highly dependent on the complexity of the project. The machinery availability and possession of a company and the ability to operate and maintain these machinery to avoid breakdown is critical to the delivery of a project.

This study's objective is to investigate and identify client-related and construction machinery-related factors that influence the contract procurement methods used in project delivery. The study intends to provide actionable insights into how to align these factors with procurement and project management strategies to improve resource management, client relationships, and operational efficiency.

2. Literature Review

2.1. Client related factor influencing the selection of contract procurement method in project delivery.

2.1.1. Client's experience in construction

Clients that has experience in construction are usually more aware of the hazards involved in building projects and may favour methods of procurement like design and build while less experienced clients on the other hand, might choose simpler, less risky options like Traditional Lump Sum contracts (Love *et al.* 2012).

2.1.2. ***Client's emphasis on low construction cost***

Construction clients were noted to focus much more on price involved in the construction of project and a little on trust (Erik Eriksson and Laan 2007). Clients always uphold value for money principle. On the other hand, they prefer methods that offers costs certainty, competitive pricing and tendering and a lesser financial risk. This method encourages reduced prices through competition by allowing numerous contractors to submit bids (Ayodele 2011). Early contractor involvement is also another technique used by clients to reduce construction cost, Through the early involvement of contractors in design and cost estimates, customers can potentially find cost-saving options and improve budget accuracy (Tang, Shen and Cheng 2019).

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*2.1.3. **Client's ability to make a decision***

Clients ability to make decision positively influence the choice of procurement method, particularly experienced clients. The client is to make a decision and develop a procurement strategy which includes several activities such as establishing the basis of selection of any procurement route, confirming the project objectives, undertaking market engagement, identifying responsibilities and identifying constraints (Al-Harthi, Soetanto and Edum-Fotwe 2014). Experienced clients in the construction industry wants to get more involved and make decisions. They could choose techniques of procurement like Integrated Project Delivery (IPD) or Construction Management which provides greater control over the design and construction phases while inexperienced clients may choose procurement approaches where the contractor assumes greater responsibility because they lack the information needed to make complex decisions (Masterman 2013).

2.1.4. Client's contribution to design and construction

The roles of clients have evolved over the years from that of a passive fund provider to an active participant and hands on manager in procurement systems (Al-Harthi, Soetanto and Edum-Fotwe 2014). At the design and specification stage it was noted that a detailed design of the construction project is produced mostly by the client and their consultant and the specification is seldom managed by the contractor (Erik Eriksson and Laan 2007). The higher constructability of design and environmental sustainability have been shown to have a greater influence on the selection of the most appropriate procurement route for off-site housebuilding as compared to those applicable to traditional construction (Agapiou 2020).

2.1.5. Client's ability to brief

The client's ability to provide comprehensive and explanatory information about the project which includes the scope of the project, objectives, quality expectation, outcome, deliverable, timeframe and the special features involved in the project would influence the selection of contract procurement method in project delivery (Al-Harthi, Soetanto and Edum-Fotwe 2014).

2.1.6 Client's emphasis on timely project delivery

Clients prefer a technique that helps with on-time project delivery such as construction management. This influences the procurement method coupled with the complexity of the project. Clients involves the construction manager early in the design phase and this lessens the chance of delays by streamlining the construction process and identifying possible problems (Love *et al.* 2014).

2.1.6. Type of client's funding

Projects funded privately through loans or investors, projects funded through public sources such as government budgets or grants may have distinct procurement requirements. Transparency, accountability, and adherence to public procurement norms are frequently given top priority in publicly funded projects, which results in the use of procurement techniques like competitive dialogue or open tender. In contrast, privately funded enterprises might place greater emphasis on risk management, creativity, and efficiency in order to draw in lenders and investors. In these situations, procurement strategies that allow integrated project delivery and risk sharing, including Design-Build or Public-Private Partnerships (PPPs), may be favoured (El Sawalhi and El Agha 2017).

2.2. Construction machinery related factor influencing the selection of contract procurement method in project delivery.

2.2.1. Poor maintenance of tools and machinery

In order to prevent equipment from impeding work progress, it is advised that the state of the equipment be carefully examined before it is mobilized on site or contract awarded. Effective maintenance of tools and machine will eliminate breakdown and ensure the completion of project as scheduled resulting in opportunity for competitive advantage (Zeb, Qudoos and Hanif 2015).

2.2.2. Difficulties in hiring construction tools & machinery

Due to the high cost of purchase of tools and machineries, it makes it difficult for outright purchase of tools and machineries and reflecting it on company's profile and negatively influencing choice of procurement. Therefore, the hiring of plant equipment must be easily accessible, thereby positively the procurement method. In some cases, purchasing is more financially advantageous, while renting can be more cost-effective and pleasant.
A contractor can acquire the use of construction equipment by purchasing, renting and renting equipment with the option of purchasing it at a later date (Asare 2022).

2.2.3. Increase in hiring cost of construction machinery

Increase in hiring cost of construction machinery is posing challenges because it influence the procurement method and will increase the bidding price in prospecting for contract. Therefore the construction team are left to manage contract with high cost of plant and equipment (Asare 2022).

2.2.4. Inadequate skills of machinery operator

Equipment operators often learn through trial and error, causing damage to the equipment. It is the organization's responsibility to ensure proper training for the operators. Due to new and advanced technologically developed tools and machines and with no trainer/training has adversely influenced contract procurement method. It has not afforded the choice of procurement method with the engagement of these new

tools and machinery for the delivery of project (Zeb, Qudoos and Hanif 2015).

2.2.5. Insufficient number of machinery available on site

Insufficient number of machinery available on site has influence the choice of procurement method for the delivery of a project. It suggests alternative methods. Before awarding a contract, it is recommended to establish tight qualifying criteria based on project requirements and ensure adequate equipment. The project should then be awarded to the contractor who meets the standards (Zeb, Qudoos and Hanif 2015).

2.2.6. Damage to tools and machinery

Damage to tools and machinery play an important role in the choice of project procurement method. This stems from the point view of easily available spare parts for replacement in cases of damage, in order to avoid delays of importation. To prevent equipment from impeding work progress, it is advised that the state of the equipment be carefully examined before it is mobilized on site. Damage to tools and machinery results in shortages of tools and machinery and adversely impacting the choice of contract procurement method and delivery of projects (Zhao, Zhang and Zhao 2013).

2.2.7. Complexities in operation of machinery

Complexity in the operation of machines leads to lack of skilled labour to operate these machines and limit the choice of selection of procurement method and negatively impact on project delivery. There is a dearth of understanding among industry specialists, and incompatibility with building components and machineries leads to greater additional expenditures and material handling costs (Waris *et al.* 2019).

2.2.8. Absolute machinery used in construction operations

Absolute machinery used in construction do not afford reliability of these machines. Constant breakdowns result and leading to difficulty regarding reliability. The non availability of spare parts of these absolute machines afford limited use of them. These constitutes problems and limitation in the procurement method. Au-Yong, Ali and Ahmad (2016) proposes that maintenance management establish a spare parts management department to regularly update stocks.

3. Research Methodology

A questionnaire survey was conducted for this study. A total of sixty-five (65) questionnaires were administered to construction professionals (Architects, consultant Quantity surveyors, contracting Quantity surveyors, project managers, contractors and others) in KwaZulu Natal Province. Forty five (45) questionnaires were administered in person to the respondents, out of which thirty one (31) questionnaires were duly completed and retrieved.

The respondents in the study held different positions in various firms. The participants' firms are Contracting firms (19.61%), Architectural firms (11.76%), Project management firms (21.57%), Quantity surveying firms (9.80%), client (13.73%) and Engineering firms (17.47%). Most of the respondents have bachelor's degree qualification (45.1%), Honours (17.65%). The average years of experience of respondents is 11-15 years and most of the respondents work for either public or private organizations. This indicates that the information obtained is deemed reliable. A quantitative approach was adopted and the data was analyzed using descriptive analysis. Simple statistical tools such as the mean score and standard deviation were used for the statistical analysis of data.

4. Data Presentation and Analysis

Table 1 presents client related factor influencing the selection of contract procurement method in project delivery. Client's emphasis on timely project delivery with a mean score of 5.39 ranked as the most vital factor influencing the selection of contract procurement. The selection of contract procurement methods is influenced by a client's priority on timely project delivery, which is demonstrated by the preference for methods that give improved control, better coordination, efficient risk allocation, and performance incentives. Clients can more effectively control project deadlines and guarantee that their goals for on-time

Table 1: Client related factor influencing the selection of contract procurement method in project delivery

S/N	Factor	Mean score	Standard deviation	Rank
1	Client's emphasis on timely project delivery	5.39	0.190	1
2	Client's emphasis on low construction cost	4.63	0.078	2
3	Type of client's funding	3.93	0.024	3
4	Client's ability to brief	2.72	0.204	4
5	Client's ability to make a decision	2.48	0.239	5
6	Client's contribution to design and construction	2.37	0.255	6
7	Client's experience in construction	1.85	0.332	7

delivery are fulfilled by selecting the right procurement strategy.

Next to client's emphasis on timely project delivery is client's emphasis on low construction cost with an MS = 4.63. The selection of contract procurement methods is greatly influenced by a client's emphasis on low construction costs hereby making competitive bidding, cost certainty, effective resource management, and cooperative ways that reward cost savings to be prioritized. Through meticulous selection of the most suitable procurement strategy, clients can attain their economic goals while guaranteeing timely delivery and high-quality projects.

The least factor on this construct regarding client related factor that influence the selection of procurement method is client's experience in construction with an MS of 1.85. Even if a client's prior construction experience can offer some valuable insights, more important factors like advice from professional advisors, established procurement frameworks, cost and time factors often outweigh it. These components guarantee that the procurement technique chosen is in line with the objectives of the project and industry norms, hence making client's experience in construction the least important. The second to the least rated factor is client's contribution to design and construction with an MS 2.37. Clients seek the services of professional consultants who advise as regards which procurement method suits the project objective and gives value for money. Even though a client's input during construction can be insightful, it is usually surpassed by more important elements like project-specific requirements, established organizational policies, contractor input, risk management techniques, legal considerations, and a focus on project outcomes.

Table 1 indicates that client trust the contractor or project team to handle projects while focusing on external factors such as delivery and cost. The table most likely reflects priorities common to many construction or development projects, where time and budget constraints take precedence.

4.1. Construction machinery related factor influencing the selection of contract procurement method in project delivery.

Table 2 presents the construction machinery related factor influencing the selection of contract procurement method in project delivery. Poor maintenance of tools and machinery with a mean score of 4.54 has the highest rating. The selection of procurement techniques is influenced by poor maintenance of equipment and machinery, which emphasizes the importance of risk management, quality control, trustworthy contractor selection, cost control, time management, safety, and flexibility. In such cases, methods that take these considerations into account and offer ways to control the risks and difficulties brought on by inadequate maintenance are more likely to be chosen. Next to poor maintenance of tools and machinery is difficulties in hiring construction tools and machinery with an MS = 4.50. Contractors who have equipments of their own or who have partnership and easy means of getting equipments and machineries from rental companies are more trusted to carry out projects according to timeline schedule. Methods of procurement that enable careful screening and selection of these contractors can reduce the risks related to challenges in hiring equipment.

Table 2: Construction machinery related factor influencing the selection of contract procurement method in project delivery

S/N	Factor	Mean score	Standard deviation	Rank
1	Poor maintenance of tools and machinery	4.54	0.301	1
2	Difficulties in hiring construction tools and machinery	4.50	0.294	2
3	Increase in hiring cost of construction machinery	4.46	0.288	3
4	Inadequate skills of machinery operator	4.37	0.275	4
5	Insufficient number of machinery available onsite	4.30	0.265	5
6	Damage to tools and machinery	4.17	0.246	6
7	Absolute machinery used in construction operations	2.59	0.012	7
8	Complexities in operation of machinery	1.85	0.097	8

The least rated factor among construction machinery related factors influencing the selection of contract procurement method in project delivery is complexities in operation of machinery with an MS=1.85. Stakeholders and clients frequently prioritize strategic goals like timely completion, cost control, and quality, which might obscure issues unique to machines. Contractors, chosen for their technical know-how and experience, are frequently tasked with overseeing the complexity of machinery functioning. As a result, the client may place more importance on choosing qualified contractors than on the intricate workings of the machineries. The second to the least factor regarding construction machinery related factor influencing the selection of contract procurement

method in project delivery is absolute machinery used in construction operations with an MS = 2.59. Although the type of machinery utilized in construction operations is crucial for project execution, project scope, complexity, budget, risk management, compliance requirements, and overall project goals have a greater influence on the procurement methods selection process.

This construct reveals that construction projects face significant challenges in terms of equipment maintenance, availability, and costs, with less concern for machinery age and operational complexity. This suggests that improving these areas will result in more efficient and cost-effective operations.

5. Findings and Discussion

The study findings in relation to client related factors influencing the selection of contract procurement methods in project delivery are: clients emphasis on timely project delivery and low construction costs. This corroborates the findings of Williams *et al.* (2015) which found that drivers of client's satisfaction and relationship depends on timely project delivery and Janipha, Ahmad and Ismail (2015) findings which found that client's involvement in procurement influences the client's budget and impacts the quality of construction environment.

The findings of the study on machinery related factors influencing the selection of contract procurement method in project delivery that states that poor maintenance of tools and machinery and difficulties in hiring construction tools and machinery are factors to be considered in relation to construction portfolio as it affects smooth operation and delivery of projects aligns with the findings of Bengtsson and Kurdve (2016) that states that the life cycle cost of the equipment provides instructions for designing and specifying the equipment while taking into account operation, maintenance, tools and energy in procurement. The findings stress the importance of timely decision-making, clear communication, and efficient procurement practices in ensuring the success of construction projects.

6. Conclusion and Further Research

This research adds to the body of knowledge in construction management by highlighting the importance of aligning client priorities with procurement and project management strategies. It provides actionable insights into improving resource management, client relationships, and operational efficiency.

From the client related factors, client's emphasis on timely project delivery, client's emphasis on low construction cost and type of client's funding are the clients related factors that most influences the selection of contract procurement method in project delivery. For the construction machinery related factor, poor maintenance of tools and machinery, difficulties in hiring construction tools and machinery and increase in hiring cost of construction machinery are the construction machinery related factor that most influences the selection of contract procurement method in project delivery.

It is recommended that client's emphasis on timely project delivery, client's emphasis on low construction cost, type of client's funding, poor maintenance and difficulties in hiring construction tools and machinery should be the primary factors considered in the selection of a procurement strategy relative to project delivery. The study contributes to both theoretical knowledge in construction management and practical strategies for more effective procurement and project delivery.

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An Appraisal of Procurement Challenges Facing Emerging Contractors in Public Sector Projects in South Africa

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Abstract

In South Africa and around the world, economic development cannot be discussed without small businesses and the impact of the construction industry on the economy. Emerging contractors' underperformance in public procurement of construction projects is a cause for concern as small businesses underpin economic growth in South Africa. Despite limited capital and financial resources, small and medium enterprises are inventing new goods and technologies to rejuvenate and advance the industry by contributing to innovation, poverty reduction, and job creation. This paper examines the challenges in South Africa's public sector procurement for emerging contractors. A quantitative approach was employed with a well-structured questionnaire survey amongst the Construction Industry Development Board (cidb levels 4 and 5) as General Builders and Civil Engineering (CE) emerging contractors on procurement challenges. The study used a random sampling technique. Seventy-five responses were received from the Participants for the analysis of the study. The result shows that late payments by the state government, political interference, and poorly managed cash flows are among the challenges faced by emerging contractors in the South African construction industry, hindering their growth in the procurement of public projects. This study assesses the challenges faced by emerging contractors in the procurement process, identifies the key challenges that need to be addressed to help emerging contractors operate efficiently in the construction sector and provides a systematic insight into the procurement challenges faced by emerging contractors and how this affects their performance in the construction industry.

Keywords: Challenges, Emerging Contractors, Procurement, Small businesses, South Africa

1. Introduction

Procurement is under increasing scrutiny, fuelled by technological advances, programme evaluations, and the public and political need for improved service quality (Ambe & Badenhorst-Weiss, 2012). The construction industry is vital for any country's economic and social development, as it provides essential infrastructure and buildings for human activities (Chuai et al., 2021). Procurement of construction works by the organs of the state amounts to an estimated expenditure of R220 billion per year and contributes about 1.4 million jobs, which is the backbone of economic growth (CIDB, 2017). According to Booi (2013), the construction industry remains a vital contributor to job creation and the development of the country's economy, even though it is perceived as the most dishonest player. Balogun et al. (2016) revealed that the contribution of emerging contractors to economic and social development has been recognised around the world as vital. Emerging contractors are seen as an effective means of creating employment opportunities, particularly due to their labour-intensive nature and strong emphasis on technical expertise. They can meet the needs of communities by providing labour and facilitating the transfer of skills (Bikitsha & Amoah, 2022).

In South Africa, emerging contractors are major contributors to the economy of South Africa through job creation for entry-level skills (Thwala & Mvubu, 2008; Sibiya et al., 2023). The persistent low participation of emerging contractors in the economic mainstream has resulted in some emerging contractors not progressing to a higher level of CIDB grading and, thus, not fully participating in the economy (Balogun et al. 2016). The study by Shwala (2019) confirms that emerging contractors face challenges related to procurement and execution of public sector projects, which in turn hinder their categorisation at the next level of the Construction Industry Development Board (CIDB) contractor register. Various studies have revealed that emerging contractors face a variety of challenges when seeking contracts from government agencies. According to the CIDB (2022)report, the board indicated that the decrease in work opportunities for black-and-women-owned companies is a threat to transformation as black-owned contractors, which make up about 56% of the register of contractors, only accessed 33% of the work from the public sector.

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According to Thwala & Mvubu (2008), among other challenges faced by emerging contractors is access to projects, which is hindered by the administrative processes that make it difficult for small contractors to secure projects. These challenges have not only hindered the emerging contractors' success in making it to the next CIDB grading but have, in many instances, engendered underdevelopment and failures for these emerging contractors. It is a great concern that even though the government has been trying to assist emerging contractors, they continue to fail due to various factors and challenges. Considering that the economic development of any nation relies significantly on the sustainability of small businesses, this study, therefore, seeks to unbundle and investigate procurement challenges facing emerging contractors in the South African construction industry.

2. Literature Review

2.1. Overview of Emerging Contractors

The South African construction industry has, over the past decade, experienced an explosion in the myriad of emerging contractors. This is due to the metamorphosis of the industry transforming through the advancement of historically disadvantaged individuals by ensuring their participation in the economy from which they were previously excluded (Martin & Root, 2010; Bangani and Mewomo, 2019). Through this advancement, emerging contractors are mainly comprised of historically disadvantaged owners. Before one takes a detailed look at the challenges facing emerging contractors, it is important first to understand who falls under the category of "emerging contractor." According to Govender's (2017) study, emerging contractors in the construction industry are the contractors at the entry level of the industry and are small companies. These companies are also defined as enterprises owned, overseen, and administered by historically disadvantaged persons. This definition was confirmed by Mohlala (2015), who concurred that there is no direct definition of emerging contractors; however, they can be defined as a person or enterprise owned by historically disadvantaged individuals (HDI), and those can be termed "small-scale contractors.

In the South African construction industry, an emerging contractor is defined as an enterprise owned, managed, and controlled by previously disadvantaged individuals and is overcoming business impediments arising from the legacy of apartheid (Muzondo & McCutcheon, 2018). In Nigeria, emerging contractors are described as small-scale construction firms that hardly employ more than 25 workers with virtually no construction plant or equipment (Ali et al., (2020). From the above, one can summarise that "emerging contractors" term as small-scale contractors at the entry level of the industry, measured by their capacity, capability, financial ability, CIDB ranking and involvement in the industry. These contractors are mainly characterised by the nature and size of the work they do, which ranges from CIDB grades 1 to 4 (Sogaxa, 2024).

According to Muzondo & McCutcheon (2018), emerging contractors are also termed small, medium, and micro enterprises (SMMEs) in the South African context. Sitharam & Hoque (2016) explained that emerging businesses as "small, medium enterprises" (SMEs) measured by their turnover, asset value, and the number of people they employ. SMEs are widely acknowledged as a vital force driving the global economy's dynamism, innovation, and adaptability, which significantly contribute to job creation, enhance productivity and fuel economic growth (Handayani et al., 2025; Mbazor et al., 2024; Sogaxa, 2024).

In 2023, SMEs accounted for 61% of Indonesia's Gross Domestic Product (GDP) and employed 97% of the workforce (Hermina, 2024; Sogaxa, 2024) Similarly, in Malaysia, small and medium enterprises (SMEs) play a crucial role in economic growth, job creation, and trade balance (Sogaxa, 2024). In South Africa, SMEs generate around 61% of employment and contribute between 52% and 57% to the Gross Domestic Product (GDP) (Amoah et al., 2022). Moreover, SME contractors are key drivers of innovation and adaptability, promoting technological advancements and industry growth (Sogaxa, 2024).

Over the past decade, the South African construction sector has seen a remarkable rise in emerging contractors, largely due to efforts to integrate traditionally marginalized individuals into the economy. Despite these initiatives, emerging construction companies face many contracting challenges that hinder their development and viability.

2.2. *Challenges faced by emerging contractors*

The success of small and emerging contractors plays a crucial role in job creation and economic development, given their significant contribution to employment in South Africa (Muzondo & McCutcheon, 2018). However, over 70% of SMEs in the country fail to sustain their operations beyond the first five years, leading to business closures (Wentzel et al., 2023; Sogaxa, 2024). The ability to perform and deliver projects is one of the most common factors affecting the success of emerging contractors, as emerging contractors tend to fail to perform and deliver projects on time (Sweis et al., 2014). Emerging contractors in the South African construction industry normally start at the bottom end of the general building market (Thwala & Mvubu, 2008). Due to various challenges encountered by those contractors along the journey, they often fail to climb up to the next level. Sogaxa (2024). identified key challenges SMEs face, including resource management difficulties, such as labor distribution, equipment allocation, and restricted access to modern technology and software for project planning, scheduling, and communication.

Additionally, several authors such as Windapo et al., 2019; Akinradewo et al., (2019) highlighted that poor recruitment and retention of skilled labor and insufficient training and development opportunities further hinder their performance. Various authors have unanimously agreed that a variety of challenges do exist that hinder the success of small contractors (Windapo,et al, 2020), as summarised in Table 1.

Table 1: Challenges experienced by emerging contractors

em No.	Challenges	Source
1	ck or poor management skills	cwadi & Dangalazana, 2005)
2	ck of access to finance	ovender, 2017; Balogun et al., 2016)
3	or record keeping.	aspar & Puddephatt, 2012)
4	ne-man-show or sole management.	hwala & Phaladi, 2009)
5	ck of understanding of pricing techniques	hwala, 2019)
6	te payments by the government	vender, 2017; Thwala and Mvubu, 2008;
7	orly managed cash flow	aba & Anugwo, 2024)
8	ne tender procedure is too complicated	ovender, 2017)
9	litical interference	hwala, 2019)
10	ne complexity of procurement regulations and eir difficulty in implementation	gobeni, 2011)
11	ne overall contract value for a single award	incze Máté, 2014)
12	pe of contract	incze Máté, 2014)
13	pe of procurer	incze Máté, 2014)
14	ne publication of prior information	incze Máté, 2014)
15	nder procedure chosen	lohlala, 2015)
16	lection criteria used	incze Máté, 2014)
17	ice of tender document	ovender, 2017)
18	o much competition	ovender, 2017)
19	sufficient bidding information	ovender, 2017)
20	dministrative burden	gobeni, 2011
21	sufficient limited time to complete bids.	ovender, 2017)

3. Research Methodology

The study adopted a quantitative method. Employing both secondary data (literature review) and primary data (field research) to gather data to analyse the procurement challenges faced by emerging contractors in South Africa. The researcher began by drawing up a pilot study questionnaire, which was sent to five industry professionals for their comments in terms of the relevance of the questions for the purpose intended. Comments received from those professionals were analysed and incorporated into the research questionnaire, which was then sent out to participants. The study used a random sampling technique. The sample of the study consists of 308 respondents. The revised questionnaire was conducted among emerging contractors in the general building (GB) and civil engineering (CE) sectors in Gauteng Province. These contractors are registered at levels 4 and 5 of the Construction Industry Development Board (CIDB) Register of Contractors. The questionnaire survey included a section for respondent biographic information such as their gender, age, qualifications, experience in the construction industry, and the level of agreement to the identified procurement challenges on a five-point Likert scale: strongly disagree-1, disagree-2, neutral-3, agree-4, strongly agree-5. According to Slovin's formula, a questionnaire was distributed to 308 individuals in the study population, constituting the sample size. The responses of 75 Participants, accounting for approximately 24.35% of the sample size, were received. This was considered acceptable based on the type of survey and target population (Dillman *et al*, 2014) The appropriate descriptive analysis of data for this study is presented using tables, and the analysis of the data was facilitated by the Statistical Package for Social Sciences (IBM SPSS Statistics 29.0.0). Mean Item Scores (MIS) were generated for all the factors investigated in this study. The scores were ranked in accordance with their significant levels. The use of MIS has been found relevant in the previous study (Moswane *et al*, 2018, Mewomo *et al* 2017).

4. Findings and Discussion

4.1. Background information of respondents.

The study conducted through a questionnaire survey showed that, out of 75 respondents, 60% were male and 40% were female. The majority of participants were between 26 and 30 years old, accounting for 41.3% of the respondents. Thirty-six percent of the respondents had 6–10 years of experience, while those who had more than 15 years of experience represented 14.7% of the population. About 60% of the respondents were from CIDB Level 4 companies, and most of the respondents' companies under the general building

classification accounted for 38.7%. Most of the respondents' Companies have done 1–5 projects under the CIDB level classification. Most of those respondents have between 0 and 5 years of experience, accounting for 37.3% of the population. About 42.7% of the participants have done 1–5 projects for the organs of the state, while 9.3% have never worked with the state before. EMEs accounted for 66.7% of the respondents, while QSEs accounted for 33.3%. Looking at access to public sector construction projects, more than half of the respondents have accessed 0–5 state-owned construction projects, which is a major problem. The majority of the respondents' companies have equal to or less than 5 years of experience in the construction industry, which roughly equates to approximately 1 project per year when compared to the projected number of projects executed in the public sector. Therefore, contractors are still encountering hurdles in procuring access to state-owned construction projects.

4.2. Procurement challenges of emerging contractors

Table 2 presents the respondents' level of agreement regarding the procurement challenges emerging contractors face in South Africa. The analysis indicated that all 21 factors examined had mean scores exceeding 2.50 (Oguntona et al., 2019), with the lowest recorded score being a relatively high 2.80. This finding suggests that all identified factors significantly impact the procurement process. However, among the 21 challenges, the study highlighted that late payments from the government (M = 3.507, SD = 1.680), political interference (M = 3.427, SD = 1.544), and poorly managed cash flow (M = 3.400, SD = 1.533) were the most critical issues encountered by emerging contractors in public sector construction projects.

Table 2: Procurement challenges of emerging contractors

hallenges	Mean	S.D.	Rank
ıte payments by the government	3.507	1.680	1
olitical interference	3.427	1.544	2
oorly managed cash flow	3.400	1.533	3
oo much competition	3.373	1.575	4
ıck of understanding of pricing techniques	3.320	1.604	5
ıck of access to finance	3.307	1.676	6
dministrative burden	3.253	1.462	7
sufficient or limited time to complete bids	3.200	1.594	8
ıe complexity of procurement regulations and their fficulty in implementation	3.187	1.513	9
sufficient bidding information	3.187	1.458	9
lection criteria used	3.160	1.551	11
ice of tender documents	3.147	1.531	12
nder procedures are too complicated	3.107	1.573	13
ıe overall contract value for a single award	3.093	1.444	14
ıe-man-show (sole management)	3.067	1.605	15
ıck of construction management skills	3.027	1.684	16
ıe publication of prior information	3.027	1.395	16
nder procedure chosen	3.013	1.409	18
oor record keeping	2.973	1.594	19
ype of contract	2.867	1.528	20
ype of procurer	2.800	1.375	21

(Source: Author,2024)

Conversely, the type of procurer (M = 2.800, SD = 1.375) was identified as the least challenging factor.

This result aligns with recent studies, such as those by Merana (2018; Amoah & Bikitsha, 2022, Mewomo, 2019), which indicate that delayed payments for completed work lead to project delays, while political interference negatively impacts project

implementation. Additionally, competition is a significant challenge for emerging contractors securing public-sector construction projects. These findings are supported by Thwala and Phaladi (2009), who confirmed that emerging contractors face increased competition due to a continuous decline in demand. Mba zor et al. (2024) highlight that insufficient technical knowledge and human resources techniques and methods remain among critical challenges. Furthermore, Amoah & Bikitsha (2022) revealed that inaccurate pricing of project documents could severely disrupt cash flow, resulting in cost overruns. This issue often stems from the underpricing of specific items in the pricing documents, ultimately leading to financial losses. Various research in South Africa have reported the increased financial difficulties faced by the emerging contractors (Maritz and Mewomo 2016; Mewomo and Maritz, 2016). The study found that these challenges significantly affect the performance and survival of emerging contractors, particularly during economic downturns, and result in cost and time overruns, which were found to have an impact.

Also, the Poorly managed cash flow was identified as another challenge facing emerging contractors; this aligns with the study (Baba & Anugwo, 2024). The findings revealed that this challenge is primarily caused by poor financial planning skills and mismanagement on the contractor's part because poor cash flow management will lead to slow progress on site. Furthermore, inadequate cash flow can cause some projects to get terminated due to cash flow problems since the contractor cannot perform his duties under these circumstances. These findings echo Jardine's (2013) observations on tendering collusion, where small contractors struggle to absorb cost overruns, unlike large firms with strong financial reserves that can distribute risks across their operations. financial constraints and procurement inefficiencies remain major barriers to the sustainability of emerging contractors in South Africa's construction industry.

5. Conclusion and Further Research

This study examined the challenges faced by emerging contractors in procuring construction projects in South Africa. Using a quantitative research approach**,** a questionnaire survey conducted among emerging contractors in Gauteng confirmed a widespread consensus regarding the existence of these challenges. The findings identified key procurement challenges**,** including late payments by the government, political interference, poorly managed cash flow, intense competition, limited understanding of pricing techniques, and restricted access to finance**.** These challenges significantly hinder the growth and sustainability of emerging contractors, which are widely recognized as key drivers of economic development. Addressing these issues is crucial to fostering a more inclusive and resilient construction industry and strengthening the national economy. From a methodological perspective, this study contributes to the field by employing a quantitative approach to assess procurement challenges. Based on the findings, several recommendations have been proposed as mitigation strategies. Strengthening Procurement Policies: the government and policymakers should enhance the procurement framework to promote greater participation of previously disadvantaged individuals in the economy capacity Building and Training**.** The Construction Industry Development Board (CIDB) should implement and facilitate targeted training programs for emerging contractors. Professionals within implementing agencies should be employed to oversee and deliver these programs to ensure effectiveness. Skill Transfer and Mentorship major contractors should be incentivized through transformation policies to transfer essential skills to emerging contractors, enabling them to improve project execution, financial management, and overall business sustainability. The study is limited to the Construction Industry Development Board (CIDB levels 4 and 5) as General Builders and Civil Engineering (CE) emerging contractors and South Africa.

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Evaluating the Current Tender Adjudication in the Western Cape Province, South Africa

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Abstract

This article investigates the effectiveness of the tender adjudication process in the construction industry in the Western Cape Province, South Africa. Currently, the construction industry has shortcomings such as delays, a lack of transparency, variations in criterion application, and concerns about corruption, all of which significantly impact the process's effectiveness. Using an online questionnaire survey (48) and online structured interviews (3), the study employs a mixed method research technique. Descriptive statistics (mean, standard deviation, and ranks) are used to analyse the data The study adopted a content analysis for the qualitative data. The findings revealed the perceptions of stakeholders on the effectiveness of tender adjudication comprising the Supply Chain Management (SCM) team involved in the tender adjudication, the current performance of the tender adjudication method and the capabilities of many contractors selected under the current tender adjudication method. The qualitative findings reveal that contractors' price estimate, contractors' experience, government budget, functionality, formal education and training, and collaboration as the most effective tender adjudication used. In the re-allocation process, the respondents noted that functionality, price, and points for employing youth are significant in the tender adjudication process. Regarding an alternative tender adjudication process, price, functionality, gender, knowledge, education, and training were noted in the qualitative findings. The findings from this research could have several impactful implications, particularly in the context of construction project efficiency, policy refinement, and stakeholder satisfaction. The study's conclusions could lead to a restructuring of the Western Cape Province's tender adjudication procedure, which would increase openness, reduce delays, and ensure fairness. These reforms would raise stakeholder trust, reduce legal issues, and boost the construction industry's competitiveness.

Keywords: Fairness and Accountability, Procurement Efficiency, Tender Adjudication, Transparency in Procurement, and Western Cape Province

1. Introduction

The tender adjudication process plays a pivotal role in the selection of an appropriate contractor and during the implementation stage of a project (Urquhart, Whyte & Lloyd, 2017). Windapo and Cattell (2013) indicate that tender adjudication involves investigating, screening, and deciding if the contractor or bidder could be accepted. Furthermore, the course of action is conducted before the contract is awarded to the successful contractor and founded on the contractor's expertise, construction knowledge, financial steadiness, current workload, safety technique, record, and other criteria. The selection of an appropriate contractor for the right project depends on the bases of the procurement process (Kog & Yaman, 2014). According to Sarker, Chowdury and Deb (2012), the contractor for projects must be sensibly selected considering their knowledge, competence, and skills to achieve the best outcome for the project in terms of cost, time, and quality.

Guida *et al*. (2023) opine that project delays and the increase in the cost of construction projects are associated with specifications and contractors' qualifications known as financial, technical, knowledge, and contract type, while variation between the contractor's bid price and the next lowest bidder's price are related with the know-how of contractors. Current research shows that although tender adjudication has faced several obstacles, it has developed and is currently a notable procurement system in the construction industry in South Africa (Bolton, 2014; Makube, 2019). Part of construction procurement in South Africa is the preferential procurement system that supports Black Economic Empowerment (BEE) to ensure that income and wealth are distributed more equally among the majority (black) population (Mazibuko, 2018).

Although there are broad appeals for improvements in public procurement methods, empirical research on what precisely impedes effective tender adjudication process is limited (Hof, 2024; Gnoffo, 2021). Furthermore, Diriye and Ogbazghi (2024) adds that a study that fills this gap would give data-driven insights that could support targeted process improvements and policy changes, ultimately increasing the overall efficacy of public procurement in the construction sector. Therefore, it was important to investigate the

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current tender adjudication process adopted by construction stakeholders and to evaluate the most effective tender adjudication factors adopted in the Western Cape Province. The majority of departments and municipalities are taking procurement seriously during various stages of the process, but others do not seem to be able to make significant progress in securing a watertight procurement and supply-chain process (Ambe & Badenhorst-Weiss, 2012). There are concerns that if the tender adjudication process in the procurement function of government Departments fails, the national government might not be able to achieve its socioeconomic objectives (Williams-Elegbe, 2019). Although the South African government has developed a tender adjudication criterion, Matemotsa (2017), there is still inconsistency in the tender adjudication process in terms of selecting a suitable competitive bid. Simone and Balasundharam (2023) noted that the South African construction industry needs to consolidate and strengthen its procurement in order to ensure that the spending of public resources is more efficient and achieve savings through an effective tender adjudication process. The study aims to give practical insights and recommendations for enhancing the effective adjudication process. The ultimate goal is establishing a more transparent, fair, and efficient procurement system that increases the construction industry's competitiveness and promotes long-term regional development.

2. Literature Review

2.1. Procurement

Procurement refers to acquiring goods or services via purchasing or contracting, influenced by delivery, marginal benefits, and price factors (Shende, 2014). In supply chain management, it is especially crucial in the public sector, where structured tendering is common. In South Africa, public procurement addresses past inequalities and is central to socio-economic development (Kettl, 2015; Leal Filho et al., 2019). The Preferential Procurement Policy Framework Act (PPPFA) of 2000 supports SMMEs, HDIs, women, and people with disabilities to foster economic transformation. Public procurement, funded by taxpayers, increasingly mirrors global trade patterns and is seen as a socio-economic force (Corvaglia, 2016).

2.2. Targeted procurement in the construction industry

The Construction Industry Development Board (cidb) (2014) defines Targeted Procurement as a government procurement intercession strategy aimed at promoting the participation of targeted enterprises and labour in government infrastructure contracts. Developed in South Africa to address the legacy of apartheid, the policy seeks to shift tender and procurement opportunities from established contractors to emerging ones, thus providing business opportunities and employment for disadvantaged communities and individuals (Adediran & Windapo, 2017; Watermeyer, 2000).

In 1995, a Procurement Development Team (PDT) introduced targeted procurement, which was later adopted and driven by the National Department of Public Works in 1997, following cabinet approval. This initiative was part of broader public sector reforms, initially outlined in the '10-point plan', which provided interim measures under the State Tender Board Act of 1968 (Riccardi *et al*., 2019). Targeted procurement is widely used in the construction industry, particularly for public infrastructure projects, given the significant role of public spending in driving the sector's performance.

2.3. Tender adjudication

Tender adjudication involves evaluating contractor bids based on set criteria, including price, experience, and capacity (Lopez & Spiegel, 2023). While lowest bids are often prioritized, this can overlook quality and reliability (Jenkins, 2016). Inadequate evaluation may result in poor contractor performance (cidb, 2014). Challenges in South Africa include corruption, skill shortages, and poor communication with bidders (Komakech, 2016; Makube, 2019; Jenkins, 2016; Akram et al., 2023).

2.4. Tender adjudication process and criteria

The tender evaluation process begins with bid submission and compliance checks (Saboonchi et al., 2021). The PPPFA stipulates an 80/20 preference point system for tenders under R500,000 and 90/10 for those above. Price accounts for 80 or 90 points, while the remaining points are awarded for goals like B-BBEE, gender equity, and job creation (Watermeyer, 2004; Volmink, 2022). Misrepresentation of preferential claims can lead to contract termination and penalties (Korman, 2014).

2.5. Competitiveness of tender

In South Africa, the public procurement process primarily uses competitive bidding to ensure fairness, transparency, and value for money in government contracts (Akcay & Manisali, 2018). Traditionally, cost has been the main criterion for selecting contractors, with the lowest bid often winning, but this approach has evolved to include other evaluation criteria such as quality, sustainability, and socio-economic objectives (Thobela et al., 2022; Gasa, 2012). While awarding contracts to the lowest bidder remains common, there are concerns that such bids may signal financial instability and the inability to meet quality and project requirements (Botlhale, 2016; Sibanda & Tshikovhi, 2022). Therefore, verifying preferential claims before awarding PPPFA preference points is crucial (Hoffa, 2022; Munzhedzi, 2016). Contractors can improve their competitiveness by leveraging experience and

knowledge from previous projects (Leal Filho et al., 2019; Herman & Yohannis, 2018), with technical and financial capacity being critical success factors in the selection process (Kim & Mauborgne, 2014). Despite the dominance of large contractors in public sector projects, the selection process should be more rigorous and consider factors beyond price to enhance contractor performance (Oyewobi et al., 2014).

3. Research Methodology

3.1. Research design

Using a sequential mixed research design, this study investigates the efficiency of the tender adjudication process in the construction industry in the Western Cape Province, South Africa. A mixed methods approach allows for both quantitative and qualitative data to be collected simultaneously, analysed separately, and thereafter merged (Creswell & Plano-Clark, 2018).

The target population for this study comprised four government departments in the Western Cape Province, including the Department of Public Works (DPW), Department of Transport (DT), Department of Human Settlements (DHS), and the local government in the Western Cape (LGWC). The director from each department were contacted to provide the register of staff members. From these, using a non-probability technique and purposive sampling the adjudication committees within the (DPW), (DT), (DHS), and (LGWC) were selected to participate in the study (Patel & Patel, 2019). The participants included directors, quantity surveyors, architects, project managers, maintenance managers, and supply chain managers which were all members of the adjudication committee, which typically comprises no more than 12 members in each department of the government sphere (national, provincial, and local) resulting in 48 participants. A total of three (3) participants were randomly selected (Saunders *et al*., 2011) from government sphere to participate in the interview session as a measure to validate the results obtained from the quantitative data. Each respondent's professional background and engagement in the tender adjudication process in relevant departments were confirmed to ensure their suitability for contributing information for the study (Muhammed *et al*., 2022). Of the 48 questionnaires administered using Google Forms, a total of 37 questionnaires were retrieved and correctly completed, representing a 77% response rate, that is good to support this study as in the construction industry, acceptable response rates to tenders typically range from 20% to 30% (Hwang & Ng, 2013).

To collect data, a structured questionnaire (primary data) was developed based on a literature review (secondary data) of the tender adjudication of construction projects in public procurement in South Africa (Creswell & Creswell, 2018). The questionnaire contained two sections. Section one obtained the biographic profile of the participants, namely position in the business, highest educational level, number of years' experience in the business, and experience in tender adjudication. Section two is a set of 10 Likert-scale items relating to the construct 'tender adjudication' in the public sector. The interview session with each participant commenced with an explanation of the study's overall goal and the title of the research lasted between 30 to 45 minutes. The semi-structured interview guide contained two sections, Section A the background information of respondents, and section B contained only one major question: "What are the alternative criteria compared to current adjudication criteria to assist with selecting the most suitable service provider?" (Watkins, 2021). This question was asked to gain, from the perceptual views of the participants, a broad understanding of construction stakeholders regarding the efficiency of the current tender adjudication in the Western Cape province.

3.2. Data analysis

The quantitative data obtained from the survey questionnaire were analysed using statistical Package for the Social Sciences (SPSS) 25 software and descriptive statistics. Quantitative analysis is the process of discovering and describing data patterns through calculated processes (Russell & Purcell, 2009). Descriptive statistics was used to calculate and report the respondent's profile and to rank the tender adjudication efficiency results including frequency distributions, percentage, mean, and standard deviation. The responses were ranked on a five-point Likert scale where 1 = Strongly disagree (SD) ($\geq 1.00 \leq$ and < 1.80), 2 = Disagree (D) (≥ 1.81 and ≤ 2.60), 3 = Neutral (N) (≥ 2.61 and ≤ 3.40), 4 = Agree (A) (≥ 3.41 and ≤ 4.20), and 5 = Strongly agree (SA) (≥ 4.21 and ≤ 5.00). Likert-type or frequency scales use fixed-choice response forms and are intended to assess attitudes, views, and perceptions (Leavy, 2017). Content analysis was adopted for analysing the qualitative data on alternative methods for procurement and tender adjudication (Fellows & Liu, 2015). A qualitative content analysis approach was employed to analyse textual data from respondents' opinions. The data were coded manually using an inductive approach, identifying recurring themes related to procurement inefficiencies.

4. Results and Interpretation

4.1. Demographic information of the respondents

Table 1 indicates that most respondents were Quantity Surveyors (35.1%) and Project Managers (24.3%), with fewer Chief Construction Project Managers (13.5%) and Professional Project Managers (10.8%). A significant portion (81.1%) had between 1 and 10 years of experience in their current positions, reflecting relatively short tenure in their roles. More than half (51.4%) had 1 to 5 years of experience in tender

Table 1: Demographic information of the respondents

Demographic	Category	Frequency (n=37)	%
Position	Regional Manager	1	2.7
	Director Property	1	2.7
	Director Projects	3	8.1
	Quantity Surveyor	13	35.1
	Architect	3	8.1
	Director Supply Chain Management	1	2.7
	Deputy Director Facilities Management	2	5.4
	Professional Project Manager	4	10.8
	Chief Construction Project	5	13.5
	Manager Chief Works Manager	2	5.4
	Others	2	5.4
Experience in current position	1 – 5 years	21	56.8
	6 – 10 years	9	24.3
	11 – 15 years	4	10.8
	16 – 20 years	2	5.4
	21 – 25 years	1	2.7
Experience in tender awards	0 Project	5	13.5
	1 – 5 projects	19	51.4
	6 – 10 projects	8	21.6
	11 – 15 projects	3	8.1
	16 and above	2	5.4
Education	Matric	4	10.8
	Diploma	11	29.7
	Bachelor/ Honours degree	18	48.7
	Master's degree	4	10.8

awarding and had been involved in 1 to 5 tender projects. Although 21.6% had 6 to 10 years of experience, they handled slightly more projects (6 to 10). Most participants (79.4%) held either a bachelor's/honours degree (48.7%) or a national diploma (29.7%) in construction-related fields. While their qualifications are adequate, the limited experience highlights the need for targeted capacity-building to strengthen tender adjudication skills and improve decision-making efficiency.

4.2. The perception of the procurement stakeholders on the efficiency of the current tender adjudication method

4.2.1. Quantitative analysis

Table 2 indicates an average mean score of 3.84 which indicates that on average procurement stakeholders agree that all the statements in the construct 'tender adjudication' influence the efficiency of the current tender adjudication method in the Western Cape Province of South Africa. With mean scores above 4.20, procurement stakeholders strongly agreed that three statements have the most influence on the efficiency of the current tender adjudication method. Rank first (MS=4.31), 67.8% of the respondents agreed that the SCM team involved in tender adjudication does not have sufficient knowledge of the PPPFA to select a suitable contractor. 81.3% of respondents were concerned that the current tender adjudication process has loopholes that permit corrupt activities to take place in tender adjudication (MS=4.21) and 83% agreed that many contractors selected under the current tender adjudication process do not possess adequate capabilities to complete the project (MS=4.21), which affects the efficiency of tender adjudication. Although these two statements share the same mean score, this study adopted the standard deviation which show the loopholes that permit corrupt activities in the tender adjudication process are more significant in influencing the effectiveness of the current tender adjudication process (SD=0.631).

Underperforming service providers, which can be attributed to the ineffective selection method used in the current tender adjudication process (MS=3.17) had the lowest ranking, but 67.8% of the respondents agreed that this statement affects the tender adjudication process.

Table 2: Ranking the efficiency of the current tender adjudication method

Statement (n=37)	***1= Strongly Disagree … 5= Strongly Agree (%)***					**MS**	**Std. dev**	**Rank**
The Supply Chain Management (SCM) team involved in the tender adjudication process do not have sufficient knowledge of the Preferential Procurement Policy Framework Act used in the adjudication process to select a suitable contractor.	10.2	0.0	22	45.8	22	4.31	0.721	1
The current tender adjudication process has loopholes that permit corrupt activities.	3.4	13.6	5.1	23.7	57.6	4.21	0.631	2
Many of the contractors selected under the current tender adjudication process do not possess adequate capabilities to complete the project.	0.0	5.1	11.8	25.6	57.4	4.21	0.907	3
The effectiveness of the tender adjudication process to select the most suitable service provider for a construction project influences the tender adjudication process.	0.0	8.4	15.7	42.3	33.6	4.13	0.629	4
The tender adjudication process is not fair in the selection of a suitable contractor for construction projects.	0.0	1.7	22.0	40.8	37.2	4.00	0.889	5
The current tender adjudication process used under the Preferential Procurement Policy Framework Act is biased in selecting a suitable service provider for construction projects.	0.0	3.4	18.6	59.3	18.6	3.73	0.803	6
The tender adjudication process is effective in assisting with the selection of a suitable service provider.	0.0	5.1	16.9	59.3	18.6	3.61	0.793	7
The Preferential Procurement Policy Framework Act is an effective policy in the tender adjudication of selecting a suitable contractor for construction projects.	0.0	1.7	22.0	59.3	16.9	3.57	0.923	8
There is no transparency in the current tender adjudication process.	0.0	5.1	28.8	39.0	27.1	3.41	0.651	9
Underperforming service providers can be attributed to an ineffective current tender adjudication process.	0.0	15.3	16.9	22.0	45.8	3.17	0.990	10
Composite score average						3.84		

4.3. Qualitative analysis

4.3.1. Background of the interviewees

Three interviews were conducted with professionals involved in tender adjudication in the Western Cape:

- Participant A, a Quantity Surveyor from the Department of Public Works, was interviewed on 19 October 2022. With a BTech in Quantity Surveying, they had 25 years' industry experience and 15 years in tender adjudication, focusing on building projects.
- Participant B, a Project Manager at the Department of Human Settlements, was interviewed on 28 October 2022. They held a Master's in Construction Management and had over 10 years' adjudication experience, including national projects.
- Participant C, a Supply Chain Director in local government, was interviewed on 11 November 2022. With a BTech in Construction Management and SACPCMP registration, they had 25+ years' industry experience and over five years in their current role.

4.3.2. Alternative criteria compared to current adjudication criteria to assist with selecting the most suitable service provider

The findings reveal that tender pricing plays a crucial role in adjudication, with *Participants A and B* emphasizing that cost, functionality, and B-BBEE status influence contractor selection. While price is a key determinant, over-reliance on the lowest bid may compromise project quality, as some contractors lower their prices despite lacking the necessary capacity and experience. Functionality, including workforce establishment, financial stability, and risk mitigation, is essential for ensuring successful project delivery. B-BBEE compliance remains a priority, fostering inclusivity without excluding qualified contractors in tender adjudication process. *Participant C* highlights the need for transparency and fairness in procurement, stressing that favouritism and bias must be eliminated to maintain integrity in the process. Furthermore, many SMME contractors lack a proper understanding of the tendering process, leading to competency concerns, and underscoring the need for contractor education and capacity-building initiatives to enhance their competitiveness and project execution capabilities. In summary, the results from participants highlight the following factors namely: price, functionality, experience, quality, B-BBEE compliance, transparency and fairness, education, and capacity building.

5. Results discussion

The quantitative results revealed that many Supply Chain Management (SCM) professionals involved in tender adjudication lack sufficient knowledge of the Preferential Procurement Policy Framework Act (PPPFA), with 67.8% of respondents agreeing it negatively impacts the process (MS=4.31). This aligns with Khuzwayo (2020) and Vinti (2021), who stress that limited PPPFA knowledge undermines preferential procurement goals and fair contractor selection. Corruption-related loopholes were identified as the second key issue (MS=4.21), with 81.3% of respondents agreeing they affect the adjudication process. Similarly, 83% agreed that many selected contractors lack the capabilities to complete projects. Mahmood (2010) notes corruption is common in construction procurement, while Bonsu et al. (2022) argue that transparent procurement practices can mitigate this. The effectiveness of current adjudication practices ranked third (MS=4.13), and fairness in contractor selection ranked fourth (MS=4.0), with 77.9% viewing the PPPFA-based process as biased (MS=3.73). This supports findings from Huang (2011) and Chen et al. (2021) regarding the lack of transparency in selection criteria. Despite these issues, many respondents acknowledged that the tender adjudication process remains important (MS=3.61) in ensuring project delivery, as also supported by Kafile (2018).

Qualitative results showed that contractor price competitiveness, experience, and capacity significantly influence adjudication outcomes. These findings align with Aljohani et al. (2017), Qiang (2015), and Akali & Sakaja (2018), who emphasize the value of tracking contractor history and resource availability. Contractor functionality and management competence were also found to be key, reinforcing the need for formal training and TVET as noted by Yangben & Seniwoliba (2014). *Participant C* emphasized collaboration between established and emerging contractors to improve competition, echoing Bemelmans et al. (2012) on the importance of networking in the industry.

6. Conclusion and Further Research

This study aims to propose effective procurement strategies adopted by construction stakeholders by proposing guidelines to enhance the efficiency of the current tender adjudication method. This study focuses on the Western Cape Province and cannot be generalized to other Provinces. Concerning the perception of procurement stakeholders on the efficiency of the current tender adjudication method, in hierarchical order, includes that the tender adjudication team does not have sufficient knowledge of the Preferential Procurement Policy Framework Act (PPPFA) used in the adjudication method to select a suitable contractor, the tender adjudication method has loopholes to permit corruption activities, and the effectiveness of the tender adjudication method in selecting the most suitable service provider for the construction is important.

Based on the qualitative findings, alternative innovative methods for public procurement should include pricing, functionality, and gender equality. The quantitative results were supported by the qualitative findings regarding the effective tender adjudication process adopted in public procurement. Therefore, the tender adjudication process needs to recognise contractor functionality as a significant criterion to ensure successful project delivery. Furthermore, using a points award system for appointing youth requires a significant consideration in tender adjudication criterion to ensure that public projects limit the unemployment rate in the South African nation. The findings provide useful insights for government agencies and stakeholders, suggesting specific reforms that can speed up adjudication and improve fairness in public procurement. The study's evidence-based recommendations help to build more equitable and efficient tender methods, with the ultimate goal of improving service delivery, resource allocation, and public trust in the province.

The study recommends that the tender adjudication stakeholders should note that the current tender adjudication method, seen tenders sometimes awarded to incorrect contractors because of the tender adjudication team’s inefficient knowledge regarding the Preferential Procurement Policy Framework Act (PFA). Thus, it is recommended that further research should be conducted on the level of training provided to the tender adjudication team to enhance the level of competency within the adjudication team. The tender adjudication team should be aware of the tender adjudication method that has loopholes that permit corruption activities in the South African procurement process. Public stakeholders should be aware of the effectiveness of the tender adjudication method in selecting the most suitable service provider, public practitioners who invest funding in the government sector should relook at the effectiveness of the current tender adjudication.

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Predictive Analytics and Stochastic Programming for Construction Resource Optimization in Developing African Economies

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Abstract

This research investigates the application of AI-driven predictive models for optimizing resource allocation and mitigating economic risks in large-scale construction projects across developing African economies. Through the development of sophisticated mathematical frameworks, including linear programming for resource optimization, multivariate failure prediction models, and stochastic programming for supply chain management, we present a comprehensive approach to addressing the complex challenges facing the African construction sector. The study demonstrates significant improvements in project outcomes, with the predictive maintenance model achieving 91.5% accuracy in equipment failure prediction and the cost estimation framework explaining 81.3% of cost variance. However, implementation challenges including data scarcity, infrastructure limitations, and the need for local expertise development must be carefully addressed. The research provides valuable insights for construction project managers, policymakers, and researchers, contributing to more efficient and sustainable infrastructure development across Africa.

Keywords: Artificial Intelligence, Construction Project Management, Resource Optimization, Risk Mitigation, African Infrastructure Development

1. Introduction

The African construction sector stands at a critical juncture where large-scale infrastructure projects are essential for economic development, yet face unprecedented challenges in resource optimization and risk management (Balasubramanian, n.d.). These challenges manifest through volatile material costs, persistent labor shortages, and complex supply chain disruptions that traditional management approaches struggle to address effectively. In this context, Artificial Intelligence (AI) emerges not merely as a technological solution, but as a transformative force capable of revolutionizing construction project management through advanced predictive analytics and optimization algorithms (Lan, 2024).

This research addresses a fundamental question in African construction management: How can AI-driven predictive models be leveraged to optimize resource allocation and mitigate economic risks in large-scale construction projects within developing African economies? The significance of this inquiry is underscored by the World Bank's estimation that Africa faces an annual infrastructure financing gap of $68-108 billion (African Development Bank, 2023), highlighting the urgent need for more efficient project management approaches.

The relevance of this investigation is threefold. First, it addresses the critical infrastructure gap facing African nations, where efficient and cost-effective construction practices are essential for economic growth and improved living standards. Second, it responds to the limitations of traditional project management methods, which have resulted in significant cost overruns, delays, and resource inefficiencies across major infrastructure projects. Third, it explores the potential of AI technologies to transform project management practices in a context where such applications remain largely unexplored.

The timeliness of this research coincides with rapid advancements in AI and machine learning technologies, offering unprecedented opportunities for innovation in construction management (Bang & Olsson, 2022). While these technologies have demonstrated success in various industries, their application in African construction contexts presents unique challenges and opportunities (Holzmann & Lechiara, 2022). This study aims to bridge this gap by examining how AI can be effectively adapted to address the specific challenges of African construction projects. Through rigorous mathematical modeling and empirical analysis, this research develops a comprehensive framework for integrating AI-driven solutions into construction project management (Rastegar et al., 2021; Hajipour et al., 2025). The findings will provide valuable insights for policymakers developing infrastructure strategies, practitioners seeking to improve project outcomes, and researchers exploring the intersection of AI and construction management in developing economies. Ultimately, this work contributes to the broader goal of establishing more sustainable and efficient infrastructure development practices across the African

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continent.

2. Methodology: Simulation and Modeling Approach

This research utilized a simulation-based methodology to rigorously assess the proposed AI-driven frameworks in the context of developing African economies. Project scenarios, equipment lifecycles, and cost variables were simulated utilizing the R statistical software environment. This method facilitated the creation of controlled datasets that mirrored standard project parameters and uncertainties present in the target context, which were later utilized to train and validate the predictive maintenance and cost estimation models outlined below. The parameterization of the simulation models was based on existing literature and recognized attributes of African construction projects.

2.1. AI-Powered Resource Allocation

2.1.1. Dynamic Scheduling and Resource Optimization

Resource allocation in large-scale African construction projects can be effectively modeled using linear programming to minimize costs while meeting project requirements. This approach directly addresses our research question by providing a mathematical framework for optimizing resource allocation and mitigating economic risks. The linear programming model is defined as follows:

$$\text{Minimize } Z = \sum_{i=1}^{n} c_i \, x_i$$

Subject to: $\sum_{i=1}^{n} a_{ij} \, x_i \geq b_j \quad \text{for } j = 1,2,\ldots,m \quad x_i \geq 0 \quad \text{for } i = 1,2,\ldots,n \quad \sum_{i=1}^{n} x_i = s$

In this model, Z represents the total cost to be minimized, where c_i is the cost per unit of resource i, and x_i is the number of units of resource i allocated. The constraints ensure that the resource requirements (a_{ij}) for each activity j are met, while not exceeding the total available resources s (Ahirrao et al., 2020). This formulation allows for the dynamic adjustment of resource allocation in response to changing project conditions, a critical feature in the volatile construction environments often encountered in developing African economies.

The power of this approach lies in its ability to handle complex, multi-dimensional resource allocation problems that are common in large-scale construction projects (Aadharshana & Shiny Mol, 2020). By incorporating constraints that reflect local conditions, such as labor availability, material costs, and regulatory requirements, the model can be tailored to the specific challenges of African construction contexts. Furthermore, the model's flexibility allows for real-time adjustments as project conditions evolve, enabling project managers to respond swiftly to unforeseen challenges and opportunities.

To implement this model, advanced optimization algorithms can be employed, such as the simplex method or interior point methods (Reeb & Leavengood, 1998), which are available in software packages like Python's SciPy or specialized optimization tools. These algorithms can efficiently solve large-scale linear programming problems, providing optimal or near-optimal solutions even for projects with thousands of variables and constraints (Chang et al., 2016).

Utilizing this mathematical framework, project managers can make data-driven decisions that reconcile cost minimization with project requirements, resulting in enhanced resource utilization and diminished economic risks. This method directly tackles the fundamental issues highlighted in our research question, providing an effective instrument for enhancing resource allocation in the intricate and evolving landscape of African construction projects.

Figure 1 illustrates the optimization model's key components in a two-dimensional representation. The shaded region represents the feasible solution space bounded by three essential constraints: minimum resource requirements (blue and orange lines) and resource availability limits (green line). The dashed red line represents the objective function's direction of improvement, showing how costs can be minimized while maintaining feasibility. This visualization demonstrates how the model balances multiple competing constraints typical in construction projects, such as labor hours, equipment utilization, and material quantities.

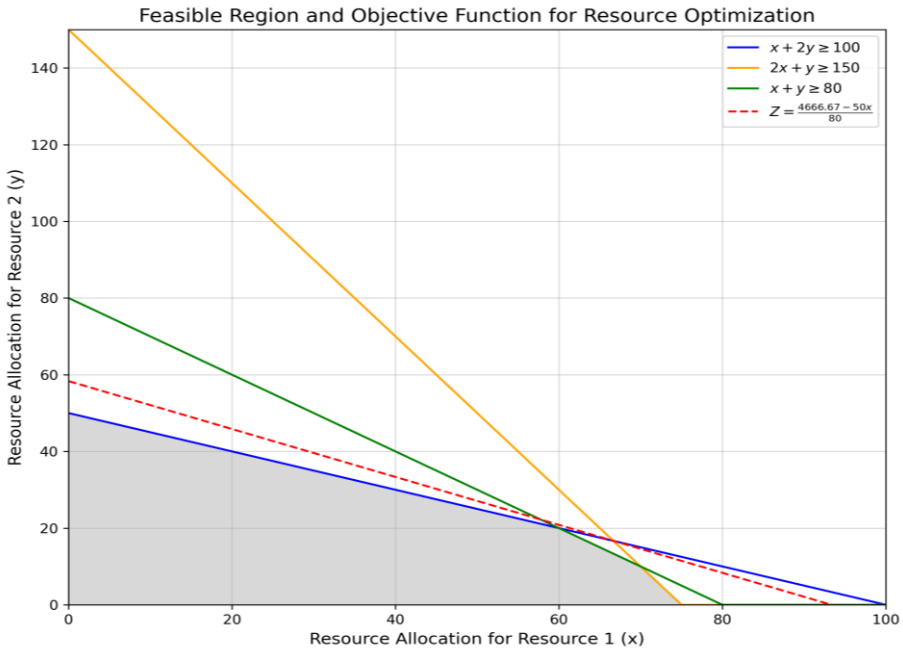


Figure 1: Feasible Region and Objective Function for Resource Optimization

The intersection points of these constraint lines represent potential optimal solutions, where resource allocation achieves maximum efficiency while satisfying all project requirements. In practice, construction managers can use this visual representation to understand how changes in resource availability or project requirements affect the optimal allocation strategy. This dynamic approach enables rapid decision-making in response to the volatile conditions often encountered in African construction environments.

2.1.2. Predictive Maintenance for Equipment

AI-driven predictive maintenance models leverage advanced machine learning algorithms to forecast equipment failures in construction projects, addressing a critical aspect of resource optimization and risk mitigation (Larocque-Villiers et al., 2021; Wang et al., 2022). The probability of equipment failure can be modeled through a comprehensive multivariate function that incorporates temporal, operational, and environmental factors:

$$P(\text{failure}) = \alpha \cdot e^{-\lambda t} + \beta \cdot \frac{u}{u_{\max}} + \gamma \cdot \sum_{i=1}^{n} w_i m_i + \delta \cdot \phi(e)$$

In this enhanced model, α, β, γ, and δ represent weighting coefficients that adjust the relative importance of each factor, where t denotes time since last maintenance, u represents usage intensity normalized by maximum capacity $u_{\max}$, m_i signifies various maintenance history indicators with corresponding weights w_i, and $\phi(e)$ is a function that transforms environmental factors into a normalized risk score.

The temporal component $e^{-\lambda t}$ models the exponential decay of equipment reliability over time, while the usage intensity factor $\frac{u}{u_{\max}}$ captures the stress on equipment relative to its designed capacity. The maintenance history term $\sum_{i=1}^{n} w_i m_i$ aggregates previous maintenance events and their outcomes, and the environmental impact function $\phi(e)$ accounts for external conditions affecting equipment performance (Znaidi et al., 2023) (Figure 2).

To train and evaluate the predictive maintenance model, a dataset reflecting equipment behavior under typical African conditions was generated via simulation in R. Key parameters influencing failure probability; such as baseline reliability decay rates (λ), usage intensity patterns (u/u_{max}), maintenance effectiveness metrics (w_i for different repair types), and the impact of relevant environmental factors ($\Phi(e)$, e.g., heat, dust levels common in certain regions); were defined based on (Makaula et al., 2021; Wang et al., 2022).

The simulation generated $N = 200$ independent lifecycle trajectories for pieces of equipment, recording time-series data for operational hours, maintenance events, environmental exposure, and operational status (Failure/No Failure). This simulated dataset, capturing the variables defined in the failure probability model, was then used to train and test a Random Forest classifier, implemented using the 'randomForest' package in R. The performance of the trained classifier

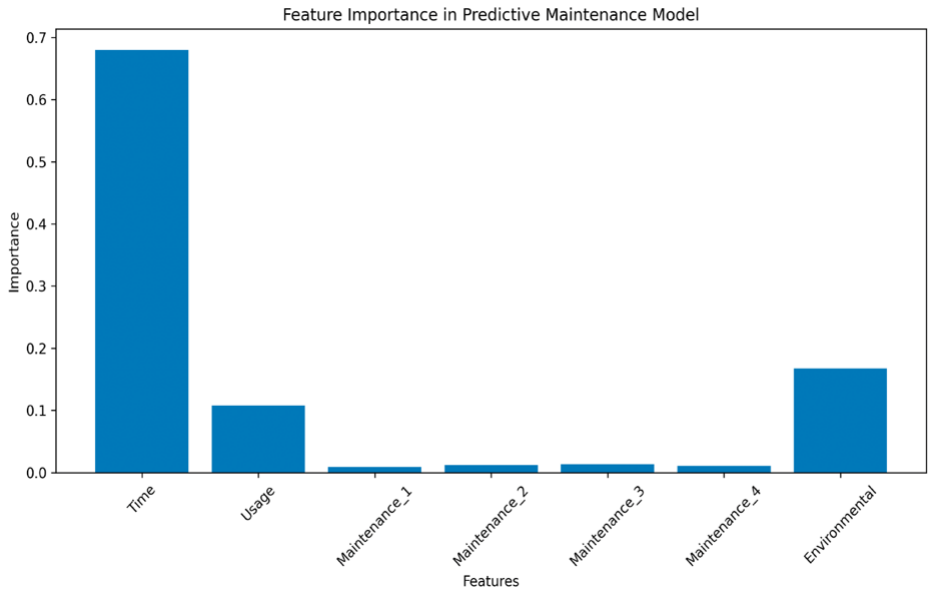


Figure 2: Simulation of Maintenance Data and Model Training

on a held-out test set from the simulated data is presented in Table 1.

Table 1: Performance of Trained Classifier

Class	Precision	Recall	F1-score	Support
No Failure (0)	0.888	0.950	0.918	100
Failure (1)	0.946	0.880	0.912	100
Accuracy	0.915	0.915	0.915	200
Macro avg	0.917	0.915	0.915	200
Weighted avg	0.917	0.915	0.915	200

The model's performance metrics and feature importance analysis provide crucial insights for our research question. The high precision (0.946) for failure prediction indicates the model's reliability in identifying potential equipment breakdowns, which is essential for risk mitigation in African construction projects [15]. The feature importance plot reveals that temporal factors dominate the prediction (approximately 67%), followed by usage intensity (10%), and environmental factors (16%), with maintenance history indicators contributing the remaining influence. This hierarchical importance aligns with the practical challenges faced in African construction environments, where time-based degradation and environmental conditions significantly impact equipment reliability.

This mathematical framework directly addresses our research question by providing a quantitative basis for resource optimization and risk mitigation in African construction projects. The model's high accuracy (91.5%) across all metrics demonstrates its potential for reliable equipment failure prediction, enabling project managers to make informed decisions about maintenance scheduling, resource allocation, and risk management strategies in the challenging context of African construction projects.

2.2. Economic Risk Mitigation

2.2.1. AI-Enhanced Cost Estimation

Construction cost estimation in African projects requires sophisticated modeling approaches that account for multiple variables and their complex interactions (Elmousalami, 2020; Ayinla et al., 2023). The advanced cost estimation model integrates both linear and non-linear components to capture the intricate relationships between project features:

$$C = \sum_{i=1}^{n} \beta_i X_i + \sum_{i=1}^{n} \sum_{j=1}^{n} \gamma_{ij} X_i X_j + \alpha e^{\Sigma_{i=1}^{k} \delta_i Z_i} + \epsilon$$

In this enhanced formulation, the total project cost C comprises three key components: a linear term capturing direct relationships, an interaction term accounting for feature interdependencies, and an exponential term modeling non-linear cost escalations. The coefficients β_i represent direct cost impacts, while

γ_{ij} captures interaction effects between features X_i and X_j. The exponential component, weighted by α, incorporates risk factors Z_i with corresponding sensitivities δ_i, addressing the volatile nature of African construction markets.

The model's error term ϵ follows a heteroskedastic distribution to account for increasing uncertainty with project size:

$$\epsilon \sim \mathcal{N}\left(0, \sigma^2(X)\right) \text{ where } \sigma^2(X) = \rho \parallel X \parallel^2$$

2.3. Simulation of Cost Data and Model Validation

To develop and validate the AI-enhanced cost estimation model, a dataset representing various construction projects was generated through simulation using R. The simulation incorporated representative project features (X_i, e.g., scale, duration, material types, complexity indices) and risk factors (Z_i, e.g., probability of labor disputes, material price volatility index, likelihood of regulatory delays) characteristic of large-scale infrastructure projects in developing African economies. The definition and distribution of these variables, along with their associated cost impacts (coefficients β_i, γ_{ij}, δ_i), were informed by [16] [20].

The simulation generated a dataset of hypothetical project profiles, each with a calculated total cost (C) based on the model structure, including simulated occurrences of risk events and the defined heteroskedastic error term (ε). This simulated dataset provided the basis for training the cost estimation model (e.g., using multiple regression techniques potentially incorporating machine learning for feature selection or non-linear term estimation) and evaluating its predictive performance through methods such as k-fold cross-validation.

2.4. Cost Estimation Model Performance Analysis

The model's performance (Figure 3) metrics demonstrate its effectiveness in addressing the research question of optimizing resource allocation and mitigating economic risks in African construction projects. With an R^2 value of 0.813, the model explains approximately 81.3% of the variance in construction costs, indicating strong predictive capability while maintaining realistic variability. The Root Mean Square Error (RMSE) of 26,858.180 and Mean Absolute Error (MAE) of 19,309.540 reflect the model's practical accuracy in cost predictions, with errors representing approximately 10-15% of typical project costs - a reasonable range given the inherent uncertainties in African construction markets.

These results are particularly relevant to our research question as they demonstrate the model's ability to capture both systematic cost patterns and market uncertainties. The lower-than-perfect R^2 value actually indicates a more realistic model that accounts for the genuine variability in construction costs, while the RMSE and MAE values provide practical bounds for risk assessment and contingency planning. This balance between accuracy and uncertainty modeling makes the framework especially suitable for the dynamic African construction environment, where perfect cost prediction is neither possible nor desirable due to market volatility and resource constraints. The model thus provides project managers with a reliable tool for cost estimation while acknowledging and quantifying the inherent risks in construction projects.

2.5. Supply Chain Optimization

The optimization of construction supply chains in African contexts requires sophisticated stochastic programming approaches that can handle multiple uncertainties while maintaining operational efficiency. The enhanced model incorporates both first-stage decisions and recourse actions through a two-stage stochastic program:

$$\text{Minimize } \sum_{t=1}^{T} c_t^T x_t + \mathbb{E}_{\xi}[Q(x,\xi)]$$

$$\text{Subject to: } \sum_{t=1}^{T} A_t x_t \leq b \quad x_t \geq 0, \quad t = 1, \ldots, T$$

Where the recourse function $Q(x,\xi)$ is defined as: $Q(x,\xi) = \min_{y}\{q^T y \mid Wy \leq h(\xi) - Tx, y \geq 0\}$

In this formulation, x_t represents first-stage decisions such as resource allocation and supplier selection, while y captures recourse actions taken in response to uncertainty realizations ξ. The matrices A_t and vectors c_t define the technological and cost coefficients respectively, while W represents the recourse matrix and T the technology matrix linking first-stage decisions to second-stage constraints.

The model explicitly accounts for construction-specific uncertainties through:

1. Material supply variations: modeled through the random vector ξ_s affecting resource availability.
2. Demand fluctuations: captured in $h(\xi)$ as stochastic requirements.
3. Cost uncertainties: represented in q^T as variable cost coefficients.

1.

This mathematical framework directly addresses our research question by providing a robust approach to optimize resource allocation while mitigating risks in African construction projects (Hsu et al., 2018). The model's ability to adapt to changing conditions through recourse actions is particularly valuable in environments with high uncertainty levels, as demonstrated by the residual analysis and feature importance plots which show significant impact of

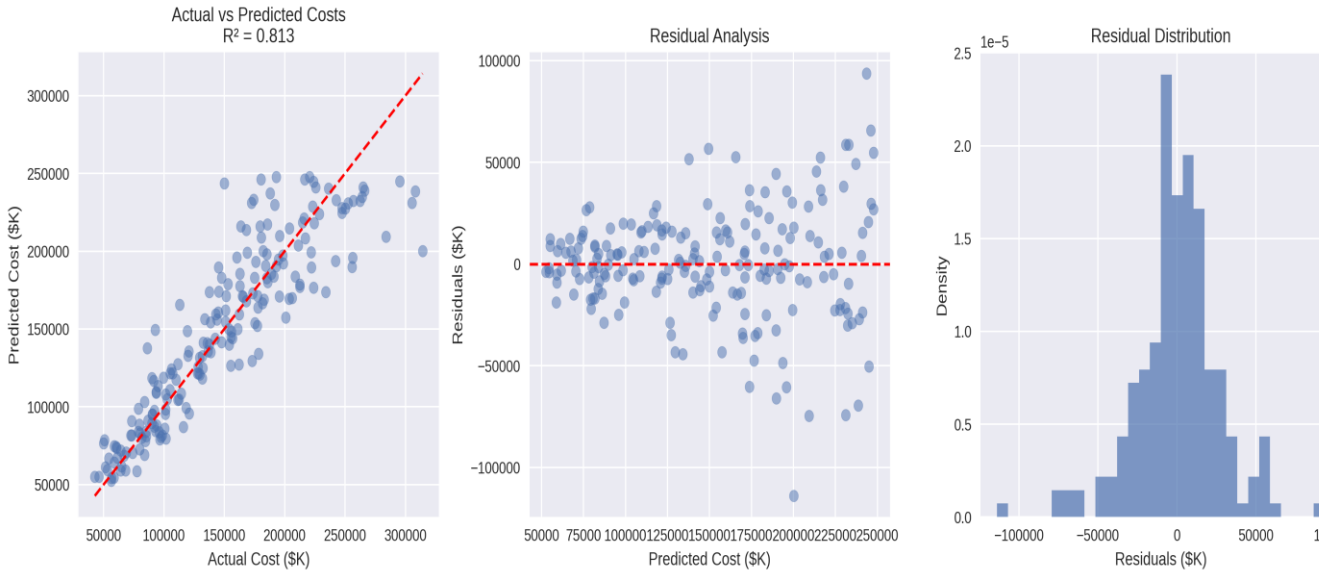


Figure 3: Cost Estimation Model Performance Analysis (Actual vs Predicted Costs, Residual Analysis, Residual Distribution)

temporal and environmental factors on decision outcomes.

The implementation through advanced optimization algorithms achieves a balance between computational efficiency and solution quality, enabling project managers to make informed decisions about resource allocation, supplier selection, and risk mitigation strategies in real-time. This adaptive capability is crucial for maintaining project continuity and cost effectiveness in the dynamic African construction sector [19], [20].

3. Discussion

This study illustrated, via simulation, the considerable potential of particular AI-driven models to improve construction project management in developing African economies. The Random Forest model attained a high predictive accuracy of 91.5% for equipment maintenance, based on 200 samples, while the AI-enhanced cost estimation framework demonstrated substantial explanatory power with a R^2 of 0.813, directly fulfilling the primary research objective of utilizing AI for resource optimization and risk mitigation. The performance levels align with benchmarks documented in pertinent predictive maintenance and construction cost modeling literature, indicating the viability of effectively implementing these advanced techniques. The recognition of temporal factors as primary in predicting equipment failure corresponds with practical realities in settings where equipment age and regular maintenance are critical variables. Thus, these findings possess considerable practical significance, providing avenues for project managers and policymakers in Africa to potentially realize substantial cost reductions through diminished equipment downtime, enhanced budget forecasting precision, and more dependable resource planning, ultimately facilitating more efficient and predictable infrastructure project execution.

Notwithstanding these encouraging simulation outcomes, the results must be evaluated in light of the study's limitations. The results are primarily based on simulations utilizing representative parameters and have not been validated with comprehensive real-world project data gathered from various construction sites throughout Africa. The chosen parameters for the simulations, while guided by existing literature, significantly affect the results, and the possible synergistic advantages of comprehensively integrating the various AI models (LP, PM, Cost Estimation, SP) were not investigated in this study. Consequently, essential future research avenues involve executing pilot studies and case-study validations of these models across diverse African nations to evaluate their real-world efficacy and adaptability. Developing strong, context-sensitive data collection frameworks and further exploring transfer learning methodologies to modify global models are essential subsequent actions. Furthermore, investigating integrated AI platforms for comprehensive project management and thoroughly examining the ethical implications of AI implementation are crucial for the responsible and significant use of these technologies in the region.

4. Contextual Challenges and Solutions

The implementation of AI-driven optimization models in African construction projects faces several interconnected challenges that require comprehensive solutions. Data scarcity and quality issues represent primary concerns, which can be addressed through the

deployment of IoT sensors for real-time data collection from construction sites (Jiang & He, 2020; Hou et al., 2022). Furthermore, transfer learning techniques enable the adaptation of models trained on comprehensive global datasets to local conditions, while strategic partnerships with academic institutions facilitate the creation of region-specific datasets essential for model accuracy.

Infrastructure limitations pose significant obstacles to AI implementation in remote construction sites. However, these challenges can be mitigated through edge computing solutions that enable on-site AI processing with minimal internet connectivity requirements (Hou et al., 2022). Additionally, satellite-based internet services provide crucial support for remote project locations where traditional connectivity infrastructure is lacking (Xiang et al., 2021).

The development of local expertise remains crucial for sustainable AI implementation. This necessitates comprehensive training programs in AI and data science, supported by strategic collaborations between construction firms and universities. These partnerships not only accelerate capacity building but also ensure the continuous development of relevant skills within the local workforce (Guo & Li, 2022).

Ethical considerations play a vital role in the implementation of AI systems in construction projects. Transparency in AI decision-making processes must be maintained throughout all project phases, while robust measures for protecting worker privacy when using monitoring systems need to be established. Moreover, careful attention must be paid to avoiding algorithmic biases that could potentially exacerbate existing socio-economic inequalities in the construction sector. These ethical considerations must be integrated into the core design and implementation of AI systems to ensure responsible and equitable technological advancement in African construction projects (Bellamy et al., 2019).

5. Conclusion

This research demonstrates the transformative potential of AI-driven predictive models in optimizing resource allocation and mitigating economic risks in African construction projects. Through the development and analysis of sophisticated mathematical frameworks, including linear programming for resource optimization, multivariate failure prediction models, and stochastic programming for supply chain management, we have established a comprehensive approach to addressing the complex challenges facing the African construction sector.

The integration of dynamic scheduling, predictive maintenance, and cost estimation models has shown significant promise in improving project outcomes. Our predictive maintenance model achieved 91.5% accuracy in equipment failure prediction, while the cost estimation framework demonstrated strong predictive capability with an R^2 value of 0.813, providing project managers with reliable tools for decision-making in uncertain environments.
However, successful implementation of these AI solutions requires careful consideration of contextual challenges unique to African construction environments. The proposed frameworks must be adapted to address data scarcity, infrastructure limitations, and the need for local expertise development. Furthermore, ethical considerations and socio-economic implications must remain central to the deployment of AI technologies in African construction projects.

Looking forward, this research opens new avenues for the application of AI in construction project management across developing economies. The mathematical models and frameworks presented here provide a foundation for future research and practical implementation, potentially transforming how large-scale construction projects are managed in Africa. By combining technological innovation with contextual awareness, these solutions can contribute significantly to reducing project risks, improving resource utilization, and ultimately supporting sustainable infrastructure development across the continent.

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ACADEMIC PAPERS: THEME 10 - CONTRACT MANAGEMENT/ COSTING AND SCHEDULING IN THE CONSTRUCTION INDUSTRY

A Conceptual Framework for Managing Employers' Claims in Mega Construction Projects

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Abstract

Mega construction projects are often associated with high-cost overruns. Most of these costs are associated with construction claims. The contractors mostly submit these claims against the employer. Contractors can successfully defend their claims. Some of these claims are supposed to be apportioned between the two parties. However, in most cases, the Employer's claims are not submitted. The purpose of this study was to determine the effect of employers' claims on the reduction of construction cost overruns. The study employed a quantitative research approach. The study adopted a purposive sampling technique with a sample size of 50 respondents. Data was collected with a survey questionnaire from professionals involved in the design and execution of projects within the construction industry, based in Gauteng province in South Africa. The respondents include Construction Project Managers and Quantity Surveyors. Results of the survey were analysed using the relative importance index statistical method, which resulted in the identification of the cost overrun factors that could lead to construction claims for a multi-contractor construction project. These factors include contract management, constructability, access to the site, coordination of the work of the contractors, incompetence of contract managers responsible for claims and poor planning. The findings of the study reveal that there is a lack of effort from the employer's side to mitigate the risk associated with the identified cost overrun factors. The study recommends that construction management companies should work together with the employer to develop practices to manage construction activities to avoid claims.

Keywords: Employer's claims, Constructability, Construction claims, Contracts management

1. Introduction

More than one contractor executes mega construction projects. This multiple-contractor set-up is complicated by the sub-contracting of some of the construction scope by the main contractors. The employer (project owner) has a contract with each of the leading contractors. The employer may enter a different contracting arrangement with each of the leading contractors. The employer is responsible for ensuring well-coordinated access to the construction site by these contractors. A well-coordinated access is required for the successful completion of the project scope without going through the claims process. Some of the contractors' access to the construction site is dependent on the completion of the works by other contractors.

An example would be Civil works to be completed before Mechanical works can commence. A delay by a Civil contractor forces a Mechanical contractor to file an access-related claim against the employer. In turn, the employer is compelled to file an access-related claim against the Civil contractor. The employer must find a mechanism to pass through the Mechanical contractor's claim to the Civil contractor. In most cases, the Civil contractor's claim cannot offset a Mechanical contractor's claim, and the employer would not be absolved from the claim. The employer is expected to manage and coordinate all the work on the construction site. The merit of the construction claim would be based on the extension of time due to late access to the construction site by other contractors. The other problem with multiple contractors working on-site at the same time is the coordination of construction work. The main aim of this study was to determine the effect of the employer's claim on the reduction of construction cost overruns. Factors contributing to cost overruns need to be evaluated to determine the extent to which they lead to employers' claims.

2. Literature Review

The process of managing claims can be complex if there are no mechanisms to manage them, and this could lead to wasteful consumption of resources like time and money (Shahhosseini & Hajarolasvad, 2021). Several factors contribute to construction claims for a mega construction project. The literature review for this study identified several factors that could lead to construction claims. These factors are grouped into the following seven categories:

2.1. Poor procurement preparation

Procurement is important for contracting and sourcing of goods and services. Poor procurement planning leads to construction claims (Lal & Mathew, 2022). A delay in procuring goods and services results in a delay in providing access to the construction site (Amoatey & Ankrah, 2017). Procurement-related claims are due to the contractors not sourcing the construction materials on time. For the employer's side, it could mean the contract was awarded late, and the construction schedule is not aligned with the delivery time of the

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material. Poor procurement planning affects the construction schedule, and this could lead to construction claims due to an extension of time. The delays in executing construction activities are due to the late delivery of construction materials (Ajibike et al., 2022; Namous & Al Battah, 2021; Oluwajana et al., 2022; Tahmasebinia & Song, 2022). Procurement planning requires adequate knowledge of the lead times of the construction materials. Shortage of materials in the market and lack of knowledge of the lead times of the construction materials are some of the factors that contribute to the late delivery of construction materials on site (Enshass et al., 2009; Habibi & Kermanshachi, 2018).

2.2. Inadequate planning

Construction projects are expected to be executed as planned. However, the reality is that most projects experience inadequate planning, which leads to a negative impact on project cost and schedule (Oluwajana et al., 2022; Ammar et al., 2022). If the poor planning is on the side of the contractor, then the employer is entitled to the Employer's claim, and if the poor planning is on the side of the employer, then the contractor is entitled to the Contractor's claim. Most construction projects are not adequately prepared for planning and execution (El-Maaty et al., 2017). Inadequate planning leads to poor contract planning (Asiedu & Adaku, 2020; Arantes & Ferreira, 2020). Poor contract planning leads to unrealistic contract duration (Albtoush et al., 2022; Badawy et al., 2022; Shashikanth & Prasad, 2021). The consequence of unrealistic contract duration imposed by the employer would be project cost overrun (Famiyeh et al., 2017; Arantes & Ferreira, 2020). The affected contractors would be entitled to a claim for an extension of time. The employer must file the Employer's claims. Poor planning could result in a delay of the delivery of materials on site (Ajibike et al., 2022; Namous & Al Battah, 2021; Oluwajana et al., 2022; Tahmasebinia & Song, 2022) and inadequate sourcing of equipment (Oluwajana et al., 2022). The delay will impact the construction schedule, and the contractor will not be entitled to the extension of time claim.

2.3. Inaccurate cost estimation

Cost estimation is one of the factors that contribute to construction claims. There is a tendency for some of the contractors to underestimate their construction costs to get a construction tender (Famiyeh et al., 2017). Underestimation of the construction cost leads to change orders, and this results in construction claims (Ammar, Abdel-Monem & El-Dash, 2022; Fashina et al., 2021; Oluwajana, Ukoje, Okosun, & Aje, 2022). The contractor should file the construction claim due to poor cost estimation. It is the responsibility of the employer to check if the estimate complies with the scope of work and the specifications. If the scope is poorly defined, then the contractor will be entitled to a claim. Poor scope definition of work contributes to poor cost estimates (Famiyeh et al., 2017).

2.4. Design changes, Change orders, Scope changes

One of the factors contributing to design changes is poor scope definition. Poor scope definition leads to inaccurate project specifications. Design changes result in changes in scope, and this has a negative impact on project cost and schedule (Ammar et al., 2022; Albtoush et al., 2022; Lal & Mathew, 2022; Rustandi et al., 2022; Ajibike et al., 2022; Ahmed & Arocho, 2021; Oluwajana et al., 2022; Tahmasebinia & Song, 2022; Alekhya et al., 2021). Scope changes lead to a substantial increase in project costs, and they can also lead to extensive delays in the project schedule (Amoatey & Ankrah, 2017; Asiedu & Adaku, 2020; Mahamid, 2017; Prasad et al., 2019). If the contractor is responsible for the designs, then the employer is entitled to file for the Employer's claim against the contractor. However, if poor specifications provided by the employer inform the design changes, then the contractor is entitled to file a claim.

2.5. Project experience of the contractor

Construction contracts for mega projects require the contractors to be competent in the scope of work that they are contracted to execute. This requires substantial construction experience in similar or related construction works. The inexperience of the contractor affects the construction activities in terms of the quality of the work and completion time (Namous & Al Battah, 2021; Oluwajana et al., 2022; Tahmasebinia & Song, 2022; Alekhya et al., 2021). Inadequate contractor experience leads to project cost overruns (Amoatey & Ankrah, 2017). Contractor experience is also demonstrated in the coordination of construction activities. Poor project coordination is associated with the inexperience of the contractor in executing the construction activities (Mahamid, 2017). The employer is entitled to file an Employer's claim because of poor project coordination. The contractor should be responsible for the extension of time, and the employer should not entertain an extension of time claim.

2.6. Site management and supervision

Managing construction claims requires proper site management and supervision of construction activities (Radzi et al., 2022; Tahmasebinia & Song, 2022; Alekhya et al., 2021). Poor construction site management is mainly caused by inadequate management skills (Namous & Al Battah, 2021; Tahmasebinia & Song, 2022; Alekhya et al., 2021). Other contributing factors to the inadequate management skills include the lack of management and technical skills of the project personnel, human capacity, and a lack of understanding and knowledge of the local context (Santoso & Gallage, 2019; Durdyev & Hosseini, 2020).

Other factors contributing to poor site management include supervision and control (Asiedu & Adaku, 2020), poor inspection and supervision of projects by contractors (Famiyeh et al., 2017; Habibi & Kermanshachi, 2018), poor project coordination (Mahamid, 2017), and project site management (Famiyeh et al., 2017; Habibi & Kermanshachi, 2018; Durdyev & Hosseini, 2020; Arantes & Ferreira, 2020). Most of these factors are under the control of the contractor. Therefore, the employer is entitled to the Employer's claim. The performance measurement must be stipulated in the contract to ensure a smooth claim process.

2.7. Project construction complexity

A mega construction project is associated with multiple contractors working on-site. This means access to the site should be properly coordinated. Therefore, contractors must understand project construction complexity due to the timing of different construction scopes (Oluwajana et al., 2022; Famiyeh et al., 2017). Contractors are expected to coordinate common activities relating to health and safety. Contractors are expected to familiarise themselves with the project environment to plan their activities in line with the schedule and access to the construction site. Lack of timely access to the site affects construction planning, resulting in a claim for an extension of time. The claim management for the lack of access is complex, as some of the claims are employer-related and others are contractor-related. A precise coordination of construction contractors by the employer would assist in apportioning the claim to the relevant contractor.

Several factors contribute to construction claims for a mega construction project, including poor procurement preparation, Inadequate planning, Inaccurate cost estimation, Design changes, Change orders, Scope changes, Project experience of the contractor, Site management and supervision, and Project construction complexity.

3. Research Methodology

The study adopted a quantitative research approach. Data was collected through a survey research design using a questionnaire. A purposive sampling of fifty respondents across the built environment industry formed part of this study, mainly professionals (Construction Project managers and Quantity surveyors) with more than three years of experience, both in the public and private sectors, who worked in a mega construction project. The questionnaire is composed of Section A: Biographical Information and Section B: Factors causing cost overruns and construction claims. A total of thirty-nine factors that could lead to cost overrun claims in a mega construction project were listed for respondents to rank. A five-point Likert scale was used to measure the relative importance of the cost overrun factors responsible for construction claims (1- very low to 5 - very high), where 1 represented 'no influence' and 5 represented a 'very serious influence'. The rationale for using the scale was to establish the level of agreement among the professionals on which factors expose the projects to the risk of construction claims. The contribution of each of the factors to construction claims was examined, and the ranking of the attributes in terms of their criticality as perceived by the respondents was done by using the Relative Importance Index (RII), which was computed using the equation below:

$$RII = W/ A*N \ (0 \leq RII \leq 1)$$

Where:

W – Is the weight given to each factor by the respondents and ranges from 1 to 5 (where "1" is "1" "Minor Influence" and "5" is "Major Influence")

A – Is the highest weight (i.e., 5 in this case) and. N – Is the total number of respondents

The RII method was used to assess the relative importance of factors that contribute to cost overruns and construction claims. The method has been used in similar studies, such as Fallahnejad (2013).

4. Findings and Discussion

Table 1 provides the biographical information of the respondents, and the results of the analysis of the RII factors are presented in Table 2.

4.1. Biographical data

The results show that respondents are highly educated (70%), with extensive project experience of more than 10 years (67%), and the majority are in senior management (73%).

4.2. Descriptive of the results

The results of the RII ranking in Table 2 show the top ten cost overrun factors contributing to construction claims. Incomplete design during the tender stage (ranked 5 and RII = 0.6945), and this factor is related to poor procurement preparation. The factor related to design changes was ranked number two (RII = 0.792) by Ammar et al. (2022) as a contributing factor to cost overruns for road network projects in Egypt during the implementation phase. If the scope is properly designed and the contractor is responsible for designs, then a construction claim related to design changes should be filed as the Employer's claim.

Inaccurate cost estimation (Insufficient planning and Inaccurate cost estimation) is ranked number one (RII = 0.729). The study by Ammar et al. (2022), for road network projects in Egypt, ranked this factor as number one (RII =0.824). Inaccurate cost estimation is the responsibility of the contractor. Should the project run

Table 1: Demographic profile of respondents

Respondents' characteristics	**Frequency (%)**
Highest Educational Level	
Degree (Bachelor, Honours and Master's)	35 (70%)
National Higher Diploma	13 (27%)
College Certificate	2 (3%)
Work Experience	
More than 10 years	33 (67%)
2 - 6 years	17 (33%)
Roles in the project	
Middle, senior and executive management level	37 (73%)
Intermediate level	10 (20%)
Entry level	4 (7%)

Table 2: RII Ranking

No	**Cost Overruns factors leading to construction claims**	**RII**	**Ranking**
1	Lack of a project risk governance structure	0,7290	1
2	Insufficient planning and inaccurate estimates	0,7290	1
3	Incompetent contractors	0,7150	3
4	Poor project controls (cost and schedule)	0,7085	4
5	Incomplete designs at the tender stage	0,6945	5
6	Lack of knowledge about the project and its complexity	0,6875	6
7	Inadequate communication and slow decision-making	0,6805	7
8	Lack of appropriate planning	0,6805	7
9	Corruption during the procurement stage	0,6735	9
10	Payment delays by clients	0,6705	10

out of funds, the employer would be entitled to the Employer's claim. The Employer's claim would be categorised as a standing claim and an extension of time claim for the affected contractors. If the inaccurate cost estimate is due to a poorly defined scope by the employer, then the Contractor would be entitled to a contractor claim, and the employer would be liable to source additional funds to allow affected activities to continue. Project construction complexity is ranked number six (RII =0.6875). The study by Famiyeh et al. (2017) found that inappropriate construction methods used by contractors lead to construction claims. Inappropriate construction methods cause delays in construction completion. The inappropriate construction methods are subject to quality assurance. Any noncompliance with quality assurance results in rework, and the cost of rework should be the responsibility of the contractor responsible for the work. The Employer's claim would be the costs associated with rework and the extension of time.

Inadequate planning is ranked seven (RII = 0.6805). Inadequate planning causes project cost overruns and extended schedules (Oluwajana et al., 2022; Ammar et al., 2022). If the inadequate planning is from the contractor's side, then the Employer's claim should be filed. If the inadequate planning is from the Employer's side, then the Contractor's claim should be filed. Project experience of the contractor (Incompetent contractors) is ranked number three (RII = 0.7150). These results are consistent with the literature that inexperience of contractors contributes to poor coordination of construction activities (Namous & Al Battah, 2021; Oluwajana et al., 2022; Tahmasebinia & Song, 2022; Alekhya et al., 2021). Poor coordination of construction activities among contractors on-site affects construction activities and would result in construction claims. The construction claims would be costs associated with access to the site for the contractors, interface-related costs, and an extension of time for all affected contractors. The construction claims management becomes complex with multiple contractors. This means that there would be a combination of the Employer's claims and the Contractor's claims. The employer could pass some of the contractor claims to contractors responsible for those specific claims. At the same time, the employer could file the Employer's claims against defaulting contractors.

Poor procurement (corruption during the procurement stage) is ranked number nine (RII = 0.6735). Procurement planning should take into consideration the lead times of the construction material. Poor procurement could lead to late delivery of construction material (Ajibike et al., 2022; Namous & Al Battah, 2021; Oluwajana, Ukoje, Okosun, and Aje, 2022; Tahmasebinia & Song, 2022). The procurement of

construction materials is the responsibility of the contractors. The Employer's claim should be filed for the late delivery of construction material. The claim should be for delayed damages and an extension of time.

5. Conceptual Framework for managing employers' claims

Table 3 categorises the cost overrun factors responsible for construction claims. The cost overrun factors could lead to both the Employer's claim and the Contractor's claim. The framework in Figure 1 will assist in the apportionment and management of these claims. The framework will assist in reducing cost overrun by reallocating some of the contractor's claims to the Employer's claim.

conditions. The employer needs to assign a resource to manage construction claims. Once claims are received, they need to be categorised into the Employer's claim and the Contractor's claim. The Contractor's claim must further be probed. In the event of concurrent claims because of concurrent delays, the Contractor's claim should be apportioned between the two parties. Where there are Contractor's claims from other contractors, the employer will pass through some of these claims to the responsible contractor, and the claims will be categorised as Employer's claims. The Employer's claims should further be categorised into delay damages and extension of time.

6. Conclusion and Further Research

Management of construction claims requires proper

Table 3: Categories of construction claims

Factors	Employer's Claims	Contractor's Claims
Poor procurement preparation	X	X
Inadequate planning	X	X
Inaccurate cost estimation	X	X
Design changes, Change orders, Scope changes	X	X
Project experience of the contractor	X	X
Site management and supervision	X	X
Project construction complexity	X	X

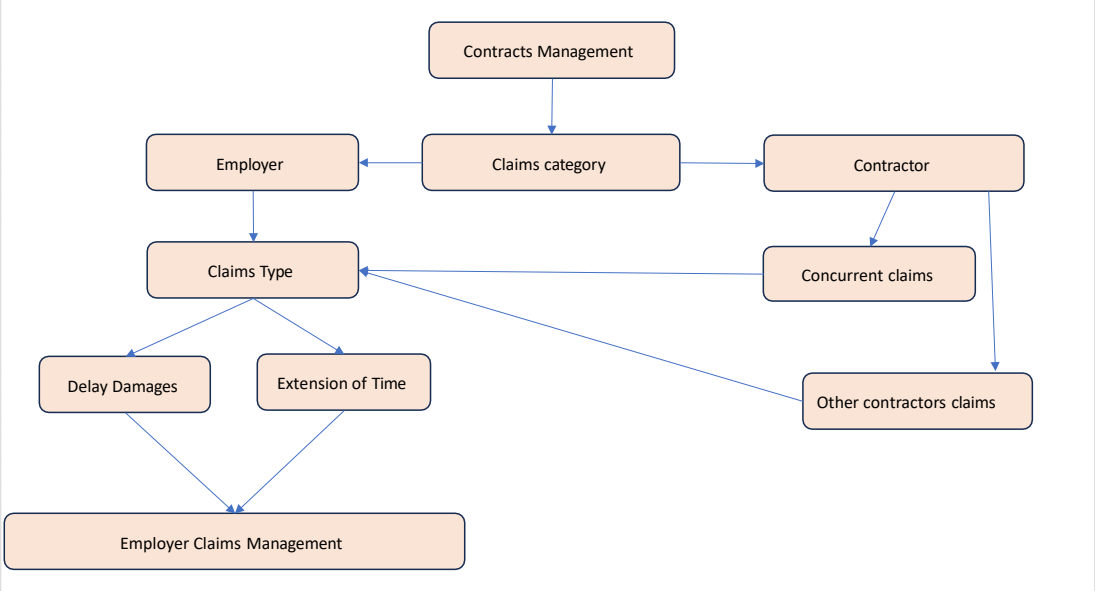


Figure 1: Conceptual Framework for Employer's Claims

Employer's claim management process starts with contract management. It requires resourcing and skilling of the contract management portfolio. Contract management requires both parties, the employer and the contractor, to be familiar with contract clauses and contract conditions. The parties will execute the construction works in compliance with the contract

coordination to apportion the claims to the relevant party. There are claims that the employer is liable for, and those that the contractor is liable for. There are several cost overrun factors responsible for construction claims. This study identified the following cost overrun factors responsible for construction claims: Poor procurement preparation, Insufficient

planning and inaccurate estimates, Incompetent contractors, design changes, Lack of knowledge about the project and its complexity, and poor site management. Proper coordination of construction claims will significantly reduce cost overruns by apportioning claims to the responsible party. Filing the Employer's claims will ensure that the contractors responsible for the delays are held accountable.

The contribution of this study is that a proper construction claims management framework will reduce cost overruns by filing Employer's claims.

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The Causes and Impact of Late Payments in The Construction Industry

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Abstract

Given that the South African construction industry is prone to late payments, and contractors experience a high level of late payment, non-payment, and insolvency, a study was conducted to investigate the causes of late payment, non-payment, negative cash flow, and payment disputes that arise during construction, and to evolve a framework of interventions to mitigate these. The quantitative method was adopted due to the nature of the data required, and an 'introductory' letter was e-mailed to medium to large general contractor members of the East Cape Master Builders Association (ECMBA), which included the online survey questionnaire URL. Given the sample size of 67 and the 20 responses, which equate to a response rate of 30.0%, the findings cannot be deemed generalisable, but are indicative. The salient findings are: late payment is a significant issue; factors such as inadequate client's finance, and inadequate client capacity for processing payments contribute to late payment; delay in completion of activities, and negative cash flow occur due to late and non-payment, non-payment by clients result in payment disputes; clients' poor financial management and clients' withholding of payments contribute to non-payment, and blockchain technology with a smart contract has the potential to mitigate payment problems. Conclusions include: the extent to which factors result in late payments indicates that it is a multi-stakeholder issue in addition to being attributable to clients, and although blockchain technology and the use of smart contracts can mitigate payment problems as they enable every transaction, payment, and business interaction to be followed, they cannot be viewed as the panacea for all payment related problems. Recommendations include consideration of a 'project payment charter', which indicates the role of all project stakeholders, and their commitment in the form of signatures to the charter.

Keywords: Blockchain, Late payment, Non-payment, Payment disputes

1. Introduction

The crucial factor to a project's success is the practice of efficient and timely payments on construction projects. Another significant issue is the delay in a project's completion, which may result in costly disputes (Koshe & Jha, 2016). Cash flow, in turn, is the lifeblood of an organisation because without it, outstanding financial obligations cannot be met (Arafat and Skaik, 2016, cited in Omopariola *et al.*, 2020). Cash flow dictates the scope, pace, quality, direction, and final product of the project (Usman *et al.*, 2016).

Azman *et al.* (2014) state that the construction industry faces more serious problems with late and non-payment than other industries. This is because, in contrast to other industries, construction projects typically take a long time to complete, each construction project is typically quite large, and progress payments are frequently quite substantial. Furthermore, payment terms are typically on credit, rather than delivery and services are provided before progress payments are made.

Delayed progress payments are ubiquitous and hinder the success of construction projects globally (Ramachandra and Rotimi, 2011, cited in Sonmez *et al.*, 2022). The causes of late payments include: claims without adequate supporting documents, and incorrectly calculated claims (Reva, 2003 cited in Ajayi *et al.*, 2018), and client's poor financial management, client's wrongful withholding of payment, conflict among the parties involved, delay in certification, and disagreement concerning the valuation of work (Hasmori *et al.*, 2012). Azman *et al.* (2014) contend that failure by the contractor to secure consistent and prompt payments could cause project delays, decreased profitability, and, in the worst scenario, a contractor's insolvency. Furthermore, the entire construction value chain will be negatively impacted because all parties in the chain suffer if a client fails to pay the contractor on time.

Given the abovementioned, a study was conducted, the aim being to investigate late payments in construction, and identify interventions to mitigate the same. The objectives were to determine the extent to which:

- ten factors result in late payments;
- ten problems occur due to late payments, and
- Industry 4.0 interventions can mitigate late payments and cash flow problems.

2. Literature Review

2.1. Late payments

According to Badroldin *et al.* (2016), late payment occurs when a business has been supplying services or products but does not get paid by the agreed deadline. Delays concerning progress payments are a common problem hindering the success of construction projects globally (Ramachandra and Rotimi, 2011, cited in Sommez *et al.*, 2022). Due to its nature and traits, the

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construction business has unfairly extended payment terms and a high rate of late payments. More fundamentally, the behaviours of construction corporations, and in some situations, government agencies that collaborate with them, are frequently directly linked to the causes of late payments (European Commission, 2020).

The Construction Industry Development Board (cidb) (2015) states that 60% of payments to contractors were delayed for longer than 30 days after invoicing, which reflects a noticeable deterioration in prompt payment practices over the period of 2012 to 2015. Furthermore, 52% of payments to the client's agents were delayed for longer than 30 days after invoicing (cidb, 2015).

2.2. Causes of late payments

According to Hasmori *et al.* (2012), clients, developers, contractors, and contractual matters are among the numerous variables that cause late payment issues. The main reason for late payment, according to Reva (2003), cited in Ajayi *et al.* (2018), is when there are errors in submitting claims. This includes claims without adequate supporting documents, incorrectly calculated claims, and those submitted without using procedures. When this happens, contractors need to resubmit the claims. According to Hasmori *et al.* (2012), there are also cases where clients' employees are wrongfully withholding payment, often to obtain a 'gift' from contractors once they expedite the payment.

2.3. Impact of late payments

According to Odenigbo *et al.* (2020), payment is the heart of the construction industry and project duration is automatically impacted by payment delays. Late payment is a significant issue in construction, and globally, the success of construction projects is hindered by late payments (Sonmez *et al.*, 2022). Late payment is a persistent and crucial issue that the construction industry faces, as it affects contractors' cash flow and impacts the delivery of projects (Ajei *et al.*, 2018). According to Mohamad *et al.* (2018), clients' inability to make timely and consistent payments can impede contractors' ability to complete their work on schedule, and both clients and contractors should equally share the risk of late or non-payment. The delays in payments, non-payments, and disputes that arise during construction can lead to contractors becoming insolvent.

2.4. Non-payment

According to Maritz and Robertson (2012), South African contractors and consultants have the same problem as those in other countries regarding non-payment for work done or services rendered. According to Ramachandra and Romiti (2015b), non-payment has an immediate effect on cash flow, which in turn drives the contractors and eventually subcontractors to source additional funding through overdrafts, trade credits, and other means. Non-payment and late payment lead to disputes and subsequent suspension and termination of projects, which marginalise the productivity of the construction industry at large, but with more dire consequences for construction parties down the supply chain (Ramachandra & Romiti, 2015b).

2.5. Causes of non-payment

According to Ramachandra and Romiti (2015a), there are many factors associated with payment defaults in the construction industry. The construction sector is known for many unique characteristics, which could primarily contribute to payment problems. Based on a literature review conducted by Hasmori *et al.* (2012), client's poor financial management, client's withholding of payment, conflict among the parties involved, the use of a pay-when-paid clause relative to subcontractors, local culture or attitude, delay in certification, and disagreement concerning the valuation of work, were identified as the primary causes of non-payment in the construction industry.

2.6. Payment disputes

Due to its complexity, competitive environment, and complicated project documentation, the construction industry is prone to conflict and disputes (Shash & Habash, 2021). According to Awwad *et al.* (2016), cited by Gamil and Abd Rahman (2023), construction projects have a distinct execution process that may be associated with uncommon disputes between construction stakeholders, which ultimately can result in a project's collapse.

Conflicts are unavoidable in the construction sector due to differences in perceptions among project participants, and conflicts can quickly develop into disputes if they are not appropriately handled (Cakmak & Cakmak, 2014). According to Hassan *et al.* (2019), payment has always been the primary source of dispute relative to many construction contracts. Furthermore, the significance of positive cash flows in ensuring the continuity of a project has elevated all issues relating to timely payment, and the need to maximise positive cash flow will continue to escalate payment disputes. Then, disputes relating to payment issues are broadening and becoming more complicated (Hasmori *et al.*, 2012).

2.7. Negative cashflow

Cash flow impacts all aspects of the construction project implementation process. Cash shortages can lead to project failure and business bankruptcy (Al-Joburi *et al.*, 2012). Negative cash flow occurs when the cash outflow surpasses the cash inflow and is indicative of an organisation in financial difficulty (Omopariola *et al.*, 2020). According to Al-Nassafi (2022), poor cash flow in construction is caused by late payments and non-payments, which may cause delays in the completion of the project and, as a result, failure to meet economic feasibility, resulting in significant financial loss for the contractor.

2.8. Potential of Industry 4.0 technologies to address payment-related problems

Perera *et al.* (2020) identify a range of applications for blockchain technology in construction and the built environment, and in terms of 'payment management', they refer to late payments and cash flow-related issues as key issues on most construction projects. They also refer to default settlement durations, partial payments, and non-payments, and state that smart contract-enabled blockchain applications with automated payments can effectively be used to resolve these issues.

Smart contracts utilise protocols and user interfaces to facilitate all the steps in the contracting process. Lamb (2018) describes a smart contract as a contract using computer protocols to formalise elements of a relationship to automatically execute the terms encoded therein once the pre-defined conditions are met. Altay & Motawa (2020) highlight how key processes can be automated in construction using smart contracts and blockchain technology. A key feature of smart contracts is that transactions are performed without intermediaries, which mitigates interference.

A blockchain consists of units of data about specific transactions arranged in an ordered list (Lamb, 2018), which allows the automation of transactions within a contract once certain predetermined project variables and principles are met (Altay & Motawa, 2020). Smart contracts enable greater traceability and provide an opportunity for increased processing efficiency.

3. Research Methodology

The survey of the literature was conducted via the Nelson Mandela University library portal, including databases such as SpringerLink and Taylor & Francis Online. Terms such as 'Causes of late payments in construction', 'Impact of late payments in construction', 'Construction smart contracts', and 'Blockchain in construction' were used as search criteria.

The quantitative research study entailed an online questionnaire survey, and the questionnaire evolved from the review of the literature while considering the study's aim and objectives. The sample included 67 potential respondents, specifically general contractors (GCs) members of the East Cape Master Builders Association (ECMBA). Members of the ECMBA were selected because the authors' university is in the same metropole as the ECMBA, which increases the likelihood of interest in the study. Furthermore, GC members are paid directly by clients, and therefore, should be familiar with the status quo relative to client payments in construction. The questionnaire consisted of 23 closed-ended and three open-ended questions. Fifteen of the closed-ended questions were Likert scale-type questions, and eight were demographic-related questions. A total of 20 Responses were received, which equates to a response rate of 30.0%. The online questionnaire process included the generation of an MS Excel data file, and the data analysis entailed the computation of frequencies and a measure of central tendency in the form of a mean score (MS).

4. Findings and Discussion

In terms of respondents' highest qualification, 45.0% have a Diploma, 25.0% have a B.Tech, 20.0% have a B.Sc. degree, and 10.0% have an honours degree. In terms of the number of years respondents have worked in construction, 35.0% have worked in construction for 11-15 years, 25.0% for 11-15 years, 20.0% for more than 20 years, and 15.0% for 16-20 years. Notably, only 5.0% have worked for less than 5 years.

Respondents were required to indicate on a scale of never to always, the frequency with which clients follow contractual progress payment requirements. The resultant MS of 3.00 is > 2.60 to ≤ 3.40, which indicates that the respondents contend clients follow the contractual progress payment requirements between rarely to sometimes / sometimes.

Table 1 indicates the extent to which ten factors result in late payments in terms of percentage responses to a range of 'Does not' and 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 0.00 and a maximum value of 5.00. It is notable that 9 / 10 (90.0%) MSs > 2.50, which indicates that, in general, respondents perceive that the factors result in late payments to a major, as opposed to a minor extent, as in the case of an MS ≤ 2.50. 4 / 10 (40.0%) Factors have MSs > 3.34 to ≤ 4.17, which indicates that respondents perceive that they contribute between some extent to a near major extent / near major extent to late payments – 'inadequate client's finance', 'inadequate client capacity for processing payments', 'client inability to process payments', and 'withholding of payment by client'. 5 / 10 (50.0%) Factors have MSs > 2.50 to ≤ 3.34, which indicates that respondents perceive that they contribute between a near minor extent and some extent to late payments. The MS of 'incomplete submission of claim documents' is > 1.67 to ≤ 2.50, which indicates that respondents perceive that it contributes between a minor extent to a near minor extent / near minor extent to late payments. This is contrary to the finding of Reva (2003) cited in Akinsiku and Ajayi (2018), that the main reason for late payment is errors in submitting claims, which includes claims without adequate supporting documents.

Table 2 indicates the extent to which ten problems occur due to late payments in terms of percentage responses to a range of 'Does not' and 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 0.00 and a maximum value of 5.00. Notably, 9 / 10 (90.0%) of the MSs are > 2.50, which indicates that, in

Table 1: The extent to which ten factors result in late payments

Factor	Response (%)							MS	R
	Un-sure	DN	Minor ……Major						
			1	2	3	4	5		
Inadequate client's finances	0.0	0.0	10.0	5.0	20.0	30.0	45.0	3.95	1
Inadequate client capacity for processing payments	0.0	0.0	10.0	15.0	15.0	10.0	50.0	3.75	2
Client's inability to process payments	10.0	10.0	0.0	5.0	10.0	35.0	30.0	3.67	3
Withholding of payment by the client	0.0	0.0	15.0	10.0	10.0	30.0	35.0	3.60	4
Delay in certification of payment	5.0	5.0	5.0	15.0	30.0	25.0	15.0	3.16	5
Disagreement regarding the value of work completed	0.0	0.0	10.0	15.0	40.0	25.0	10.0	3.10	6
Inadequate project cost estimate by the client's agent	10.0	5.0	15.0	15.0	15.0	15.0	25.0	3.06	7
Involvement of too many parties in the process of honouring certification	10.0	5.0	10.0	30.0	15.0	10.0	20.0	2.83	8
Delay in the contractor's submission of the invoice	5.0	10.0	20.0	15.0	20.0	20.0	10.0	2.67	9
Incomplete submission of claim documents	15.0	5.0	10.0	45.0	15.0	5.0	10.0	2.24	10

Table 2: The extent to which ten problems occur due to late payments

Problem	Response (%)							MS	R
	Un-sure	DN	Minor ……Major						
			1	2	3	4	5		
Negative cash flow	0.0	0.0	10.0	0.0	15.0	40.0	35.0	3.90	1
Delay in the completion of activities	0.0	0.0	5.0	15.0	15.0	15.0	35.0	3.90	1
Inability to secure enough material to deliver the project	10.0	10.0	0.0	10.0	20.0	20.0	30.0	3.44	3
Loss of trade discount from suppliers	20.0	15.0	5.0	0.0	0.0	35.0	25.0	3.38	4
Poor productivity	10.0	10.0	5.0	10.0	10.0	40.0	15.0	3.22	5
Change in the sequence of programmed work	0.0	15.0	10.0	10.0	10.0	25.0	30.0	3.10	6
Loss of key personnel	5.0	10.0	5.0	15.0	30.0	10.0	25.0	3.05	7
Loss of expected profit due to high interest on overdue accounts	15.0	15.0	5.0	10.0	10.0	25.0	20.0	3.00	8
Low employee morale	5.0	10.0	0.0	0.0	45.0	20.0	20.0	2.89	9

general, respondents perceive that the problems occur due to late payments to a major, as opposed to a minor extent in the case of an MS ≤ 2.50. 4 / 10 (40.0%) Problems have MSs > 3.34 to ≤ 4.17, which indicates that respondents perceive the problems occur between some extent to a near major extent / near major extent due to late payments. 5 / 10 (50.0%) Problems with MSs > 2.50 to ≤ 3.34, indicates that respondents perceive the problems to occur between a near minor extent to some extent / some extent due to late payments. The MS for 'abandonment of the project' is > 1.67 to ≤ 2.50, which indicates that respondents perceive that it occurs between a minor to near minor extent / near minor extent due to late payments. The findings are reinforced in terms of project delays (Odenigbo *et al.*, 2020; Ajei *et al.*, 2018; Mohamad *et al.*, 2018) and cash flow (Ajei *et al.*, 2018).

Table 3 indicates the extent to which Industry 4.0 interventions can mitigate late payment and cash flow problems in the construction industry in terms of percentage responses to a range of 1 (Minor) to 5 (Major), and MSs ranging between a minimum value of 1.00 and a maximum value of 5.00. It is notable that 4 / 8 (50.0%) of the MSs are > 3.00, which indicates that in general, respondents perceive that the Industry 4.0

Table 3: The extent to which Industry 4.0 interventions can mitigate late payments and cash flow problems

Industry 4.0 intervention	Response (%)						MS	R
	Un-sure	Minor ……Major						
		1	2	3	4	5		
Blockchain technology for monitoring the progress of payment and mitigate late payment	15.0	0.0	5.0	45.0	20.0	15.0	3.53	1
Blockchain technology for monitoring contracts and mitigating non-payment	20.0	0.0	5.0	35.0	40.0	0.0	3.44	2
Blockchain technology for smart contracts to mitigate non-payment	10.0	15.0	10.0	30.0	25.0	10.0	3.17	3
Blockchain technology for mitigating payment disputes during construction	15.0	10.0	10.0	30.0	30.0	5.0	3.12	4
Blockchain technology for accelerating payments	30.0	5.0	15.0	35.0	10.0	5.0	2.93	5
Artificial Intelligence for Predicting Cost Overruns	30.0	10.0	30.0	5.0	15.0	10.0	2.79	6
Artificial Intelligence for reducing negative cash flow	45.0	5.0	25.0	5.0	20.0	0	2.73	7
Blockchain technology for boosting transparency to reduce disputes	10.0	25.0	15.0	35.0	10.0	5.0	2.50	8

interventions can mitigate late payments and cash flow problems to a major, as opposed to a minor in the case of a MS ≤ 3.00. 2 / 8 (25.0%) MSs are > 3.40 to ≤ 4.20, which indicates that the respondents perceive that they can mitigate late payments and cash flow problems between some extent to a near major / near major extent. 5 / 8 (62.5%) MSs are > 2.60 to ≤ 3.40, which indicates that respondents perceive that the Industry 4.0 interventions can mitigate late payments and cash flow problems between a near minor extent to some extent / some extent. Only 1 / 8 (12.5%) MSs is > 1.80 to ≤ 2.60, which indicates that respondents perceive that the Industry 4.0 intervention can mitigate late payments and cash flow problems between a minor to near minor extent / near minor extent. These findings are supported by Perera *et al.* (2020) regarding potential blockchain technology applications and by Altay and Motawa (2020) regarding smart contracts using blockchain technology.

5. Conclusions, Recommendations and Further Research

Given the sample size, the findings cannot be deemed generalisable, but are indicative, and hence the need for further in-depth related research.

Late payments are a persistent issue that the construction industry faces and have a significant impact on contractors' cash flow. A range of factors, such as inadequate client finance, inadequate client capacity for processing payments, client's inability to process payments, and withholding of payment by clients, contribute to late payment. The client's poor financial management and withholding payment to obtain some 'kind of gift' from contractors results in non-payment. Non-payment by clients, in turn, results in payment disputes and financial problems for contractors and their supply chain.

Inadequate client capacity for processing payments, and client inability to process payments allude to competency challenges. This is likely to be more common in the case of 'once-off' clients who may not be familiar with construction contracts and payment processes. In such cases, the client's consulting quantity surveyor should assist along with the principal agent.
The extent to which factors result in late payments indicates that it is a multi-stakeholder issue in addition to being attributable to clients e.g., delay in certification of payment may result from either a delay in contractor's submission of invoices, or an incomplete submission of claim documents by a contractor, or involvement of too many parties in the process of honouring certification, or a combination of all three factors.

Although the review of the literature indicates that blockchain technology with automated payments and smart contracts can be used to mitigate payment problems in the construction industry, the findings of the study marginally underscore the review of the literature. This is likely attributable to the respondents' lack of experience and exposure relative to blockchain technology. This, in turn, amplifies the need for further in-depth related research to interrogate and unequivocally confirm that blockchain technology can mitigate payment-related problems in construction.

Furthermore, given the extent to which factors result in late payments, blockchain technology cannot be viewed as a panacea for all payment-related problems. Therefore, a further intervention in the form of, say, a 'project payment charter' should be considered, which charter indicates the role of all project stakeholders, and their commitment in the form of signatures to the charter. Following this, the required performance by the respective stakeholders will facilitate an effective implementation of blockchain technology, resulting in an indelible record of actions and transparency.

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Effectiveness of Existing Insurance Frameworks in Addressing the Risks of Contractors

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Abstract

The construction industry is inherently risky and involves risks of project delay and cost overruns, safety issues, and contractual disputes. Therefore, these risks require insurance frameworks to address the unique challenges contractors face. This study used a critical analysis to show how existing insurance frameworks mitigate risks associated with construction projects. The study employed a mixed-method approach and used 100 contractors with 15 industry experts for the qualitative study by purposive sampling. The study reveals significant gaps in the adaptability and inclusiveness of existing insurance products, particularly in addressing emerging risks such as cyber threats and environmental liabilities. The results indicate that the effectiveness of existing insurance frameworks in addressing contractor risks varies significantly across different policy types. Cyber Liability Insurance for Construction Firms and Environmental Liability Insurance rank among the most effective, reflecting the industry's growing awareness of digital threats and environmental risks. The qualitative analysis revealed that many contractors face financial challenges due to limited coverage options for specific risks, such as delays or project-specific liabilities. Future research was recommended to explore contractors' specific challenges in accessing and utilising insurance coverage, particularly for policies with lower effectiveness ratings, such as Employers' Liability Insurance and Group Personal Accident Insurance.

Keywords: Contractors' Risk, Insurance frameworks, Risk management, Industry Challenges and Collaborative Approaches.

1. Introduction

The construction industry is a foundation of economic development and infrastructure growth in many nations (Ofori, 2015), including Ghana. As the country continues to experience rapid urbanisation and infrastructure development (Turok & McGranahan, 2013), the construction sector will face many risks that can knowingly impact project outcomes (Jaafari, 2001)—these risks range from regulatory challenges and financial uncertainties to environmental hazards and safety concerns. Therefore, effectively managing these risks is important for seeing the sustainability and viability of construction projects (Winch, 2012). This need raises important questions about the adequacy of existing insurance frameworks in addressing the different construction risks in Ghana (Kheni & Braimah, 2014).

Risk management is an insurance tool that can mitigate financial losses arising from unknown events in construction projects (Banaitiene & Banaitis, 2012). In the construction industry, the purpose of insurance is complex (Owusu-Manu, 2021), involving various types of coverage, such as professional indemnity insurance, liability insurance, workers' compensation, and property insurance. Each one of these insurance types or products is designed to address specific risks. Kochenburger and Salve (2023) state that the effectiveness of the products can usually vary based on the regulatory environment, the specificities, and the market dynamics of the construction sector in which they are applied. The existing insurance frameworks in Ghana must be examined to determine their capacity to protect stakeholders (Oscar & Abor, 2013), including project owners, contractors, and workers, from the inherent construction risks.

Over the past decade, the Ghanaian construction industry has witnessed important growth (Osei, 2013), driven by government initiatives, foreign investments, and a burgeoning private sector. Moreover, this growth has not been without its challenges. Lack of skilled labour, inadequate project financing, and regulatory inefficiencies have plagued the sector, making it progressively vulnerable to risks. Furthermore, the

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historical context of construction practices in Ghana, characterised by a tendency towards informal agreements and a lack of comprehensive risk management strategies, exacerbates the situation. Due to this, the effectiveness of existing insurance frameworks in addressing these challenges becomes a pressing concern (Boateng et al., 2022).

The study aims to find the adequacy of current insurance products available to stakeholders in the Ghanaian construction industry, which is one of the objectives of this study. This assessment involves a critical analysis of the types of insurance coverage prevalent in the sector, perceptions of industry stakeholders, and the regulatory landscape governing insurance practices regarding the effectiveness of these frameworks. By assessing the strengths and weaknesses of existing insurance mechanisms, this research seeks to provide insights into how those frameworks can be improved to serve Ghana's industry's needs better (Owusu-Manu, 2021).

By combining the two, local practices and international influences shape Ghana's insurance landscape. The insurance industry in the country is small, with a regulatory framework that has developed over the years in response to domestic and international trends. The primary regulatory body overseeing insurance operations in Ghana is the National Insurance Commission (NIC), which is assigned to ensure fair practices and protect the interests of policyholders. Moreover, concerning the regulatory framework, there are concerns about the accessibility and affordability of insurance products for construction stakeholders, mainly small and medium-sized enterprises (SMEs) that control the sector (Philipo et al., 2023).
The cultural context in Ghana changes risk perception and management practices within the construction industry. Traditionally, construction projects have been closed with a reactive mindset, where risk management is most often relegated to post-event responses rather than proactive strategies. Important financial losses, project delays, and safety incidents result from reactive measures, underscoring the need for a paradigm shift in how risks are perceived and managed within the industry. Insurance plays a central role by providing a safety net and inspiring stakeholders to adopt proactive risk management strategies (Chang et al., 2018).

Alongside examining the current insurance frameworks, this study seeks to explore the role of education and awareness in fostering effective risk management practices. Many stakeholders within the construction industry lack a comprehensive understanding of the available insurance products and their benefits. The study identifies a knowledge gap related to underinsurance and inadequate coverage, which leaves stakeholders exposed to financial losses. By pinpointing educational initiatives and awareness campaigns that can enhance understanding of insurance products, this research aims to contribute to the development of a more knowledgeable construction workforce capable of utilising insurance as a tool for risk management (Kousky, 2022).

Moreover, the study will examine the impact of emerging trends and technologies on the construction insurance landscape in Ghana. The advent of digital platforms, data analytics, and innovative insurance products presents new opportunities for addressing construction risks. For instance, integrating technology into project management can enhance risk assessment and monitoring, allowing for more tailored insurance solutions to meet specific project needs. Understanding how these trends can be harnessed to promote the effectiveness of insurance frameworks is a critical aspect of this research.

In conclusion, effectively managing construction risks in Ghana is a complex challenge that requires a comprehensive understanding of existing insurance frameworks and their limitations (Osei, 2013). By evaluating the adequacy of current insurance products, the regulatory environment, and the perceptions of industry stakeholders, this study aims to provide valuable insights into how the insurance landscape can be improved to better address the unique risks of the construction sector. As infrastructure and urban landscapes continue to develop in Ghana, the role of insurance in facilitating risk management will be increasingly vital. This research contributes to the academic discourse on construction and has practical implications for policymakers, industry stakeholders, and the broader community.

2. Literature Review

Ghana's construction industry has grown significantly over the past few decades, primarily fuelled by public and private investments. However, this growth is accompanied by various risks that can harmfully affect project outcomes. One way to manage these risks is through insurance frameworks; evaluating their effectiveness is critical for the industry. This literature review examines existing research on construction risk management in Ghana, centring on the effectiveness of insurance in mitigating these risks.

2.1. The Role of Insurance and Construction Risks in Ghana

In Ghana, construction projects encounter numerous risks, which can be categorised into financial, operational, and environmental (Ofori et al., 2023). Financial risks generally encompass delays in contract payments, budget overruns, and unstable economic conditions that affect project financing. Operational risks arise from insufficient project management practices, unforeseen logistical challenges, and a shortage of skilled labour (Obokulovich, 2024). Environmental risks are increasingly interconnected,

particularly due to the impacts of climate change, leading to project delays and escalating costs (Mensah, 2020). Grasping these risks is essential for recognising the need for robust insurance frameworks.

In the construction industry, insurance serves two primary functions: risk transfer and mitigation (Pinto et al., 2021). Construction firms can protect themselves against potential financial losses from unforeseen incidents by transferring risk to the insurer, such as accidents or project delays. In the Ghanaian context, traditional insurance models have primarily focused on property risks rather than operational or financial risks (Boakye Danquah et al., 2022). This limited focus can create important gaps in coverage, leaving construction stakeholders open to risks not addressed in traditional insurance policies. Subsequently, the literature highlights the need for reform in the insurance framework to safeguard comprehensive coverage of the diverse risks in the construction sector (Agyekum et al., 2021).

2.2. Exploring the Effectiveness of Existing Insurance Frameworks

Numerous studies have assessed the effectiveness of existing insurance frameworks in addressing construction risks. Agyei et al. (2020) conducted an extensive survey among construction professionals in Ghana, revealing that most respondents lacked awareness of the full range of available insurance options. Many construction organisations perceive insurance as an unnecessary expense rather than a strategic investment in risk management. This lack of awareness can significantly undermine the effectiveness of current frameworks. Furthermore, in another study, Obokulovich (2024) demonstrated the slow adoption of modern insurance products, such as construction credit and performance bonds. Their research indicates that only a small percentage of construction projects secured insurance coverage, highlighting the industry's limited engagement with innovative risk management solutions. The authors argue that educational initiatives and collaborative frameworks between insurers and construction firms are essential for enhancing the implementation of comprehensive insurance packages. The Ghana Insurance Association (2020) reported and emphasised that construction firms are generally uncertain about utilising these products, despite the various options available. Factors contributing to this reluctance include a lack of trust in insurance providers, claim denials, and an insufficient understanding of the benefits of insurance (Darimaani, 2024). These findings underscore the necessity for regulatory frameworks that promote transparency and accountability among insurers, thereby fostering a more reliable environment for the construction industry.

2.3. Regulatory Frameworks and Policies

The insurance regulatory landscape in Ghana significantly impacts the effectiveness of insurance frameworks in managing construction risk. The National Insurance Commission (NIC) manages the insurance sector, yet the existing regulations often lag behind the construction industry's dynamic needs (Baffoe et al., 2022). Reforms to align insurance products with industry-specific risks have been suggested as imperative. Obokulovich (2024) proposes a multi-stakeholder method involving insurers, construction firms and regulatory bodies to formulate insurance products tailored to the construction sector's unique risks. Additionally, incorporating risk assessment methodologies into insurance products can improve coverage and provide a more responsive safety net for construction stakeholders.

2.4. Challenges in Implementing Effective Insurance Frameworks

Despite the recognised benefits of insurance, several challenges impede the effective implementation of insurance frameworks in the Ghanaian construction sector. As Owusu-Manu (2021) noted, issues such as premiums, the complexity of insurance products, and a general distrust of insurers discourage construction firms from securing insurance. Moreover, the lack of standardisation in insurance policies creates confusion and mismatched expectations between construction stakeholders and insurance providers (Ofori et al., 2023). The sector faces a gap in education and training regarding construction risk management and insurance. Osei-Tutu et al. (2021) suggested that incorporating insurance literacy into construction management programmes could equip future industry professionals with the knowledge to navigate insurance options effectively.

In conclusion, existing research indicates that while there are frameworks for addressing construction risk in Ghana, several factors limit their effectiveness, including a lack of awareness and trust in insurance products, regulatory challenges, and a need for increased education. Enhancing the insurance landscape to include comprehensive, tailored products that address the unique construction risks in Ghana is essential. Future research should concentrate on exploring innovative insurance models specifically designed for the distinct risks of the construction industry. Additionally, examining the role of technology in improving insurance processes could provide valuable insights into how stakeholders can navigate the complexities of the insurance market.

3. Research Methodology

This study utilised a mixed-methods approach, integrating quantitative and qualitative techniques to gather comprehensive data. A questionnaire survey involved 100 respondents from the construction

industry and the Ghana insurance sector. The study applied Krejcie and Morgan's (1973) sampling estimation formula to select 100 respondents. Krejcie and Morgan's sampling yields precise sample sizes with reduced Bias. Additionally, qualitative interviews were conducted with 12 key industry experts, including project managers, risk assessors, and insurance underwriters, to gain insights into practical challenges and solutions. The interview guides were created based on an extensive review of existing literature and consultations with industry experts to ensure relevant and targeted questions.

To enhance the data collection instruments, pre-testing was carried out, and the interview process was carefully structured to include follow-up questions. At the same time, a detailed thematic analysis was performed on the collected data. Data were gathered between 2nd and 28 January 2025 using a structured questionnaire designed to capture demographic details and specific information related to contractor insurance. The questionnaire addressed various aspects of the effectiveness of existing insurance frameworks in managing contractors' risks. Furthermore, the survey was augmented by in-depth interviews with 15 key informants from the insurance industry, construction firms, and regulatory bodies. Quantitative data were analysed using SPSS, employing descriptive statistics such as frequency distributions and means to evaluate key factors.

4. Findings and Discussion

This section presents the findings from the mixed-methods study conducted to explore the effectiveness of existing insurance frameworks in addressing construction risk in Ghana. The study utilised quantitative and qualitative data collection methods, including surveys of construction industry professionals and semi-structured interviews with key stakeholders. The results are organised into three main themes: (1) Quantitative Survey Results, (2) Qualitative Interview Insights, and (3) Integration of Findings.

4.1. Quantitative Survey Results

One hundred surveys were distributed to construction professionals across Ghana, including project contractors. Of these, 97 responses were received, yielding a response rate of 97%, as shown in Table 1. The survey aimed to assess the effectiveness of existing insurance frameworks in addressing contractors' risks.

Table 2: Existing Contractor Insurance Framework

Insurance framework	Mean	Std. Dev.
Contractors' All Risks (CAR) Insurance	3.07	1.46
Public Liability Insurance	3.17	1.5
Workers' Compensation Insurance	3.0	1.32
Professional Indemnity Insurance	2.98	1.45
Employers' Liability Insurance	2.89	1.4
Equipment & Plant Insurance	2.96	1.44
General Third-Party Liability Insurance	2.98	1.3
Erection All Risks Insurance	3.13	1.51
Group Personal Accident Insurance	2.85	1.34
Fire and Allied Perils Insurance	3.13	1.36
Fidelity Guarantee Insurance	3.07	1.56
Motor Fleet Insurance for Construction Vehicles	3.02	1.46
Performance Bond Insurance	3.02	1.43
Environmental Liability Insurance	3.24	1.33
Cyber Liability Insurance for Construction Firms	3.41	1.37

Source: Field Data (2025)

Awareness of Insurance Frameworks

The survey revealed mixed results regarding awareness of insurance frameworks in the construction industry. Although many respondents were aware of available insurance policies, the complexity and variability of these products contributed to challenges in fully utilising them. Contractors tended to be more aware of traditional insurance products, but emerging risks such as cyber and environmental liabilities were less widely recognised despite showing higher mean effectiveness.

Utilisation of Insurance Products

Survey results highlighted that insurance products are underutilised in the construction industry due to various barriers. The high cost of premiums, the complexity of policies, and limited coverage for project-specific risks were cited as primary reasons for low adoption. Emerging insurance products like Cyber Liability Insurance (Mean = 3.41) and Environmental Liability Insurance (Mean = 3.24) were noted to be underutilised despite their high perceived effectiveness. Conversely, traditional policies such as Public Liability Insurance and Erection All Risks Insurance maintained steady use, indicating their continued importance.

Perceived Effectiveness of Insurance Frameworks

The perceived effectiveness of insurance frameworks varied considerably across different types of coverage. Cyber Liability Insurance demonstrated the highest effectiveness (Mean = 3.41), while traditional policies, such as Employers' Liability Insurance, received lower ratings (Mean = 2.89). Several contractors indicated that traditional policies were insufficient to meet modern risk management requirements. Claims processing inefficiencies were often cited as key factors affecting the effectiveness of insurance frameworks. A significant proportion of respondents (40%) highlighted the complexity of policies as a barrier, while 35% noted high premiums as a concern for smaller businesses.

4.2. Qualitative Interview Insights

In addition to the quantitative survey, 12 key stakeholders, including project managers, risk assessors, and insurance underwriters, were interviewed semi-structured to gain deeper insights into the effectiveness of existing insurance frameworks in addressing contractors' risks. The profiles of the respondents are shown in Table 2.

Table 2: Profile of Respondents

	Location	Participant Job title	Code-named
1	Kumasi	Broker	C1
2	Kumasi	Broker	C2
3	Kumasi	Broker	C3
4	Kumasi	Project Manager	C4
5	Kumasi	Broker	C5
6	Kumasi	Broker	C6
7	Kumasi	Project Manager	C7
8	Bekwai	Managing Director	C8
9	Bekwai	Project Manager	C9
10	Bekwai	Broker	C10
11	Bekwai	Broker	C11
12	Bekwai	Project Manager	C12

Source: Authors Construct, 2025

Challenges in the Insurance Market

Interviews with industry stakeholders revealed multiple systemic challenges within the construction insurance sector. Regulatory Constraints Were cited as a primary concern, with respondents indicating that outdated frameworks failed to account for emerging risks, such as those linked to climate change. One executive mentioned, "*The current insurance frameworks are somewhat effective, but there are significant gaps (C7, 2025)*."

Another critical challenge discussed was the limited availability of insurance products tailored to the construction industry's unique needs. Many participants noted that generic insurance options did not adequately address the distinct risks associated with construction projects, particularly concerning local environmental and political factors. A construction manager emphasised, "*Many contractors encounter financial difficulties due to restricted coverage options for specific risks such as delays or project-related liabilities. Existing policies often fail to account for unforeseen risks like market fluctuations or environmental influences, leaving contractors vulnerable under certain circumstances (C4, 2025)*."

Claims processing delays were also highlighted, with several interviewees expressing frustration over lengthy claims settlement periods. This issue often caused financial instability and project delays; a broker explained, " T*here have been occasions where contractors struggled to receive full compensation after claims, especially regarding project delays or damages caused by third parties (C2, 2025)*."

Opportunities for Improvement

Despite these challenges, interviews also uncovered opportunities for improvement within the construction insurance framework. A major opportunity identified was increased education and training for contractors on risk management and insurance. Many respondents suggested that workshops and seminars could help improve understanding and awareness of available insurance products.

Additionally, there was a call for greater collaboration between insurers, construction firms, and regulatory bodies to develop more tailored insurance products that better meet the industry's needs. One insurance provider noted, "*The claims process can often be slow and cumbersome, with a lack of transparency in how decisions are made (C8, 2025).*"

Several participants also highlighted the potential of technology to streamline insurance processes. Leveraging digital platforms for policy management and claims processing could enhance efficiency and transparency. One executive said, "*Leveraging technology can assist us in navigating the complexities of insurance and make the process smoother for all parties involved" (C11, 2025).*

Alignment of Awareness and Utilisation
The findings reveal a gap between awareness of insurance products and actual use. Although contractors are aware of various insurance products, cost, complexity, and limited coverage are significant barriers to adoption. This highlights the importance of a more holistic approach to insurance education that addresses knowledge gaps and practical constraints.

Addressing systemic Challenges
The systemic challenges identified, particularly those related to outdated regulatory frameworks and inefficient claims processing, require urgent attention. *Modernising regulations and streamlining claims processes would significantly enhance insurance products' ability to address the evolving risk landscape in the construction industry (C12, 2025).*

5. Conclusion and Further Research

In conclusion, the effectiveness of existing insurance frameworks in addressing contractor risks varies significantly, with emerging risks such as cyber threats and environmental liabilities receiving higher effectiveness ratings compared to some traditional policies. While essential coverage, such as public liability insurance and erosion risk insurance, remains fundamental to risk management, gaps in policies like employers' liability insurance and group personal accident insurance indicate the need for policy enhancements to protect contractors and workers better. The findings emphasise the importance of continuously evaluating and adapting insurance frameworks to meet evolving industry challenges. By improving coverage accessibility, streamlining claims processes, and ensuring comprehensive protection, insurers and policymakers can create a more resilient insurance landscape that effectively mitigates financial and operational risks within the construction sector.

Future research should concentrate on exploring innovative insurance models tailored to the specific risks of the construction industry. Additionally, examining the role of technology in enhancing insurance processes could provide valuable insights into how stakeholders can navigate the complexities of the insurance market. The study emphasises the necessity for policymakers and industry stakeholders to revise and modernise existing insurance frameworks. The effectiveness of Cyber Liability Insurance and Environmental Liability Insurance indicates that regulatory bodies should contemplate promoting these types of coverage, possibly mandating them for construction firms. Furthermore, the moderate effectiveness of traditional policies underscores the requirement for improvements in claims processing, coverage scope, and contractor education. Insurers should also consider revising underwriting requirements and streamlining claims management to enhance the accessibility and reliability of policies such as Performance Bond Insurance and Fidelity Guarantee Insurance.

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Developing a Cost Estimating Conceptual Framework that Leverages on Knowledge

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Abstract

Literature on the accuracy of cost estimates in construction projects has reported that attempts to improve accuracy were focused on the methods, tools/techniques, and the factors affecting accuracy. This confirmed that attempts at addressing these inaccuracies were based on reductionism. To avert these inaccuracies, there is a need to go beyond reductionism and adopt a multi-theoretical approach, such as leveraging knowledge. This paper reports the effort made to incorporate different and relevant theories to develop a framework that would be used to improve accuracy. A systematic literature review was used to identify and examine factors that affect leveraging knowledge within the cost estimating process. The factors include: cost estimating process models, factors affecting accuracy, information and knowledge required for estimating. Relevant theories were then used to underpin the concepts and finally develop the conceptual framework. The paper is one step in a larger study aimed at developing a knowledge-based cost estimating process model for construction projects. The developed framework will bridge the gap between research and practice. It provides a structured approach to cost estimating and improves the accuracy of estimates. The framework will enhance research rigour, foster advancements in cost estimating methodologies, and inform industry best practices.

Keywords: Accuracy, Cost Estimates, Conceptual Framework, Knowledge and Projects

1. Introduction

Cost estimating plays a crucial role in construction projects as it forms the foundation for informed decision-making throughout the project lifecycle (Valtanen, 2020). Accurate cost estimates are vital for determining project feasibility, securing funding, and ensuring project success (Akinradewo, Aigbavboa & Oke, 2020; Jiang, 2020). However, achieving accuracy in cost estimating has been a persistent challenge in the construction industry. Inaccurate estimates can lead to misallocation of resources and project failures (Ibrahim & Elshwadfy, 2021; Albtoush *et al*., 2022). Inaccurate estimates can have detrimental consequences, leading to budget overruns, delays, and disputes between stakeholders (Egboga, Daniel, & Abubakar, 2022).

The construction industry has been grappling with cost estimating accuracy issues for decades, with slight improvement in accuracy levels (Dandan, Sweis, Sukkari & Sweis, 2019; Chimdi, Girma, Mosisa & Mitiku, 2020). This persistent challenge has spurred research efforts to improve cost estimating practices. Attempts made at improving the accuracy of cost estimates focused essentially on methods, or tools and techniques, and the factors affecting accuracy (Fazeli *et al*., 2020; Hashemi *et al*., 2020; Khodabakhshian & Toosi, 2021; Ning *et al*., 2020). While inaccuracies in cost estimates have remained unabated, attempts to address them are based on a reductionist approach by examining the various factors that affect the accuracy of estimates (Wang *et al*., 2022; *Sayed et al*., 2023; Chimdi *et al*., 2020; Egboga *et al*., 2022). Therefore, calls have been made to go beyond the reductionist approach and adopt a multi-theoretical approach, such as leveraging Knowledge (Kumar *et al*., 2021; Areed *et al*., 2021). Existing cost estimating process models are information-centric instead of being knowledge-centric; as such, they are not capable of handling the paucity of information at early stages of construction projects (Albtoush *et al*., 2022; Chimdi *et al*.,2020; Ibrahim & Elshwadfy, 2021). Therefore, there is an absence of a mechanism that leverages knowledge within the existing process models.

This study is a part of a larger study that aims to develop a process model that leverages knowledge within the cost estimating process to improve the accuracy of cost estimates for construction projects. To achieve the aim of the study, five objectives were formulated. First to identify factors that affect the leveraging of knowledge within cost estimating process, secondly to develop a cost estimating conceptual framework that leverages on knowledge; Thirdly, to assess cost estimating practices in construction projects, Fourth, to determine the requirements for leveraging knowledge within the cost estimating process and lastly to develop and implement the knowledge-based cost estimating process model.

This paper addresses the first and second objectives of the larger research. Therefore, to be able to achieve the aim of this research paper, the study identified factors that affect the leveraging of knowledge within cost estimating process, it undertakes a systematic and critical literature review to specifically understands the Cost estimating Process, Factors affecting accuracy of cost estimates, information required for cost estimating and knowledge required for improving cost estimate

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accuracy, and finally developed the cost estimating conceptual framework that leverages on knowledge by, understanding theories that underpins the research, understand the concepts/constructs to be investigated, relate theories to the study constructs and then establish interrelationships between the study constructs. The conceptual framework will help identify the practice in Quantity surveying Firms and also help in the development of the final model.

2. Literature Review

2.1. Existing Cost Estimating Process Models

There is a necessity for a standardised guide for cost estimating practitioners to ensure uniformity and consistency in estimate preparation. Several cost estimating process models exist. A current review of the literature points us to three readily available guides, which are specific to industries in the UK and U.S. These guides are considered "best practices" from the UK and U.S. Studies relating to cost estimating have focused on methods and techniques most of which are outlined in the New Rules of Measurement (NRM) 1(RICS, 2009). These process models guide estimators to prepare accurate estimates. Subsequently, more organisations like RICS (2020) and NASA (2008) have since published a set of steps. To reinforce the importance of an accurate conceptual cost estimate, authors like Kirkham (2015) and Ashworth & Perera (2015) have also extensively examined the order of cost estimate.

2.1.1. Department of Energy (DOE) cost estimating process model developed in the U.S.

The U.S. Department of Energy (DOE), through collaborations, developed a 12-step process model recommended by the Government Accountability Office (GAO) to serve as an estimating guide for capital projects. The DOE model comprises 12 steps, which can be divided into three stages. Pre preparation consisting of five (5) steps (Define the Estimate's Purpose, Develop an Estimating Plan, Define the Program Characteristics, Determine the Estimating Structure, Identify Ground Rules and Assumptions); preparation stage consisting of four (4) steps (Develop a Point Estimate, Compare to Independent Estimate, Conduct sensitivity analysis, Conduct Risk & Uncertainty Analysis) and post preparation stage consisting of three (3) steps (Document the Estimate, Present Estimate to Management for Approval, Update the Estimate to Reflect Actual Costs and Changes).

2.1.2. The Infrastructure Project Authority (IPA) process model was developed in the UK.

The IPA document provides a best practice approach to cost estimating for UK infrastructure projects. It is designed for project leaders and delivery teams to improve estimate quality and decision-making. The process involves eight steps divided into three stages: pre-preparation, preparation, and post-preparation. This guidance aims to enhance project delivery and benefit UK citizens. The process consists of eight (8) steps classified in to 3 stages as well including the pre-preparation steps consisting of one (1) step (Establish brief and engage the team), the preparation steps consisting of three (3) steps (Gather data and evidence, Select cost estimating methodology, Calculate base cost estimate, uncertainty, risk) and the post preparation steps consisting of (4) steps (Produce cost estimate report, Review and assure, Project leadership sign-off, Use the cost estimate to support decision- making).

2.1.3. New Rules of Measurement (NRM1) 1 Order of Cost Estimates from Handbook of Cost Management

NRM also has 13 steps, the Pre-Preparation Stage having 1 step (Basic information gathering), the Preparation Stage with 10 steps (Produce building work estimate, Ascertain work cost estimate, Produce project and design team fees estimate, Produce development and project cost estimate, Ascertain base cost estimate, Produce risk allowance estimate, Ascertain cost limit exclusive of inflation, Produce inflation estimate, Ascertain cost limit inclusive of inflation, Produce VAT assessment) and Post-Preparation Stage having two steps of activities (Produce order of cost estimate report, Issue order of cost estimate report).

2.2. Factors affecting the accuracy of cost estimates

A review of 73 studies reveals the existence of 160 disaggregated factors, as reported by Musarat et al. (2021), Albtoush et al. (2021), Dandan et al. (2020), and Chimdi et al. (2020). These factors were then critically reviewed and studied to reveal 58 aggregated factors across the literature (Dandan et al., 2020; Chimdi et al., 2020; Albtoush et al., 2021). The criterion used to reduce the factors was based on the fact that some of the factors repeated themselves across different authors. Out of these 58 factors, 22 are knowledge-related while 20 are process-related. Within the process-related factors, 13 are about information (See Table 1 in the Appendix).

These factors are considered to affect the accuracy of an estimate. Authors have tried to group the factors into five groups: Group A, client-related factors; Group B, consultants, design, and information-related factors; Group C, cost-evaluation procedure-related factors; Group D, project attributes-related factors; Group E, contract and offering-related factors; and Group F: Market and External condition-related factors. However, the top 10 based on the research requirements were selected and used for the framework.

2.3. Information required for cost estimating

Information is the basis upon which estimates are prepared; however, the amount of information needed to prepare an estimate at an early stage is deficient in

projects (Albtoush *et al*., 2022; Ibrahim & Elshwadfy, 2021). Given that existing cost estimating process models are information-centric, specific information is required when preparing an estimate (DOE, 2016; Benge, 2018; IPA, 2020). The details/amount of information required is dependent on the type of estimate and when it is prepared (RICS, 2012, 2014; DOE, 2016; Benge, 2018; IPA, 2020). The NRM1 provides a comprehensive list of information required to prepare a cost estimate, which is an early-stage estimate (RICS, 2012). It specifically outlines 16 types of information from the employer, 11 from the architect, four from the M&E Engineer, and three from the Structural Engineer.

2.4. Knowledge required for improving the accuracy of cost estimates

Since existing Models are information-centric, the only information required for preparing estimates has been captured from the literature. However, to improve the accuracy of estimates, we need much more than information; there is a need to leverage the knowledge and experience of the project team to come up with information where it is not available or not complete. Figure 1 highlights the knowledge considerations for developing a cost estimate.

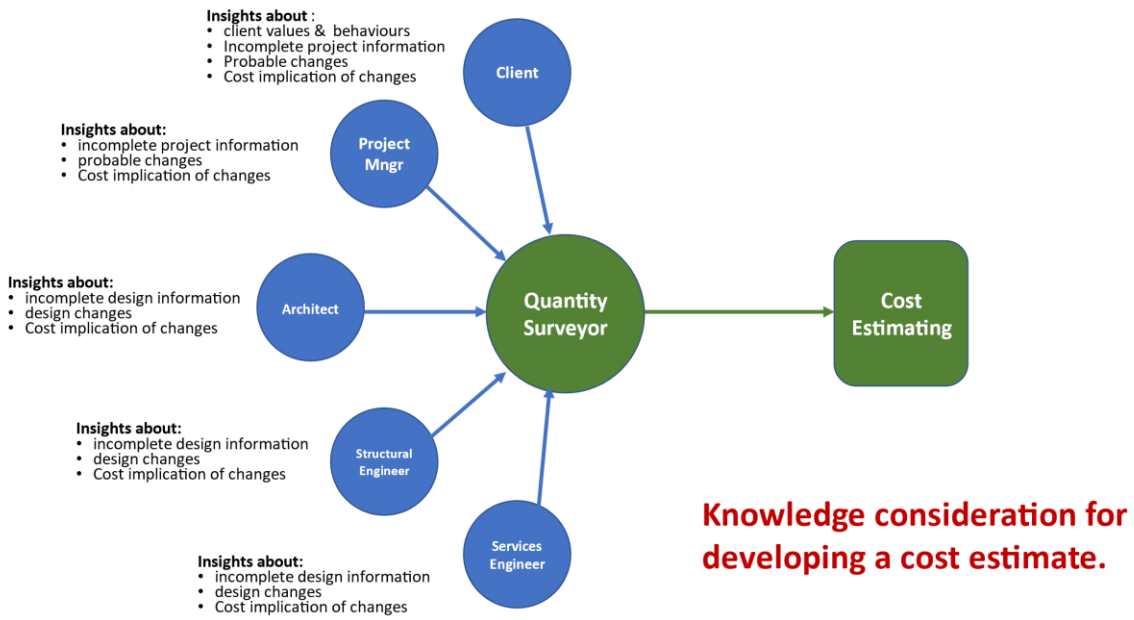


Figure 1: Knowledge consideration for developing a cost estimate

2.5. Theories that underpin the Research

Resource-based view requires that organisations focus on the uniqueness of their internal resources to gain organisational efficiency, such as improving the accuracy of estimates (Lewis et al., 2010; Lyons & Brennan, 2019). Systems theory emphasises considering the interrelatedness of various components, engaging in iterative improvement through feedback loops and accounting for the complexities in projects and hence the cost estimating process (Guan et al., 2020; Ongkowijoyo & Doloi, 2018; Boateng, 2017). The contingency theory suggests that there cannot be a "one-size-fits-all" solution. Hence, solutions are situation-specific. To this end, therefore, the dynamic nature of an organisation has to be taken into cognisance (Azman *et al*., 2020; Bryan & Brennan, 2019).

3. Methodology

The study adopted a two-stage process. At the first stage, articles were identified using the keywords to search from these online databases: Science Direct, Emerald Insight, Google Scholar, Taylor and Francis, and ASCE Library. The keywords were selected from review articles (Albtoush et al., 2021; Chimdi et al., 2020; Hatamleh et al., 2016) on cost estimating related topics, based on the common keywords used by researchers. For this study, the search words include: "Cost Estimating", "Accuracy of cost estimates", "Factors affecting accuracy", "Information required for estimating", etc. Several different variations of the search words were used to collate articles within this domain over a ten year period (2013-2023). Consequently, a total of 115 articles were found and, more importantly, reduced to 73 articles as a result of systematic refinement to collate articles that are more relevant to the study. Furthermore, these articles were then reviewed to capture details of existing information regarding cost estimating and factors affecting the accuracy of estimates in construction projects, as well as project information used in the selected articles. The following were the inclusion criteria in the selection of articles:

1. Only accessible articles within the following databases: Science Direct, Emeraldinsight, Google Scholar, Taylor and Francis and ASCE library were used
2. Articles selected must focus on cost estimating in the construction industry
3. Articles must have been published between 2013 and 2023
4. Articles must be within the cost estimating process, factors affecting the accuracy of estimates, and theories in cost estimating research.

For the exclusion criteria, it has to be "cost estimate", not cost separately and not " estimating separately. It must be for construction projects as well; therefore, the respective bullet points used by the various databases were utilised.

4. Findings and Discussion

4.1. Cost Estimating Process

For the sake of meeting this study's goal, these three industry/organisational documents i.e, from the IPA 8 steps, the GAO 12 steps and the 13 steps NRM 1 process models have carefully been reviewed by identifying and merging similar steps, even if phrased differently, and recognising sub-steps within larger steps to create a unified 10-step model that encompasses the essential elements of cost estimating, drawing from the best practices of various methodologies. The Unified 10 steps have Pre-Preparation Stage (Plan Cost Estimating, Gather Information), Preparation Stage (Gather Data/Evidence, Select Methodology, Compute Base Estimate, Conduct Risk Analysis, Firm up Estimate) and Post-Preparation Stage (Document Estimate, Issue Estimate, Update Estimate).

4.2. Factors affecting the accuracy of cost estimates

out of the 58 aggregated factors revealed across the literature, a critical review showed that 12 relate to knowledge and/or experience relating to either participants or the project (Table 2). These factors were selected to form the basis of developing the conceptual framework, which is the main aim of this research paper, because the focus of this work is on knowledge; it will also be the basis of assessing current cost estimating practices and developing the final process model. The consideration of the factors also provides a significant modification to the existing process models.

Table 2: Factors affecting the accuracy of cost estimates

S/N	Factors Affecting Estimate Accuracy
1	Pricing experience of construction projects
2	Perception of estimation importance
3	Experience and skill level of estimators
4	Certainty of project brief
5	Experience on similar projects
6	Past relationship with clients
7	Level of competition/construction activities
8	Labour cost & performance
9	Number of bidders on competitive projects
10	Stability of market conditions
11	Interest & inflation rate
12	Currency exchange fluctuation

Source: Musarat, et al. (2021); Albtoush et al. (2021); Dandan et al. (2020); Chimdi et al.(2020)

4.3. Relating Theories to the Study Constructs

The RBV theory suggests that by tapping into the knowledge base inherent within a construction project, improvements in the accuracy of cost estimates can be achieved. That is why the study used the RBV theory and leveraged knowledge. The systems theory explicates the fact that for significant improvement to be made in the accuracy of cost estimates, the consequences of the interaction among the factors, knowledge and the estimating activities must be considered as a whole instead of in isolation. Literature has only been addressing issues of accuracy without examining the process holistically, rather than in isolation. Founded on the contingency theory, the process model to be developed should be able to accommodate project peculiarities. Hence, there would not be any definitive set of factors, knowledge and activities that apply to all projects. Therefore, process requirements are derived based on project characteristics.

4.4. Interrelationship between the study constructs

Intrarelationships had been designed between the study constructs, the constructs, theories, and how they relate, as shown in the conceptual framework in Figure 2.

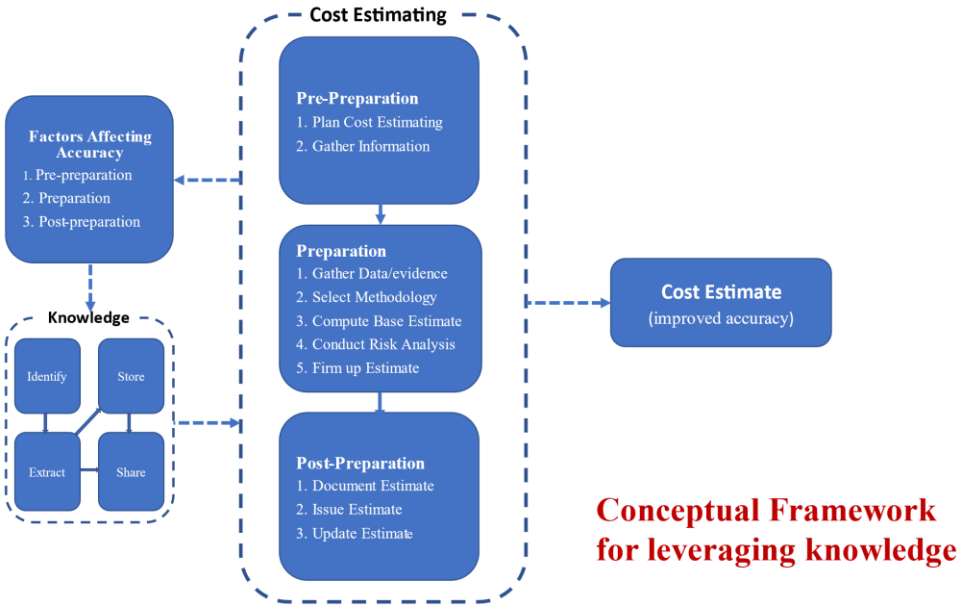


Figure 2: Cost Estimating Conceptual Framework for Leveraging Knowledge

This framework addresses gaps in existing literature by focusing on cost estimating activities, emphasising their iterative and flexible nature, where stages may loop back to previous ones for refinement. It integrates factors affecting estimate accuracy and highlights the importance of knowledge as a unique organisational resource, managed through identification, extraction, storage, and sharing processes. By incorporating the Resource-Based View (RBV) theory, contingency theory, and systems theory, the framework considers knowledge, accuracy factors, and the estimating process holistically, moving beyond reductionist approaches that isolate aspects of estimating. This comprehensive approach aims to improve estimate accuracy by addressing the entire system and process rather than focusing on individual components in isolation.

5. Conclusion and Further Research

The goal was to develop a cost estimating conceptual framework that leverages knowledge in order to achieve the bigger aim of developing a knowledge-based cost estimating process model for construction projects. The study developed the framework and features the various constructs of the research, mainly: Cost estimating Process, factors affecting accuracy of cost estimates, knowledge required to improve accuracy, all viewed under the theoretical Lens of Resource-Based View theory, Systems theory and contingency theory. The research was conducted mainly using a systematic and critical review of the literature. The developed framework has identified project-specific factors, especially those related to knowledge, that affect the accuracy of cost estimates, thereby bridging the gap between research and practice. It provides a structured approach to cost estimating, which in turn improves the accuracy of estimates. The framework will enhance research rigour, foster advancements in cost estimating methodologies, and inform industry best practices.

The following stages of the research that the researcher will conduct are to operationalise the study constructs to determine the cost estimating practices in Quantity Surveying firms, which will help in developing the as-is model of the research and then determine requirements for leveraging knowledge within the estimating process and finally develop a knowledge-based cost estimating process model for construction projects

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Appendix 1

Table 1: Factors affecting the accuracy of cost estimates

S/N	**Factors affecting the accuracy of cost estimates**
1	Pricing experience of construction projects
2	Perception of estimation importance
3	Equipment (cost/availability/performance)
4	Clear scope definition
5	Site constraints (access, storage, services)
6	Financial capabilities of the client
7	Availability of a database of bids on similar projects (historical data).
8	Clear and detailed drawings, specifications and project documentation.
9	Experience and skill level of estimators.
10	Completeness of cost information, accuracy, reliability, quality and details
11	Materials (prices, availability, quality, imports).
12	Experience on a similar project.
13	Accuracy of BOQ.
14	Management team (suitability, experience, performance
15	Quality of assumptions used in preparing the estimate
16	Complexity of design and construction
17	Build ability
18	Scale and scope of construction
19	Construction techniques
20	Construction location (regions / rural; urban)
21	Project duration
22	Certainty of project brief
23	Client requirements on quality
24	Type of client (public/private)
25	Experience on similar projects
26	Past relationship with clients
27	Current workload
28	Need for work
29	Planning capability
30	Absence of alterations and late change
31	Procurement method
32	Type of contract
33	Tendering method
34	Variation order
35	Level of competition and Level of construction activity
36	Material cost
37	Labour cost /performance
38	Number of bidders on competitive projects
39	Stability of market conditions
40	Interest rate/inflation rate

41	Poor tender document
42	Insufficient estimating time
43	Insufficient analysis of the tender document
44	Shortage of project requirements.
45	Basis of selection (open, selective and direct negotiation).
46	Commitment of the client to the project.
47	Project technology and complexity level.
48	Ability of quantity surveyors to cope with stress (work pressure).
49	Communication barrier.
50	Familiarity of quantity surveyor with the type of projects.
51	Perception of estimating importance.
52	Expected level of error in estimates.
53	Limited time to prepare the estimate due to the deadline.
54	Estimating method used in the preparation of estimates.
55	Organisation's estimating procedure
56	Border closure and blockade.
57	Currency exchange fluctuation.
58	Clear contract conditions.

Source: Musarat, et al. (2021); Albtoush et al. (2021); Dandan et al. (2020); Chimdi et al. (2020)

Inflation and Quality Attributes in Construction Projects in Cities: An Empirical Analysis of the Federal Capital Territory (FCT) Abuja, Nigeria

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Abstract

Given the current inflationary effects in the country, this study examines the nexus between inflation and the quality attributes in construction projects in FCT, Abuja, to enhance real estate construction and mitigate the effects of inflation on construction in Nigeria. An exploratory research design was adopted using both primary and secondary sources of data. Two sets of questionnaires were administered, one to the property owners and the other to the Real Estate Developers. Using stratified sampling techniques, structured questionnaires were administered to the respondents, while 95 (63.33) and 210 (52.50) copies were retrieved from the Real Estate Developers and Private Landowners, respectively. Key findings from the study indicate that the rate of inflation increased from 11.40% in 2019 to 26.31% in 2024. These consequently affected the prices of building materials within the said periods, as the major quality attributes identified were sustainability, strength, and performance of structures, ranked 1st and 2nd respectively, with mean scores of 4.7368, For suitability attributes among Real Estate Developers, meeting requirements topped the list (4.6737), followed by proper handling (2nd, 4.4947) and desirability/demand (3rd, 4.3474). Results showed significant differences in the opinion of the respondents based on the nature of project qualities. It was concluded that, for the Nigerian economy to improve, policy formulations, intervention strategies such as the use of local building materials, appropriate budgeting, inflation reduction measures, amongst others, are essential to mitigate the effects of inflation and enhance real estate development in the country.

Keywords: Construction, FCT Abuja, Inflation, Nigerian Economy, Quality Attributes

1. Introduction

Nigeria's construction industry is a nascent sector that is seen as a development engine whose success indicates the state of the country's economy (Akanni *et al,* 2014). The construction sector plays a pivotal role in the socio-economic advancement of a country, primarily responsible for the physical development and transformation of the built environment. As highlighted by Alaloul *et al*. (2020) and John-Nwagwu *et al.* (2021), construction activities are vital drivers of economic growth. This industry's influence extends globally, significantly contributing to economic prosperity by generating millions of jobs (Okosun *et al.* 2021). According to Doyle (2019), the construction sector employed approximately 7.5 million individuals as of July 2019, with projections indicating an addition of 864,700 new jobs by 2026, corresponding to a growth rate of about 12%. Beyond its sheer size, the construction industry's relevance is underscored by its substantial contributions to other economic sectors (Diamini, 2012; Musarat & Ahad, 2016; Okosun *et al,* 2021). However, Obiegbu (2003) notes that the inherent demand for substantial resources in construction projects renders quality susceptible to material price inflation. Ogun *et al* (2014) indicate that construction materials can represent 35-45% of project costs, and in some scenarios, this figure could escalate to 60%. Consequently, the Nigerian construction sector grapples with critical challenges, primarily inflation and construction quality. These challenges adversely affect not only the industry itself but also have broader implications for the national economy and its populace. The persistent inflationary environment in Nigeria particularly impacts the construction sector, leading to escalated costs for materials, labour, and equipment rentals. Such increases foster project delays, budget overruns, and a decline in construction quality (Oluwajana *et al.* 2022). Consequently, real estate contractors often face considerable challenges in managing rising expenses, frequently compromising on quality to maintain profitability.

In this context, Okosun *et al.* (2021) argue that the significance of project quality is often underestimated, with insufficient emphasis placed on this key parameter within the industry. Quality remains a primary indicator of project outcomes, accentuating the necessity for implementing quality management practices to align construction projects with client specifications and standard codes. However, the ramifications of inflation on construction quality are starkly felt. Onashile (2008) points out that the Nigerian construction sector is navigating a turbulent landscape, where inflation and soaring material costs hinder projects that could enhance living standards, leading to either

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abandonment or stalling of prospective initiatives. Moreover, Oluwajana *et al.* (2022) further assert that building costs may surge by as much as 30% year-over-year due to inflation, compelling developers and builders to compromise on quality standards in response to persistent increases in material prices.

Okosun *et al* (2021) also noted that in today's construction industry, there is evidence of an unpredictable market, inflation, price changes of building materials, and other effects of inflation, making it challenging to have high-quality construction projects. Hence, the expansion of the construction industry is significantly impeded by inflation and the proliferation of sub-standard structures. Based on the aforementioned, this study aims to look at the effect of inflation on the quality of construction projects in the Federal Capital Territory, Abuja, to enhance real estate construction as well as mitigate the effects of inflation on construction in Nigeria.

2. Literature Review

Inflation is defined as a period of consistently rising prices in an economy. Okosun *et al* (2021) defined inflation as a widespread and continuous increase in prices of products. Economists use the term "inflation" to refer to a continuous increase in prices at the overall level expressed in monetary units. Accordingly, inflation is the result of an absolute decrease in purchasing power or money per unit, which is equivalent to a decline in the actual value of the unit of account and medium of exchange in an economy. The International Standard Organisation (ISO) defines quality as the full features and properties that fulfil stated needs (ISO, 2000). Therefore, project quality can be defined as either "meeting customer expectations" or "meeting customer specifications."

Quality attributes: Daniel (2024) describes quality attributes as the measures and methods related to a product or service. Key attributes include: (i) Functionality: The degree to which a product performs its intended function; (ii) Performance: How well it meets its intended use; (iii) Reliability: The ability to perform as intended without failures under normal conditions; (iv) Relevance: Meeting the actual needs of beneficiaries, being applicable and appropriate; (v) Timeliness: Delivery in time to address needs; (vi) Suitability: Fitness and correctness for the conditions of use; (vii) Completeness: Inclusion of the entire scope of services; (viii) Consistency: Uniform service delivery for all beneficiaries, ensuring standardised procedures.

Effect of inflation rate on construction projects: The impact of inflation on construction projects has been widely studied. Ogun *et al.* (2014) analysed construction material prices in Nigeria from 1998 to 2007 and found a third-order polynomial relationship with the cumulative inflation rate. Akanni *et al* (2014) conducted a survey in Lagos State, revealing significant effects of inflation on material prices. Alabi and Fapohunda (2021) noted that rising costs lead to instability in the industry, resulting in profit forecasting challenges and layoffs. Adu and Ekung (2019) identified inflation and other factors as primary causes of increased building material prices, leading to contractual claims and declining profit margins. Bello *et al.* (2020) found significant effects of inflation on residential property development in Bauchi, while (Otunola et al., 2021) highlighted land acquisition and material costs hindering real estate development in Bariga, Lagos. In Ethiopia, Wondimagen and Essubalew (2022) noted poor risk management contributing to inflation in building materials, while Belay and Jain (2023) identified key factors affecting project costs in Adama, including fluctuating currency rates and supply-demand imbalances.

The study area (FCT, Abuja, Nigeria)
The Federal Capital Territory (FCT) Abuja is situated in the North-Central zone of Nigeria; Abuja is the capital of Nigeria's Federal Capital Territory (FCT). The FCT is around 8,000 square kilometres in area and shares borders to the North with Kaduna State, to the west with Niger State, to the east and southeast with Nasarawa State and the southwest with Kogi State (Okosun *et al,* 2021).

3. Research Methodology

An exploratory research design was adopted for this study. Data were derived from both primary and secondary sources. The primary data includes individual interviews, postal questionnaires, street interviews, telephone interviews and direct observation. Secondary data were derived from the files and records of real estate construction, the NBS and the CBN. The research examines the rate of inflation, nature of project qualities and in FCT, Abuja, between 2019 and 2024 (6 years). To demonstrate a clear correlation between inflation and the quality of real estate construction, the duration was deemed sufficient due to the country's economic recession. The target populations were the Real Estate Developers (REDs) and the private land owners in FCT Abuja. The sample size of property owners in Abuja is 400. At the same time, due to the relatively small number of Real Estate Developers Association of Nigeria (REDAN) members in Abuja, a sampling frame of 150 was adopted as the sample size, as suggested by Israel (2002) for a population of less than 200. According to the National Directory of REDAN, FCT Abuja has about 1,700,000 housing units and over 150 REDAN in FCT, Abuja. Questionnaires were administered (Type A and Type B) to the property owners and the Real Estate Developers. The first section dealt with questions on the background and characteristics of the respondents and the sampled firms in terms of sex, age, office location, employment, year of establishment, etc.

In contrast, the second section sought to gather vital information about their perceptions on the subject matter of the effect of inflation on the quality of construction in Abuja. In all, 305 out of the 650 questionnaires were distributed to the target population, resulting in a 46.92% recovery rate. This indicates a low proportion of response, due to the difficulty in persuading, accessing and retrieving the questionnaires. Using stratified sampling techniques, structured questionnaires were administered and retrieved from 95 (63.33) REDs and 210 (52.50) Private Land Owners (Table 1). The descriptive analysis and inferential analysis methods were used. Data collected were analysed using descriptive statistics and the Weighted Mean Score.

Table 1: Questionnaire administration schedule

Respondents	No Administered	No Retrieved	Percent
Real Estate Developers in Abuja	150	95	63.33
Private Land Owners in Abuja	400	210	52.50
Total	**650**	**305**	**46.92**

Source: Author's field survey (2024)

4. Findings and Discussion

The findings of the inflation and quality attributes in construction projects in the Federal Capital Territory (FCT), Abuja, Nigeria, are presented below;

4.1. The rate of inflation between 2019 and 2024 in the FCT, Abuja

Relative to the inflation rate in the economy (Table 2), data derived from the Nigerian Bureau of Statistics (NBS) revealed that the inflation rate in 2019 dropped to 11.40% and further increased to 13.25% in 2020 due to economic fluctuations. However, the impact of the COVID-19 pandemic further affected the level of inflation. It increased the prices of goods and services when the inflation rate rose to 13.25%, indicating a 1.85% increment from the previous year. Furthermore, the inflation rate increases to 16.95% in 2021 and 18.85% in 2022. As a result of the inadequate balance in the economy, the inflation rate in 2023 increased to 24.66% representing a 5.81% increment in the rate of inflation. As of mid-2024, the rate of inflation in Nigeria stood at 26.31% which caused significant increases in the price of goods and services and had a subsequent effect on the real estate construction sector. Thus, the rate of inflation and the rate of annual Change in the rate of inflation over the years show inflation is associated with increases and decreases in prices over the years. However, if adequate economic policies are not introduced to curb its effects on the economy, many existing real estate construction sectors will become moribund. This finding is corroborated by Okosun et al. (2021), who claimed that, irrespective of the prices of materials, Real Estate Developers and Property Owners are mainly concerned with profit-making in order to remain in business.

4.2. Nature of project qualities within the selected period in the study area

After analysing the opinions of Real Estate Developers and Property Owners in Abuja regarding key quality attributes, a Mann-Whitney U test was conducted within the selected period in the study area to identify any differences among respondents. Eight main factors were carefully examined and analysed, namely functionality, performance, reliability, relevance, timeliness, suitability, completeness, and consistency. Results showed significant aspects of project qualities and the differing perspectives of Real Estate Developers and Owners/Occupants in FCT Abuja, as detailed in Table 3 (Appendix 1). The primary quality attributes identified in the study were sustainability, strength, and performance of structures, ranked 1st and 2nd respectively, with mean scores of 4.7368. Ease of use, indoor air quality, and functionality of building systems ranked 3rd to 5th with mean scores of 4.7158 and 4.6211. In terms of timeliness, the period of construction ranked 1st (4.7263), followed by feedback (2nd, 4.1684) and maintenance policy timing (4th, 3.8526).

For suitability attributes among Real Estate Developers in Abuja, meeting requirements topped the list (4.6737), followed by proper handling (2nd, 4.4947) and desirability/demand (3rd, 4.3474). Conformity to international standards (4th, 3.8842) and capacity support (5th, 3.8526) were also noted. It could be deduced that, as presented in Table 3. Inconsistent quality elements, quality assurance was ranked 1st (4.4105), with project requirements (2nd, 4.3263) and financial accuracy (3rd, 4.1474) following. Building techniques and uniformity were 4th and 5th with mean

Table 2: The rate of inflation between 2019 and 2024

	2019	2020	2021	2022	2023	2024
Inflation (%)	11.40	13.25	16.95	18.85	24.66	26.31
Annual Change (%)	-0.70	1.85	3.71	1.89	5.81	1.65

Source: Bureau of Statistics (2024)

scores of 4.0737 and 4.0211. However, most of the sampled defects shows that there are significant differences in respondents opinions on the nature of project qualities with a significant level of lesser than 0.05($p \leq .05$). The finding is supported by Oluwajana *et al.* (2022), who indicated that inflation has an adverse effect on construction project attributes in Nigeria, which is against the expected outcome of the respondents. This implies that there are some somewhat significant differences in the response of the respondents based on the nature of project qualities within the selected period in the study area.

4.3. The extent to which inflation has affected project quality in FCT, Abuja

From Table 4, the relationship between inflation and project quality attributes showed both statistically significant and non-significant relationships. There are positive and negative relationships between inflation and project quality attributes in Abuja, as evidenced by the correlation coefficients, which have both positive and negative values.

As indicated in Table 4, inflation exhibits a correlation of -0.589 with functionality in terms of project quality. This negative relationship suggests that an increase in inflation corresponds to a decline in the functionality associated with the quality of real estate construction. Additionally, the analysis of other attributes reveals a mix of positive and negative correlations, indicating their varying impacts on project quality. The correlation coefficients for the majority of quality characteristics fall within the range of ±0.41 to ±0.70. Therefore, the relationship between inflation and these quality characteristics is considered moderate. This suggests that inflation is not the sole factor influencing project quality.

5. Conclusions and further research

The study shows fluctuation in the rates of inflation in FCT Abuja, Nigeria. At the same time, the prices of building materials have continued to increase as a result of the high rates of inflation The study concludes that, appropriate policy formulation as well as intervention strategies is essential; this includes the use of local building materials, appropriate budgeting inflation

Table 4: Extent to which inflation has affected project quality in FCT, Abuja

		Inflation	Functionality	Performance	Reliability	Relevance	Timeliness	Suitability	Completeness	Consistency
Inflation	Pearson Correlation	1								
	Sig. (2-tailed)									
	N	305								
Functionality	Pearson Correlation	-.589**	1							
	Sig. (2-tailed)	.001								
	N	305	305							
Performance	Pearson Correlation	-.640*	.531	1						
	Sig. (2-tailed)	.014	.585							
	N	305	305	305						
Reliability	Pearson Correlation	.454**	-.584**	-.507	1					
	Sig. (2-tailed)	.007	.001	.897						
	N	305	305	305	305					
Relevance	Pearson Correlation	.443*	-.564**	.450	.466**	1				
	Sig. (2-tailed)	.012	.004	.388	.004					
	N	305	305	305	305	305				
Timeliness	Pearson Correlation	.662**	-.681**	-.559	.477	.524**	1			
	Sig. (2-tailed)	.005	.002	.303	.181	.000				
	N	305	305	305	305	305	305			
Suitability	Pearson Correlation	.534*	.519	.550	-.439*	.131*	.531	1		
	Sig. (2-tailed)	.019	.744	.382	.015	.422	.591			
	N	305	305	305	305	305	305	305		
Completeness	Pearson Correlation	-.634*	.490	-.502	-.576**	.458	-.517*	.553	1	
	Sig. (2-tailed)	.019	.117	.966	.002	.315	.042	.354		
	N	305	305	305	305	305	305	305	305	
Consistency	Pearson Correlation	.537*	-.559**	.591	.515**	.474**	.482	-.403	-.460	1
	Sig. (2-tailed)	.017	.005	.114	.000	.002	.152	.959	.296	
	N	305	305	305	305	305	305	305	305	305

**. Correlation is significant at the 0.01 level (-2-tailed).

*. Correlation is significant at the 0.05 level (2-tailed).

Source: Author's field survey, 2024

reduction measures as this will help enhance real estate development and investment in the country. Ultimately, the construction industry, private developers, governmental organisations, and corporate bodies will all greatly profit from the study, as it will also function as a manual and source of information for further studies and researchers who may undertake research work on a similar subject. Given the foregoing, the study conclude that, the Government should look into the creation of favourable policies that will reduce the rate of inflation as well as its subsequent effects on the prices of building materials; Furthermore, The Government and relevant stakeholders should reduce the inflation on the prices of building materials, support and encourage innovative research in the development of new local building materials for production; government should take drastic measures to counter the problem of transportation costs, cost of power supply, and the increase in fuel prices in order to improve the ease of movement and distribution of raw materials to the factory (distribution of the finished products from the factory to the end-user) and finally, the study conclude that, there should be a shift from over-dependency on imported materials to the use of local materials. Further research should be carried out on the performance attributes of major quality attributes in building constructions in Abuja.

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Appendix 1

Table 3: Nature of project qualities within the selected period in the study area

Nature of project qualities	REDAN Members		Property Owners		Mann-Whitney U					
Functionality	**Mean**	**Rank**	**Mean**	**Rank**	**Mann-Whitney U**	**Wilcoxon W**	**Z**	**Asymp. Sig. (2-tailed)**	**Kendall's Tau_b**	**Sig.**
Strength and Performance	4.7368	2nd	4.6286	2nd	8899.00	31054.00	-1.851	.064	1.00	
Dwelling	4.4421	6th	4.4190	4th	9282.00	31437.00	-1.132	.258	-.046	.425
Durabilitity	4.3053	7th	4.2952	5th	9480.50	31635.50	-.791	.429	-.243	.000
Sustainability	4.9684	1st	4.5476	3rd	6849.00	29004.00	-5.840	.000	.202	.000
Extent of Usage	3.2632	10th	3.7190	9th	7679.50	12239.50	-3.331	.001	.056	.328
Maintenance	3.4737	9th	4.0381	6th	7052.00	11612.00	-4.312	.000	-.021	.717
Aesthetic perception	3.8211	8th	3.7857	8th	9867.00	32022.00	-.158	.874	.327	.000
Project Ease of Use	4.5684	3rd	4.6714	1st	8916.00	13476.00	-1.821	.069	-.133	.020
Indoor Air Quality	4.7158	4th	3.7000	10th	5303.50	27458.50	-7.008	.000	-.101	.079
Building System Functionality	4.6211	5th	3.9429	7th	5790.00	27945.00	-6.279	.000	-.008	.886
Performance										
Cost	4.1684	9th	4.2571	3rd	9633.00	14193.00	-.519	.604	1.00	
Capacity	4.4947	5th	3.5857	10th	5368.00	27523.00	-6.749	.000	-.204	.000
Serviceability	4.2632	6th	3.7286	8th	6825.00	28980.00	-4.641	.000	-.230	.000
Convenience	4.2632	6th	4.3286	2nd	9130.00	13690.00	-1.314	.189	-.111	.033
Accuracy	3.8632	10th	3.6762	9th	8820.50	30975.50	-1.690	.091	-.326	.000
Robustness	4.7579	1st	4.0857	7th	6145.50	28300.50	-5.942	.000	-.146	.004
Resilience	4.6526	3rd	4.1762	6th	7241.50	29396.50	-4.223	.000	-.201	.000

Comfort	4.5158	4th	4.2190	5th	8430.00	30585.00	-2.366	.018	-.229	.000
Safety	4.1789	8th	4.2476	4th	9098.00	13658.00	-1.333	.183	.066	.198
Energy Efficient	4.7053	2nd	4.3714	1st	7572.00	29727.00	-3.829	.000	.066	.213
Reliability										
Specific function	4.7474	1st	3.5048	10th	2756.00	24911.00	-10.594	.000	1.00	
Cost of Rework	3.9789	9th	3.6905	9th	7721.50	29876.50	-3.334	.001	.248	.000
Failure Cost	4.6737	3rd	4.5095	4th	9177.00	31332.00	-1.357	.175	.057	.265
Prevention Cost	4.2842	6th	4.1143	7th	9093.00	31248.00	-1.346	.178	.304	.000
Project Delivery	4.1895	7th	4.6095	1st	7833.00	12393.00	-3.561	.000	-.143	.005
Design	4.4947	2nd	3.6524	8th	4838.00	26993.00	-7.568	.000	.458	.000
Operation and Maintenance	4.4632	4th	4.5143	3rd	9648.00	31803.00	-.557	.577	.103	.043
Installation of Components	4.4316	5th	4.3857	5th	8827.00	30982.00	-1.819	.069	.066	.199
specific stability	4.0526	8th	4.5810	2nd	7324.00	11884.00	-4.291	.000	.071	.158
flexibility of work	2.6316	10th	4.2762	6th	2943.50	7503.50	-10.316	.000	-.388	.000
Relevance										
Cost of Maintenance	4.4526	1st	4.4857	1st	9595.00	31750.00	-.620	.535	1.00	
Ease of Servicing	4.2947	2nd	4.1238	4th	9316.00	31471.00	-1.001	.317	.413	.000
Ease of Management and Maintenance	3.9789	6th	4.3619	3rd	8281.00	12841.00	-2.594	.009	.166	.001
Project Reliability	4.0632	4th	3.8714	6th	9176.00	31331.00	-1.183	.237	.295	.000
Continuous Service	3.7684	10th	4.1048	5th	8323.00	12883.00	-2.479	.013	.296	.000
Ease of Project Delivery	3.9474	8th	3.0095	10th	5682.00	27837.00	-6.183	.000	.109	.028

Project Cost Estimates	3.9789	6th	3.5524	9th	7265.50	29420.50	-4.007	.000	.157	.002
Project Schedule	3.8842	9th	4.4190	2nd	7062.00	11622.00	-4.451	.000	.098	.059
Project Delivery Date	4.0211	5th	3.5524	8th	7495.50	29650.50	-3.634	.000	.190	.000
Costs of Materials	4.0737	3rd	3.8571	7th	8678.50	30833.50	-1.910	.056	.149	.003
Timeliness										
Construction Period	3.8211	5th	4.2571	4th	8115.00	12675.00	-2.800	.005	1.00	
Project Timeline	3.2526	10th	3.4667	10th	8787.00	13347.00	-1.763	.078	-.011	.829
Project Delivery	3.7474	7th	3.5238	8th	8504.00	30659.00	-2.194	.028	.149	.003
Feedback	4.1684	2nd	3.8048	6th	7461.00	29616.00	-3.765	.000	.046	.356
Time taken to Rectify Defects	3.2632	9th	3.5476	9th	8396.00	12956.00	-2.344	.019	.098	.049
Maintenance Schedule	3.8737	3rd	3.7238	7th	9160.50	31315.50	-1.239	.215	-.200	.000
Period of Construction	4.7263	1st	4.3810	2nd	7811.50	29966.50	-3.500	.000	-.271	.000
Duration of the schedule	3.4211	8th	3.8429	5th	7666.50	12226.50	-3.372	.001	-.102	.038
Maintenance policy and timing	3.8526	4th	4.2619	3rd	7274.50	11834.50	-4.035	.000	-.137	.007
Repair Functions and Services	3.7895	6th	4.5762	1st	4715.00	9275.00	-8.208	.000	.075	.141
Suitability										
Optimal Use	3.2526	9th	4.1286	7th	5144.00	9704.00	-7.075	.000	1.00	
Capacity Support	3.8526	5th	3.8000	9th	9142.50	13702.50	-1.228	.219	-.164	.001
Building Features	3.5368	7th	3.4619	10th	9490.50	31645.50	-.702	.483	.307	.000
Client Satisfaction	3.4526	8th	4.6381	2nd	3302.00	7862.00	-10.337	.000	.217	.000

Conformity to International Standards	3.8842	4th	4.7571	1st	3729.00	8289.00	-10.009	.000	.331	.000
Meeting Requirements	4.6737	1st	4.6048	3rd	9608.50	31763.50	-.629	.529	.232	.000
Fitness for Purpose	3.0737	10th	4.5429	4th	2495.00	7055.00	-11.272	.000	.263	.000
Handling	4.4947	2nd	4.3667	5th	9716.50	31871.50	-.411	.681	.098	.054
Strenght	3.5579	6th	4.1286	7th	6635.50	11195.50	-4.922	.000	-.064	.194
Desirability and Demand	4.3474	3rd	4.2095	6th	9326.00	31481.00	-.991	.322	.042	.409
Completeness										
Specification Requirement	4.2737	9th	3.8905	6th	8256.00	30411.00	-2.587	.010	1.00	
Minimal Absence of Deficiency	4.2526	10th	4.3286	2nd	9509.50	14069.50	-.720	.472	.252	.000
Report of Claims	4.8632	1st	3.7190	9th	5195.50	27350.50	-7.456	.000	-.145	.004
Minimal Absence of Rework	4.3579	7th	4.0952	4th	8503.00	30658.00	-2.283	.022	-.018	.724
Compliance	4.8211	2nd	4.6762	1st	8901.00	31056.00	-2.116	.034	.028	.600
Consistency	4.5579	3rd	3.7952	7th	6480.00	28635.00	-5.377	.000	-.069	.169
Usability	4.4526	5th	3.7286	8th	5016.00	27171.00	-7.374	.000	-.099	.047
Accurate	4.4947	4th	4.2429	3rd	6612.50	28767.50	-5.207	.000	.112	.028
Project Delivery	4.3684	6th	3.4190	10th	4424.00	26579.00	-8.137	.000	.155	.002
Materials and Deliverables	4.3474	8th	3.9000	5th	6979.00	29134.00	-4.456	.000	-.091	.066
Consistency										
Project Components	3.8842	8th	4.1381	6th	9899.00	14459.00	-.115	.909	1.00	
Desired Specification	3.1158	10th	3.9571	7th	6153.50	10713.50	-5.567	.000	.464	.000
Quality Assurance	4.4105	1st	3.8905	9th	6802.50	28957.50	-4.723	.000	.153	.002
Project Required	4.3263	2nd	4.3524	3rd	9601.50	14161.50	-.588	.556	.208	.000
Uniformity	4.0211	5th	3.4714	10th	6920.50	29057.50	-4.441	.000	.390	.000

Financial Accuracy	4.1474	3rd	4.2905	5th	9404.50	13694.50	-.874	.382	.491	.000
Fluidity of Concrete	3.8105	9th	4.6905	2nd	5541.50	10101.50	-7.218	.000	-.-008	.871
Confidence	3.9895	6th	4.3524	3rd	8132.00	12692.00	-2.871	.004	.297	.000
Building Techniques and Practices	4.0737	4th	4.8095	1st	5135.00	9695.00	-8.232	.000	.096	.064
Right Mix and Proportions	3.9368	7th	3.9381	8th	9897.00	32052.00	-.115	.908	.340	.000

Source: Field Survey (2024)

Disputes on Construction Projects: The Role Of Procurement Methods and Payment Strategies

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Abstract

This study examines the interplay between procurement methods, payment strategies and the occurrence of disputes in construction projects within South Africa. The construction sector plays a critical role in economic development; understanding these relationships is essential for improving project outcomes. The study employed a quantitative approach, utilising questionnaire surveys to gather data from 56 construction professionals. It was found that traditional procurement methods and unit price payment strategies are associated with a higher frequency of disputes, particularly in projects related to education, water and sanitation, and power and energy sectors. The study found that 60% of respondents experienced cost overruns due to disputes, while 70% reported time overruns. Key themes identified include the impact of external factors, scope creep, and the importance of positive stakeholder relationships. Based on these findings, the study concludes that payment strategies and procurement methods indirectly impact disputes, and the more flexible the procurement method, the fewer the project disputes. Therefore, the study recommends that stakeholders adopt collaborative procurement methods, implement transparent payment strategies, and enhance communication among project participants to mitigate conflict and bring about positive project performance. Further research is recommended using a larger sample size to validate the findings.

Keywords: Construction Management, Dispute Resolution, Design and Build, Traditional Procurement, Unit Price

1. Introduction

The construction industry serves as a cornerstone for economic development and is critical to a nation's growth and prosperity (Wu et al., 2023). It encompasses various activities, including infrastructure design, development, operation, and maintenance, which significantly contribute to economic development, making effective construction management practices essential (Amila, 2023). Central to these construction management practices are procurement methods and payment strategies, which play a vital role in project delivery and can significantly influence project outcomes, costs, and stakeholder relationships (Odeyinka & Kaka, 2005).

Procurement methods are described as organisational systems that delineate specific responsibilities and authorities among stakeholders involved in a construction project (Love et al., 1998). These methods establish the relationships between various elements of project execution, where payments for goods and services are a fundamental concern (Odeyinka & Kaka, 2005). The evolution of construction procurement—from a focus on the lowest cost to a more nuanced approach emphasising the best value—reflects the complexities of construction projects (Okunlola, 2012). The choice of procurement methods and payment strategies has consequences. Inappropriate selections can lead to disputes, increasingly recognised as a universal and unavoidable phenomenon in construction projects (Tariq & Gardezi, 2023). According to Johnson (2008) and Sithole (2016), disputes often arise from issues related to payments, inadequate planning, changes in project scope and deadlines, poor communication, and quality of work, making the notion of a conflict-free project unrealistic. McGregor et al. (2008) noted that disputes are an integral part of the construction process, while Gebken II and Gibson (2006) describe disputes as disagreements that necessitate external intervention for resolution. According to Sithole (2016), disputes in construction projects can result in significant delays, cost overruns, and strained stakeholder relationships (Sithole, 2016).
The inherent complexity of the construction industry, involving a multitude of stakeholders such as clients, contractors, subcontractors, suppliers, and regulators, makes it particularly susceptible to disputes (Harmon, 2003; Elmarsafi, 2008). This complexity is often compounded by the diverse skill sets and cultural backgrounds of subcontractors working on the same site, which can lead to misunderstandings and disputes (Brockett et al., 2019). In South Africa, procurement and payment strategy challenges are further exacerbated by a history of failed public sector projects, often caused by insufficient cash flow (Chadee et al., 2023).

Despite the acknowledged importance of procurement methods and payment strategies, there remains a significant gap in research examining their direct impact on dispute occurrences in construction projects. In South Africa, there is a need for more focused studies on dispute-resolution procedures, including adjudication and mediation (Povey, 2005; Maritz & Hattingh, 2015). This research seeks to bridge this gap

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by examining the interplay between procurement methods, payment strategies, and the occurrence of disputes in construction projects, towards identifying effective strategies for preventing and mitigating disputes on construction projects.

The following sections of this paper will present a review of the South African construction industry, explore the benefits and challenges associated with various procurement methods and payment strategies, outline the methodological approach employed in the study, present the findings and discussion, and conclude with actionable recommendations to address dispute-related issues in construction projects.

2. Literature Review

2.1. The South African Construction Industry

The construction industry is vital to South Africa's economy, significantly contributing to job creation, infrastructure development, and overall economic growth (Soni & Smallwood, 2023). In 2023, the South African construction sector added approximately 109.5 billion rand (roughly 5.79 billion U.S. dollars) to the country's GDP (Statista, 2024), significantly contributing to the Gross Domestic Fixed Investment. However, the industry faces numerous socioeconomic challenges, such as a shortage of skilled labour, public sector capacity to deliver infrastructure projects, load shedding and construction mafias (Mongane, 2024) that complicate project delivery and management. These challenges necessitate examining procurement methods and payment strategies, which are important for minimising disputes and enhancing project outcomes.

Procurement methods in South Africa are designed to meet both primary (performance in terms of time, cost and quality) and secondary objectives (promote broad-based economic empowerment and alleviate poverty), with the public sector often bound by legislative requirements that emphasise community empowerment and skills transfer (IDMS, 2011). The selection of procurement techniques must consider these objectives to ensure effective project delivery. However, the public and private sectors exhibit different procurement dynamics, with the latter having more flexibility in method selection.

2.2. Disputes and Their Causes

Disputes in construction projects are prevalent and arise from various factors, including conflicting objectives between clients and contractors (Rauzana, 2016). The complexity of construction projects, characterised by multiple stakeholders and intricate processes, exacerbates the likelihood of disputes (Aigbavboa & Thwala, 2014). Key project goals—time, cost, and quality—are often compromised due to these disputes, which can divert resources and hinder project success. Research indicates that most disputes stem from contractual disagreements, with Gamage (2023) highlighting that many of these disputes could be mitigated through effective contract management. The fragmented nature of construction work processes, each with teams with distinct goals and expectations, contributes to an adversarial environment prone to conflict (Nasrun et al., 2014). Disputes often escalate from claims related to financial compensation, with Oladapo and Onabanjo (2009) noting that disagreements over contract interpretation are common.

The literature also identifies several root causes of disputes, including unclear contract terms, poor communication, and unbalanced risk allocation (Fenn et al., 1997; Aigbavboa & Thwala, 2014). As the construction landscape evolves, the complexity of procurement methods increases, making it challenging to select the most appropriate strategy for a given project (Naoum & Egbu, 2016). This complexity is further compounded by external factors such as economic instability and regulatory changes, which can lead to unpredictable project outcomes (AlSabah & Refaat, 2019).

2.3. Procurement Methods and Payment Strategies

The choice of procurement methods significantly influences project delivery and the occurrence of disputes. Traditional procurement methods have been predominant in South Africa, characterised by sequential design, bid, and construct tasks (Oshungade & Kruger, 2015). However, alternative procurement methods, such as Design/Build (DB) and Construction Management (CM), have gained traction due to their potential for improved collaboration and efficiency (Mathonsi & Thwala, 2012; Shrestha et al., 2012).

Payment strategies also play a critical role in shaping project dynamics. Various pricing mechanisms, including lump sum, unit price, and cost reimbursement, present different levels of risk and reward for stakeholders (Higham et al., 2022; Windapo et al., 2020). While popular for its predictability, the lump sum pricing mechanism can lead to disputes if project scopes change unexpectedly (Windapo et al., 2020). Conversely, unit price contracts offer flexibility but can result in uncertainty regarding final costs, potentially leading to payment disputes (Ogwueleka, 2021).

2.4. Conceptual Framework

Based on the literature synthesis, a conceptual framework shown in Figure 1 is proposed to examine the interplay between procurement methods, payment strategies, and the occurrence of disputes in construction projects. The framework shown in Figure 1 posits that:

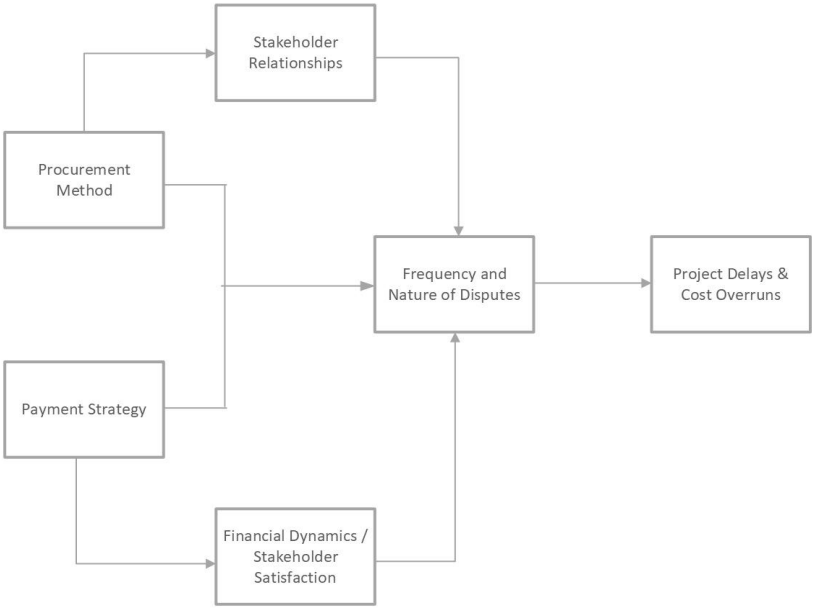


Figure 1: Interaction between Procurement Method and Payment Strategy

- the choice of procurement method directly influences stakeholder relationships and project outcomes, noting that traditional procurement methods may lead to increased disputes due to their rigid structure. In contrast, alternative methods such as the Design and Build and Management-oriented procurement methods bring about collaboration and reduce conflict.
- The selected payment strategy affects the financial dynamics of a project, influencing stakeholder satisfaction and the likelihood of disputes, suggesting that payment strategies that promote transparency and equitable risk distribution are likely to minimise conflicts.
- The interaction between procurement methods and payment strategies shapes the frequency and nature of disputes. Misalignment between these elements can lead to misunderstandings, contractual disagreements, project delays and cost overruns.

This conceptual framework provides a foundation for further empirical investigation into the relationships between procurement methods, payment strategies, and dispute occurrences on construction projects, which will be explored in the following sections.

3. Research Methodology

This section outlines the research design and methodological choices employed in this study, which investigates the relationships between procurement methods, payment strategies, and dispute occurrences in construction projects. The study adopts a positivist research paradigm and a quantitative research approach. The quantitative approach allows for an objective measurement and data analysis, facilitating the identification of patterns and relationships between variables (Cresswell, 2014). The population for the study consists of projects that experience disputes, and the construction professionals involved in the construction procurement and dispute resolution process, such as quantity surveyors, engineers, construction and project managers, and legal experts.
A purposive sampling technique is employed to select participants who possess relevant experience and knowledge (Saunders et al., 2012) regarding construction disputes from a sample frame obtained from the University of Cape Town's CBPM research database. A total of 56 responses are utilised to achieve the research objectives. According to Ott and Longnecker (2010), the Central Limit Theorem states that the sampling distribution of the sample mean approaches a normal distribution as the sample size increases, generally considered valid for sample sizes of 30 or more.

Primary data was collected using questionnaires distributed to 250 respondents that fit the study criteria with the expectation that a response rate of at least 20% would be achieved, which is usual in construction research studies (see Idrus & Newman, 2002 -27.3%; Adnan & Morledge, 2003 – 20%; and Takim & Adnan, 2008 – 20.9%). These studies demonstrate that a 20% response rate can be sufficient in drawing meaningful conclusions in construction management research. The questionnaire was composed of seven main questions. The data was analysed using descriptive statistics – means, frequencies and percentages, which facilitate the identification of the common procurement methods, payment strategies, frequency and nature of disputes and the relationship between the procurement methods, payment strategies and disputes on construction projects.

The ethical principles adhered to during the research process involved obtaining ethical clearance, participants reserved the right to refuse participation in the research at any point without facing repercussions, responses were processed without revealing the participants' identities, careful consideration was given to the questionnaire design to avoid personal and irrelevant questions, ensuring that all inquiries were pertinent to the study's objectives.

4. Data Presentation, Analysis and Discussion

This section presents the findings obtained from the data collected through questionnaire surveys. The study aimed to explore the relationships between procurement methods, payment strategies, and dispute occurrences in construction projects in South Africa. The findings are categorised into the biographical details of the survey respondents, key procurement methods and payment strategies, frequency and nature of disputes, financial dynamics/stakeholder relationships, project performance and the relationship between procurement methods, payment strategies and disputes on construction projects.

4.1. Biographical Details of the Respondents

The respondents in the study consist of a diverse set of professionals within the South African construction industry, including 17 construction managers, representing 30.36%, 16 project managers, accounting for 28.57%, and five engineers and five quantity surveyors, each making up 8.93% of the respondents. The balance of 13 respondents, representing 23.21%, held various other roles, including positions such as company and managing directors. Most have over 16 years of experience, reflecting a significant representation of experienced professionals, emphasising their knowledge and quality of input.

4.2. Project Details

The respondents were asked to identify a project in which they were involved in the last five years and on which there was a dispute. The construction projects identified are to remain confidential to protect those involved and to maintain the appeal of the development that took place. The study sought to know the type of client involved in the project, the level of client experience, and the client's organisational structure. The data collected shows that construction projects mainly in education (16.98%), water and sanitation (15.09%), and power and energy (13.21%) public sector projects are the most prone to disputes. It was also found that the different clients, private (34.62%), the three tiers of government – provincial (32.69%), municipal (26.92%), and national (5.77%) in South Africa, frequently encounter disputes on construction projects. The clients' organisational structures predominantly include functional setups, influencing dispute management capabilities.

4.3. Key Procurement Methods and Payment Strategies used on the Identified Projects

The most common procurement methods are Traditional (41.18%) and Construction management-oriented (33.33%). Unit price or measurement pricing (75%) is the predominant payment strategy, which may influence dispute occurrences in projects and impact project outcomes.

4.4. Frequency and Nature of the Disputes on the Identified Construction Projects

The study sought to know the frequency and nature of disputes on the identified projects. The answers to this question were not mutually exclusive, and the respondents could select multiple options applicable to the identified projects. The responses showed that a project may encounter more than one type of dispute. Payment disputes were identified by 27 of the 50 (54%) respondents as the most common dispute on projects, followed by scope of works disputes. Issues like late payments, scope creep, poor project management and community protests were found to contribute to these disputes, complicating resolution efforts.

4.5. Impact of Dispute Occurrence on Project Performance

The study also sought to understand the respondents' perceptions of the dispute's impact on the identified project. The data collected in this regard are presented in Table 1. The options were not mutually exclusive. Of the 50 respondents who answered the question, 75 options were selected, translating into an average of 1.5 outcomes per respondent. The data presented in Table 1 indicates that disputes often lead to increased costs - 30 respondents (60%), and time overruns - 21 respondents (42.00%), with some projects even being abandoned - nine (18.00%). Financial losses and

Table 1: Impact of the Dispute Occurrence on the performance of the identified Project

Impact of Dispute Occurrence	Frequency (No.)	Percentage (%)
Increase in cost (cost overrun)	30	60.00%
Increase in time (time overrun)	21	42.00%
Project abandonment	9	18.00%
Poor quality	3	6.00%
Other (e.g. positive outcome)	12	24.00%

disruptions during the project implementation phase were identified as common outcomes, although some rare cases see disputes lead to positive financial resolutions in favour of the contractor.

4.6. Relationship between the Payment Strategies and Disputes

The study sought to find out whether there is a relationship between the payment strategies used and dispute occurrences on the identified construction projects. The participants were offered fifteen disputes. They were allowed to pick multiple options, but they could only select a single option for the procurement method question. Of the fifteen dispute events, for 12 of them, the traditional unit price or measurement pricing was predominantly used; for one of them, a mix of lump sum, unit rates and reimbursable for various contractors was dominant; and for two disputes (termination disputes and environmental and regulatory issues), no payment strategy was selected as they did not occur. When normalised by the number of projects on which the payment strategies are used – Unit price (98), Cost-reimbursement (12), Lump-sum pricing (2), Other hybrid payment strategies (15), the results indicate that the hybrid payment strategy (3.75) has the most dispute per project, followed by Unit price payment strategy (2.51), Cost-reimbursement (2.0), and Lump-sum pricing (0.67). This suggests systemic influences of payment methods used on dispute frequency.

4.7. Discussion of Findings

The study examines the relationships between procurement methods, payment strategies and the occurrence of disputes in construction projects. The study showed that education, water and sanitation, and power and energy projects are particularly prone to disputes. The predominance of private clients (34.62%) and various levels of government involvement suggest that stakeholder relationships are complex and often influenced by the procurement methods employed. The findings align with the literature, which posits that effective stakeholder engagement helps minimise disputes (Tariq & Gardezi, 2023). As one respondent noted, "indecisiveness of the client" can lead to significant delays, highlighting the importance of clear communication and defined roles among stakeholders.
The study found that the traditional (41.18%) and Construction management-oriented (33.33%) procurement methods were the most used. This finding suggests that procurement methods significantly influence project dynamics and the likelihood of disputes. The traditional procurement method was associated with a higher frequency of disputes, supporting the idea that its rigid structure can lead to misunderstandings and conflicts. In contrast, alternative procurement methods, such as Design and Build, have been shown to bring about collaboration and reduce conflict (Mathonsi & Thwala, 2012).

Similarly, the payment strategies employed were found to impact project performance. The predominant use of unit price or measurement pricing (75%) suggests a preference for flexibility; however, this can also lead to disputes if not appropriately managed. One respondent noted, "Payment delayed", indicating that financial issues are a common source of conflict. The findings suggest that payment strategies promoting transparency and equitable risk distribution are more likely to minimise disputes, echoing findings from previous studies (Higham et al., 2022).

This research provides empirical evidence on the interplay between procurement methods, payment strategies and dispute occurrences in the South African construction industry. The findings highlight the need to carefully select procurement methods and payment strategies to bring about positive stakeholder relationships and minimise financial dynamics and disputes. The implications of this finding are significant for construction stakeholders and policymakers in the construction sector because, with an understanding of the factors that contribute to disputes, stakeholders can implement strategies to enhance communication, clarify project scopes, and establish fair payment practices. Additionally, the findings highlight the importance of stakeholder engagement and community involvement in project planning to mitigate potential conflicts.

5. Conclusion

This research examines the relationship between procurement methods, payment strategies, and the occurrence of disputes on construction projects. The findings suggest that certain project types are more susceptible to disputes, particularly in the education, water and sanitation, and power and energy sectors. It emerged from the study that traditional procurement methods and construction management-oriented approaches were the most utilised, with traditional procurement being associated with a higher frequency of disputes, supporting the notion that rigid procurement structures can lead to misunderstandings and conflicts among stakeholders. In contrast, alternative procurement methods, such as Design and Build, have the potential to bring about collaboration and reduce disputes, aligning with existing literature that emphasises the benefits of flexible procurement strategies.

The research also highlighted the role of payment strategies in shaping project dynamics. The predominant use of unit price or measurement pricing indicates a preference for flexibility; however, this approach also results in disputes if not properly managed. Based on the conclusions, the following recommendations are made to address the study problems – stakeholders should adopt procurement methods that promote collaboration and flexibility,

such as Design and Build or Construction Management, to reduce the likelihood of disputes; employ payment strategies that ensure timely payments and equitable risk distribution by establishing clear financial agreements to minimise conflicts related to payments; ensure effective communication among all parties involved in construction projects by clarifying expectations, project scope and responsibilities, thereby reducing the potential for misunderstandings. Further research is recommended using data from other contexts to enable the generalisability of the findings.

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ACADEMIC PAPERS: THEME 11 - ARTIFICIAL INTELLIGENCE IN CONSTRUCTION AND PROJECT MANAGEMENT/CONSTRUCTION-RELATED DISASTER MANAGEMENT/PRODUCTIVITY

Exploring Integration of Artificial Intelligence in Construction Bid Automation: A Review Approach

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Abstract

This paper explores artificial intelligence (AI) integration in construction bid automation. The literature review suggests that currently, construction firms generally rely extensively on manual processes to produce their technical and commercial bid proposals. The problem with this existing practice in many firms is that it often requires extensive manual inputs and resources to execute most of the activities in the process. However, there is often a relatively short bidding time frame, poor quality information, loss of organisational knowledge from staff turnover, and limitations to human ability. A literature review of 21 purposively selected relevant articles was carried out to explore AI applications, automation strategies, and digitalization efforts within the bidding process and to propose an AI-based theoretical bid automation model. The findings reveal that while AI has been applied to specific tasks such as cost estimation, risk assessment, and document analysis, no unified AI-driven framework exists for automating the bid preparation process in construction sector. The main contribution of the study to current knowledge and practice is the development of a theoretical bid automation model designed to minimize human input in the bid preparation process, which could serve as a blueprint for informing the actual development process of the model/tool. Such a model/tool will be handy in times/seasons when firms have a high volume of bids to prepare within short bidding timeframes, with limited human resources, and it is beneficial to draw on historical information from previous projects.

Keywords: Artificial intelligence, bid automation, construction bid automation, theoretical model

1. Introduction

In the construction industry, one of the strategies used by clients to award project work is the tendering or bidding process (Park *et al.,* 2021). This entails a process whereby a client will invite tenders from interested firms, and the firms use the information in the tender documents to prepare their bids/tenders which they submit to clients, normally in competition against others (Park *et al.,* 2021). This is akin to multiple shops providing quotes for a service, with the client choosing the most appealing offer. The bidding firms often follow a bid preparation process to develop their bid proposal. The bid preparation process often commences from the time of the bid notification to the time of bid submission (Manchanda, 2021; Laryea, 2022).

The bidding firms often follow a bid or tender preparation process to develop their bid proposal. The bid preparation process often commences from the time of the bid notification to the time of bid submission (Laryea, 2022). The technical and commercial teams in a construction firm typically follow their internal processes and execute various activities to prepare the bid. In current practice, the team(s) will typically prepare a technical and price proposal. The technical proposal will often comprise the methodology and technical resources to execute the work (Laryea, 2022). The commercial proposal will often include a price, which includes costs and markup.

Currently, construction firms generally rely extensively on manual processes to produce their technical and commercial bid proposals (Heo *et al*., 2024; Li & Sun, 2024). The problem with this current practice in many firms is that it often requires extensive manual inputs and resources to execute most of the activities from start to finish. However, there is often a relatively short bidding time frame, poor quality information, loss of organizational knowledge from staff turnover, and limitations to human ability which often leads to the best possible bid submission rather than the optimal bid submission (Manchanda, 2021; Park *et al.,* 2021).

According to Manchanda (2021), Cusumano *et al.* (2022), and the research by Laryea (2009), based on a live observation of how contractors put a bid together, showed a significant reliance on manual processes and inputs from supply chain partners. The recent developments in AI applications offer a significant possibility to develop a tool that can assist in automating the bid preparation process to an extent that is practically possible, that is automating key automatable activities (Liu, 2022) that can assist in overcoming some of the challenges associated with the current way that firms prepare their project bids.
Therefore, the main argument in this study is that some of the key activities in current bid preparation practice may be capable of being fully or partially automated to assist firms in doing their bid preparation more efficiently and accurately. Hence, this paper explores

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artificial intelligence (AI) integration in construction bid automation and proposes a theoretical AI-based bid automation model.

2. Context of Automation in Bid Preparation

In the competitive landscape of the construction industry, bid preparation plays a pivotal role in securing projects. However, this process is often labour-intensive, time-consuming, and prone to human error. Consulting or construction firms must review complex project requirements, assess previous proposals, and customize submissions to meet the specific demands of clients. Given the complexity of the task, inefficiencies in bid preparation can lead to missed opportunities, increased costs, and delayed responses. A research study focused on automating the bid preparation process aims to address these challenges by leveraging advanced technologies to streamline bid preparation processes. The study seeks to assist consulting or construction firms in automating activities like extracting project details from bid documents, generating customized proposals based on historical data, and allowing expert review before submission. Such an approach is expected to not only enhance efficiency but also improve the strategic decision-making capabilities of firms in responding to project bids, ultimately giving them a competitive edge.

2.1. Conceptual Framework for Automation of Project Bidding

Maxwell (2022) emphasizes that a conceptual framework essentially represents the subject under study, outlining the elements involved, their interactions, and underlying reasons. It serves as a preliminary theory guiding the research process, aiding in goal refinement, formulating relevant research questions, and the selection of suitable methodologies. It either explains graphically or in narrative form, the main things to be studied and the key factors, concepts, or variables; and the presumed relationships among them (Tamene, 2016). For this study on developing a bid automation model using artificial intelligence, some assumptions are made and these include; a) *some activities in the bid preparation process can be automated by leveraging new technologies like artificial intelligence*, b) *automating key activities of the bid proposal preparation process can increase process efficiency and reduce associated costs, time and errors in bid preparation*, and c) *leveraging historical bid data through AI techniques can enable firms to prepare future bids more accurately*. Based on these assumptions and concepts, a conceptual framework is developed. Figure 1 illustrates the conceptual framework, detailing the conceptual analysis process adopted to view automation integration into the bid proposal preparation activities. This conceptual framework serves as a foundation for understanding how automation can lead to greater efficiencies and more sustainable outcomes in the construction project bid preparation process.

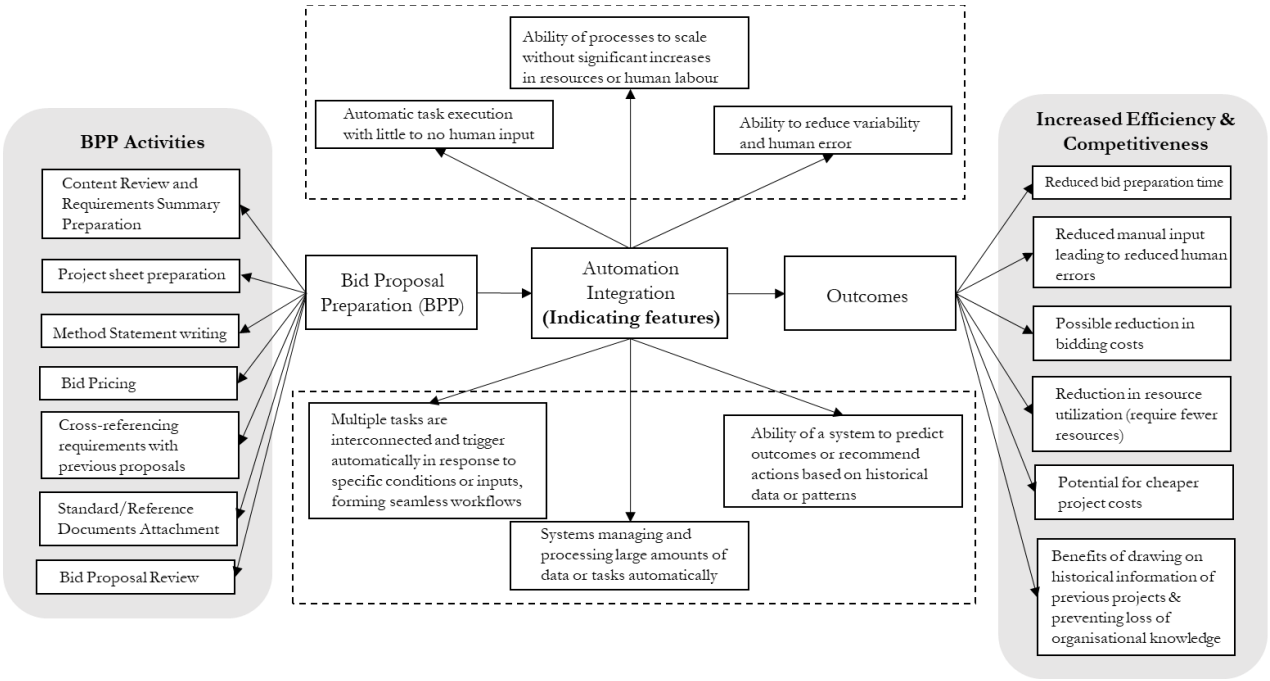


Figure 1: Conceptual framework of automation integration into bid preparation process

3. Research Method

Relevant literature on artificial intelligence (AI) integration in construction bid automation was purposively identified from academic databases,

including Scopus and Google Scholar. According to researchers like Hallinger and Kovacevic (2019); and Mongeon and Paul-Hus (2016), empirical research indicates that Scopus provides a broader range of sources compared to the Web of Science, particularly in fields beyond medicine and the physical sciences, making it suitable for construction-related research.

A total of 21 studies focusing on construction project bid preparation and automation were purposively identified and reviewed. The selection criteria emphasized studies that explored AI applications, automation strategies, and digitalization efforts within the bidding process. These studies provided a foundation for understanding the current state of automation in construction project bid preparation and identifying potential gaps where AI-driven solutions could be further developed.

Previous research indicates that construction bidding remains predominantly manual, with automation efforts primarily directed toward cost estimation, bid evaluation, and risk assessment (Cusumano *et al.*, 2022; Kim *et al*., 2020; Park *et al.*, 2021). However, a comprehensive AI-driven model for bid preparation is notably absent in the existing literature. This study, therefore, sought to analyze existing automation efforts to establish a framework for integrating AI into the bid preparation process.

3.1. Analysis

The analysis involved a content review of the 21 selected studies, focusing on their contributions to AI integration in the construction bid preparation process. The reviewed studies provided insights into various automation efforts, highlighting both advancements and existing gaps in the field. These studies revealed key insights regarding the extent to which AI has been leveraged to enhance bid-related activities, including document analysis, decision-making support, and predictive modelling. This review has been instrumental in shaping the theoretical foundation for developing a comprehensive AI-based bid automation model.

3.2. Model Development

The proposed model for automating bid preparation will integrate artificial intelligence (AI) techniques, specifically designed to streamline key activities such as content extraction, bid/no-bid decision support, and automated proposal generation. The development process will begin with a comprehensive analysis of current bid preparation practices in construction firms to identify tasks that are suitable for automation. These tasks will be selected based on their repeatability and the availability of sufficient data for training AI models.

3.2.1. Data Pre-processing and Feature Extraction

Bid data will undergo a pre-processing phase to ensure its readiness for model training. This includes data cleaning (removing duplicates, and irrelevant information), text normalization (lowercasing, tokenization, etc.), and data transformation (such as converting documents into structured formats). Feature extraction will focus on extracting key attributes from tender documents, including project scope, requirements, deadlines, budget, and evaluation criteria. The extracted features will be used to create training datasets, which will represent the core attributes that the model needs to understand.

3.2.2. Model Selection and Training

For document parsing and requirements extraction, natural language processing (NLP) techniques will be employed. If bid documents are provided in scanned formats, Optical Character Recognition (OCR) will be performed using a third-party OCR engine (such as Tesseract OCR) to extract machine-readable text, which will then be processed using OpenAI's GPT-4o Mini large language model (LLM). Pre-processing steps such as format normalization, tokenization, stop word removal, and lemmatization will be applied to handle inconsistent formats, incomplete data, and unstructured text. The OpenAI embedding model (Ada-002) will be used to generate vector representations of past bid proposal documents, which will be stored in a vector database (Pinecone) to enable efficient semantic similarity searches using cosine similarity in identifying the closest match to the current bid. Named Entity Recognition (NER) will be used to extract key bid requirements.

The LLM will be used to generate bid recommendations and draft proposal content. The training datasets will include historical bid proposals, tender documents, and relevant project data, ensuring that the model learns to generate high-quality content that aligns with real-world expectations.

3.2.3. Validation Techniques

The model's performance will be validated through a combination of expert reviews, automated testing, and real-world simulations. Validation is crucial as industries and governments depend increasingly on predictions by computer models to justify their decisions (Sornette *et al*., 2007). Initial testing will involve comparing the model's outputs to manually prepared bid proposals to assess accuracy, quality, and relevance. Expert feedback will be incorporated into the model through multiple iterations to refine its functionalities, including improving content extraction accuracy and enhancing the natural language generation (NLG) process. Validation metrics, such as precision, recall, and F1-score, will be used to evaluate the effectiveness of the feature extraction and bid proposal generation processes.

Additionally, user feedback on performance metrics, including processing time, error rates, and accuracy of extracted information, will be recorded to identify any limitations or areas for improvement and benchmarked against manual processes to assess the model's usability and impact on the bid preparation process.

4. Findings and Discussion

4.1. Review studies

A review of existing literature on automation integration into construction bid preparation highlights various research efforts across different focal areas. Table 1 presents an evaluation of these studies based on their specific automation areas of focus. The analysis reveals a growing interest in leveraging digital technologies to enhance efficiency in bid preparation, yet significant gaps remain in developing an automated bid proposal preparation model.

The Fourth Industrial Revolution (4IR) is largely centered on technology-driven automation and intelligent systems, with AI emerging as a fundamental enabler of these advancements (Sarker, 2022). However, building effective AI models remains difficult because of the complexity and variability of real-world data and problems. To address this, AI is categorized into several types: Analytical AI, which derives insights from data to support data-driven decision-making; Functional AI, which, unlike Analytical AI, executes actions rather than just providing recommendations; Interactive AI, which facilitates automated yet interactive communication, such as chatbots and virtual assistants; Textual AI, which encompasses natural language processing tasks like text recognition, speech-to-text conversion, machine translation, and content generation; and Visual AI, which focuses on computer vision and augmented reality applications.

Table 1: Areas of focus on automation integration into the construction bid preparation process

Automation areas of focus	Authors	No. of studies
Risk management	Tirmizi and Arif (2022); Choi et al. (2021); Park et al. (2021); Padhy et al. (2021); Kim et al. (2020); Huber and Imhof (2019); Pakgohar et al. (2013)	7
Bid Opportunities Identification	Lu et al. (2022)	1
Bid pricing	Heo et al. (2024); Li (2022); Kim and Jung (2019); Chou et al. (2015); Kandanala et al. (2005); Tavakoli Amir and Juliana Lano Utomo (1989).	6
Content Review Summary Preparation	Cusumano et al. (2022); Manchanda (2021); Cao et al. (2002)	3
Bid Selection and Evaluation	Chiu et al. (2014); Soroor et al. (2012); Chan et al. (2007); Ekström and Björnsson (2000);	4
Total number		21

While AI has been applied to specific tasks such as cost estimation, risk assessment, and document analysis, no unified AI-driven framework exists for automating the bid preparation process. Most studies focused on isolated automation efforts rather than an integrated approach.

These findings informed the theoretical model development, graphically presented in this study. The model outlines essential AI functionalities, including intelligent data extraction, and decision-support mechanisms, offering a structured approach to AI-driven bid automation.

4.2. AI-Based Modelling

This paper sought to explore the development of an AI-based bid automation model for firms in the construction industry. Achieving this, therefore, requires understanding and unbundling the activities involved in the existing process to a medium level of abstraction.

Machine learning (ML) is a highly promising AI technique that focuses on developing computer algorithms capable of automating the creation of analytical models (Sarker, 2021). These ML models typically consist of rules, processes, or complex transfer functions designed to identify meaningful data patterns or predict behaviors (Dua & Du, 2016). Machine learning, also referred to as predictive analytics, makes predictions about certain unknowns in the future through data, and is used to solve many real-world business issues, e.g., business risk prediction. Figure 2 illustrates a general framework for a machine learning-based predictive model, where historical data is used to train the model, enabling it to generate outcomes for new test data during the prediction phase. Depending on the specific problem domain, various

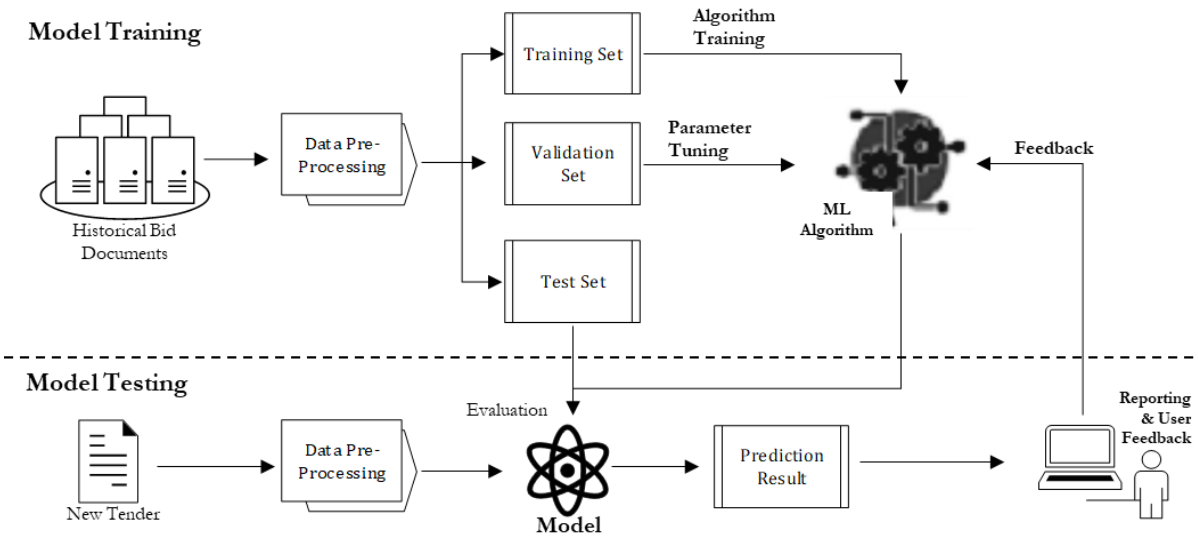


Figure 2: A general structure of a machine learning-based predictive model considering both the training and Testing phase

machine learning techniques can be applied based on their underlying learning principles and capabilities.

4.3. Theoretical Bid Automation Model

The purpose of this study is to develop an AI-based bid automation model for consulting firms in the construction industry. Achieving this, therefore, requires understanding and unbundling the activities involved in the existing process to a medium level of abstraction, which is capable of communicating important ideas and concepts about the bid automation model and informing the development process by serving as a blueprint.

4.3.1. Model Overview

The model is divided into three primary stages:

Content Review and Extraction*:* As shown in Figure 3, the extraction process will aid in the Bid/No-Bid decision-making by identifying key requirements from a document that assist management in evaluating whether to proceed with a bid (Manchanda, 2021). In this process, the user uploads the new invitation document through a user interface, usually in PDF format, and for scanned formats, Optical Character Recognition (OCR) will be performed using a third-party OCR engine (such as Tesseract OCR) to extract machine-readable text. The contents of the input document are extracted and separated into sections based on the various paragraphs within the document. These sections are then processed using a customized Natural Language Processing (NLP) engine, designed to extract the relevant requirements, such as the project type, scope of services, eligibility and evaluation criteria, and required documents to be submitted (Heo *et al.*, 2024; Li & Sun, 2024).

NLP engine uses standard dictionaries, custom-made domain dictionaries and state-of-the-art deep learning neural network algorithms to identify the right set of requirements (Liu, 2022). Once these requirements are extracted, the requirements output file is displayed to the user/decision authority to support final Bid/No Bid decision-making. If the decision is No-Bid, the process terminates at this stage. However, if a Bid decision is made, the system proceeds to the next step of proposal preparation, by conducting a bid matching to identify the closest matches in the database.

*Closest Bid Matching***:** Once a 'Bid' decision is made, the system begins searching for the most similar bid within the repository of historical bid documents. This matching process relies on Cosine similarity techniques to compare extracted requirements and identify the closest bid proposals. Based on this, relevant recommendations are generated using past bids. There are two possible outcomes: either a closely matching proposal exists in the database, or no suitable match is found.

*Proposal Generation***:** Once close matches or a suitable match is found, they serve as the foundation for creating the new bid proposal documents. However, if no matching bid meets the eligibility criteria, the model generates the document using a predefined format from the database, incorporating information from the uploaded RFP. The new bid document is automatically drafted through a natural language generation (NLG)-based proposal engine (Liu, 2022), specifically utilizing a Large Language Model (LLM) for automatic bid proposal generation. The generated proposal is then reviewed by the bid preparation team of experts, and after several revisions, a final draft is prepared. Following the review process, the final bid proposal is

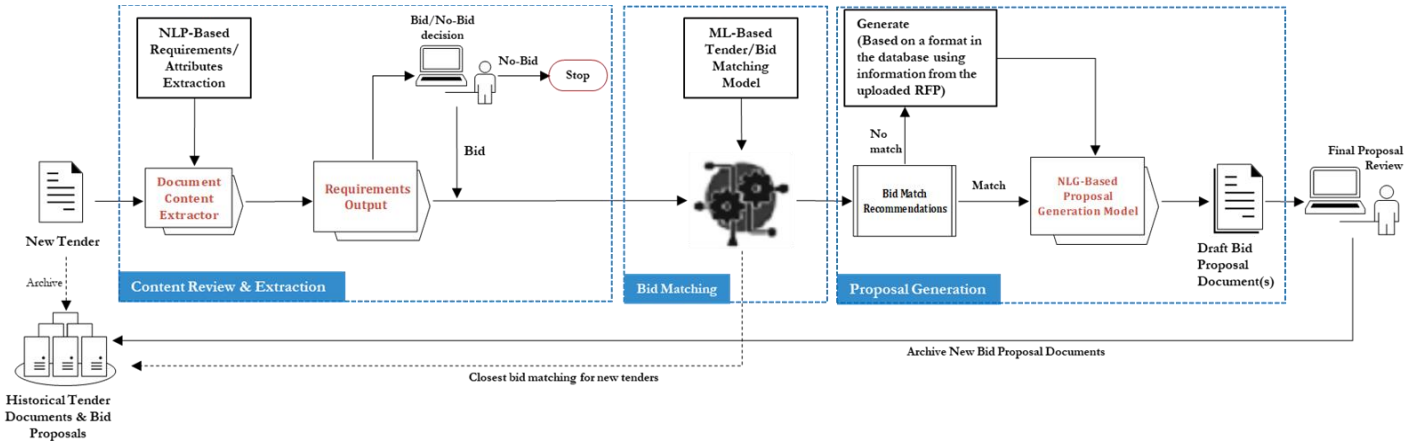


Figure 3: Theoretical AI-Based Bid Automation Model

submitted, and both the tender and the final proposal are archived for algorithm training and future use.

5. Conclusion and Further Research

This paper conceptualizes automation integration in the bid preparation process for construction firms, and proposes a theoretical artificial intelligence (AI)- based project bid automation model. The proposed AI-based bid automation model was depicted through a theoretical model that illustrated key phases, from content review and requirements extraction to bid proposal generation and recommendation. Each phase leverages AI-driven tools to reduce manual effort while enhancing accuracy, efficiency, and decision-making in bid submissions. Importantly, the "human-in-the-loop" feature integrated within the model ensures that critical tasks such as content review and bid proposal finalization retain the benefit of human oversight, providing a fail-safe mechanism to enhance the reliability of the automated outputs.

The main contribution of this study to existing knowledge and practice is the development of a conceptual bid automation model designed to minimize human input in the bid preparation process, which could serve as a blueprint for informing the actual development process of the model/tool. Such a tool will be handy in times/seasons when construction or consulting firms have a high volume of bids to prepare within short bidding timeframes, with limited human resources. Thus, this proposed model is beneficial to draw on historical information from previous projects. Future research should focus on empirical validation and refinement of the proposed AI-based bid automation model, exploring its practical implementation in real-world construction firms, assessing its scalability, and evaluating its impact on bid quality, time efficiency, and cost reduction.

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Digital Transformation of Construction and Project Management through Artificial Intelligence

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Abstract

Artificial intelligence (AI) is increasingly recognised as a transformative force in construction and project management, thereby automating tasks traditionally dependent on human intelligence. It has emerged as a game-changing tool, enhancing operational efficiency, proactively managing risks, and improving project outcomes. This study explored the application of AI in the construction industry and its associated benefits using systematic literature review approach. Despite these advantages, the industry faces significant challenges integrating AI with existing construction and project management systems. The study analysed approximately 75 relevant articles using a systematic literature review approach. Based on the findings, a comprehensive AI implementation strategy was developed to maximise its benefits while addressing potential risks and challenges.

Keywords: Application, Challenges, Construction, Implementation, Strategy

1. Introduction

The construction and project management sectors, traditionally characterised by labour-intensive processes and fragmented workflows, are undergoing a profound transformation driven by advancements in digital technologies. Among these technologies, artificial intelligence (AI) has emerged as a pivotal force, reshaping how projects are planned, executed, and monitored (Lu et al., 2024). By leveraging AI, stakeholders can enhance efficiency, reduce costs, and mitigate risks, thereby addressing long-standing challenges in the industry. AI is reshaping every stage of the construction project lifecycle, from smart design software that optimises architectural plans to predictive maintenance systems that anticipate equipment failures (Baduge et al., 2022).

Integrating AI into Building Information Modelling (BIM) exemplifies its transformative potential. It enhances BIM by automating design optimisation, clash detection, and resource allocation, streamlining stakeholder collaboration and ensuring better project outcomes (Timilsena *et al.*, 2024). This transformation is about adopting new technologies and fostering a culture of innovation, collaboration, and adaptability. By embracing AI, the construction and project management industries are addressing long-standing challenges such as delays, cost overruns, and resource inefficiencies and paving the way for sustainable and resilient infrastructure development (Shamim, 2024).

Despite its benefits, the adoption of AI in construction and project management faces challenges, including resistance to change, data privacy concerns, and the need for skilled personnel to operate advanced systems (Shoushtari *et al.,* 2024). Addressing these barriers is critical to unlocking the full potential of AI and fostering a culture of innovation in the industry.

This study outlines the foundational principles and key components of designing an AI implementation strategy for construction and project management. By grounding the discussion in scholarly research and industry best practices, it provides a comprehensive framework for stakeholders seeking to harness the transformative power of AI in the construction industry.

2. Literature Review

Historically, construction processes were marked by hierarchical systems and rudimentary project management principles, emphasising craftsmanship and manual labour with minimal reliance on formalised planning or scheduling tools. The introduction of computers in the 1990s, as Eastman (2018) noted, revolutionised project management by enabling the adoption of systems theory. This allowed for the integrated management of resources, time, and costs. In the 21st century, advanced digital technologies have further transformed construction and project management. According to Lu et al. (2024), these technologies emphasise sustainable practices and lean construction principles that minimise waste and risk while improving overall efficiency.

Although, the construction industry has been slow to adopt technological innovations, recent advancements in AI are driving significant changes. AI technologies such as machine learning, computer vision, natural language processing, and robotics are increasingly being integrated into construction processes to enhance efficiency, accuracy, and safety (Korke et al., 2023). Akhmedov (2023) and Khan et al. (2024) emphasised that integrating AI technologies into the construction

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and project management industry has been transforming construction processes. They highlighted AI's role in enhancing project efficiency, productivity, accuracy, and decision-making, addressing long-standing challenges such as cost overruns, schedule delays, risk mitigation, and resource mismanagement. However, despite these advantages, the widespread adoption of AI faces significant challenges, including technological, organisational, financial, and cultural barriers. Regona et al. (2022) identified issues such as data quality and availability, platform integration, lack of standardisation, and cybersecurity threats as major obstacles. Oke et al. (2023) pointed to resistance to change, while Shang et al. (2023) highlighted a shortage of professionals skilled in AI and data science. Shakibaei (2024) also noted regulatory compliance and ethical concerns as critical barriers to implementing AI in the construction and project management sector.

These challenges highlight the importance of developing a comprehensive AI implementation strategy that integrates education, policy support, stakeholders and industry collaboration to drive the adoption of AI in construction and project management.

3. Research Methodology

The study employs a systematic literature review methodology, adhering to a structured research approach to ensure a rigorous and transparent analysis of existing literature. Review research involves the application of scientific methods to analyse and synthesise previous studies, thereby generating new knowledge for academic, practical, and policy-making purposes (Kunisch *et al.*, 2023). The primary motivation for reviewing and analysing academic articles is to identify research gaps, explore under-researched areas, and facilitate the development of new theories or ideas (Marzi *et al.,* 2024).

This research study review follows a series of steps to achieve the desired outcome. In the initial phase, a comprehensive keyword search was conducted across leading academic databases, such as Scopus, Google Scholar, Web of Science, IEEE Xplore, and ResearchGate, using terms like Artificial Intelligence in Construction, Construction Industry, Construction Project Management, Construction Automation, Construction Design, and Predictive Analytics in Construction. The search produced a total of 458 articles.

The inclusion and exclusion criteria were defined to maintain a clear focus on the research area. Studies were included if they met the following criteria: they examined the impact of artificial intelligence in construction and project management; were published in peer-reviewed journals, academic conferences, or reputable research reports; were written in English; and specifically addressed aspects of construction and project management. Conversely, studies were excluded if they were purely theoretical or conceptual without empirical evidence on the adoption of artificial intelligence in construction and project management or if they focused broadly on digital technologies rather than artificial intelligence specifically.

A thorough screening process was then carried out following the defined inclusion and exclusion criteria to guarantee relevance and quality. Duplicate entries and articles unrelated to the construction industry or without AI applications were removed, yielding a final selection of 75 articles. Furthermore, a strong focus was placed on articles published between 2018 and 2024 to capture the latest trends and advancements, this narrowed the selection to 28 articles.

The study progressed to a comprehensive thematic analysis phase, aiming to clarify the current status, limitations, and future trends of AI applications in construction and project management. The focus was primarily on key findings and conclusions from the reviewed articles, specific challenges and opportunities identified, and recommendations for policy, practice, and further research. Ultimately, 24 articles were finally cited in this study.

4. Findings and Discussion

4.1. Application of Artificial Intelligence in Construction and Project Management

The integration of artificial intelligence (AI) into construction and project management involves exploiting advanced technologies to improve efficiency, accuracy, and decision-making, thereby addressing the inherent challenges in the industry, such as cost overruns, schedule delays, risk mitigation, and resource mismanagement. According to Akhmedov (2023), AI-driven tools, like generative design software, enable architects and engineers to rapidly explore numerous design alternatives while optimising key factors like cost, sustainability, and structural integrity. Similarly, Baduge *et al.* (2022) posit that AI algorithms leverage historical data to predict project timelines and identify potential risks, forecasting delays and propose corrective actions. These are made possible through the optimisation of project schedules using generative scheduling, resource allocation, and risk assessment.

Yu and Wang (2022), assert that AI-powered systems enable organisations to identify trends, predict potential issues, and make informed decisions based on accurate and up-to-date information. This assertion is corroborated by Khan *et al.* (2024), the authors confirm that the excellent performance of AI systems in analysing real-time data from Internet of Things (IoT) devices, cameras, and sensors, making them highly effective in predicting and preventing accidents on

construction sites. Technologies such as computer vision and AI-driven drones enhance site safety by providing real-time monitoring and ensuring compliance with project specifications (Khan *et al.,* 2024),

Putha (2022) maintains that AI-driven predictive maintenance uses machine learning models and data analytics to process extensive sensor data from equipment, identifying patterns and anomalies indicative of potential failures. According to Qi and Tao (2018), predictive maintenance is an advanced equipment management strategy that employs AI algorithms to analyse real-time data, predict potential failures, and implement preventive measures. It adopts a proactive approach, unlike traditional maintenance methods that rely on scheduled inspections or reactive repairs. In the construction industry, the AI systems utilise condition-based monitoring and predictive analytics techniques to analyse sensor data that enables proactive maintenance, minimise equipment downtime, and enhance the efficiency of construction projects (Shoushtari *et al.,* 2024 and Singh *et al.,* 2023).

Furthermore, Pan and Zhang (2021), submit that adopting AI models in construction and project management has significantly improved the accuracy of risk assessment and management by analysing extensive datasets, such as weather patterns, financial trends, and stakeholders' behaviours. The AI systems have been able to leverage on historical project data and external variables to predict risks like cost overruns, delays, and quality issues (Korke et al., 2023).

Construction projects are inherently complex and multifaceted, demanding effective coordination and streamlined material procurement and logistics management. Okoye et al. (2024) maintain that the success of construction projects hinges on the efficiency of the construction supply chain, encompassing the acquisition and movement of materials throughout the project lifecycle. The integration of AI into project management platforms has enhanced inventory tracking, demand forecasting, and procurement processes through smart procurement strategies, ensuring the timely delivery of materials and equipment (Culot et al., 2024). The adoption of AI in construction and project management has thereby led to a more cost effective, efficient, productive, proactive, safe and sustainable construction industry.

4.2. Challenges of Artificial Intelligence Implementation in Construction Industry

Integrating artificial intelligence (AI) into the construction and project management sector holds significant promise for enhancing efficiency, accuracy, and decision-making. Despite this potential, its widespread adoption faces several challenges. These challenges can be broadly classified into four categories: technological, organisational, financial, and cultural.

According to Regona et al. (2022) and Obiuto et al. (2024), construction projects often lack standardised data collection processes, leading to inconsistent, incomplete, or siloed data that limit the effectiveness of AI functionalities. Pan & Zhang (2021) argue that the lack of standard data formats and protocols within the construction sector further complicates AI implementation, as AI systems rely heavily on large volumes of accurate and structured data.

Similarly, challenges like resistance to change, leadership commitment, and manpower capability gap are pronounced. Oke et al. (2023) argue that many construction professionals hesitate to adopt new technologies due to a lack of familiarity with AI technology or fear of job displacement, while Shang et al. (2023) posit that the construction industry faces a shortage of professionals skilled in AI and data science, creating a bottleneck for implementation. Besides, Fasasi et al. (2024) noted that the industry's conservativeness and high fragmentation, characterised by numerous small players and subcontractors, complicate collaboration on AI initiatives. More so, the concerns about the transparency of AI decision-making processes further erode trust and acceptance among stakeholders (Pan & Zhang, 2021).

Financial constraints are also identified as a significant challenge in adopting AI systems within the construction and project management sector. Oke et al. (2023) highlight the financial and economic hurdles the construction industry faces, particularly the high costs associated with developing and deploying AI solutions, and Korke et al. (2023) submit that implementing AI requires substantial initial software, hardware, and skilled personnel investments. These upfront costs can be prohibitive, particularly for smaller construction firms.

AI models face challenges in handling unstructured environments typical of construction sites, and computational demands often constrain their ability to make real-time decisions. These technical limitations diminish AI's effectiveness in dynamic construction settings.Zhang et al. (2021) highlight regulatory and ethical barriers like data privacy concerns, algorithmic bias, and accountability for AI-driven decisions as challenges to AI adoption. Similarly, Shakibaei (2024) underscored the necessity for AI systems to adhere to various regulations, which remain inadequately defined for the construction sector. The summarised AI categorised challenges, impact and mitigation strategies in construction sector is presented in Table 1.

Table 1: AI Challenges and Impact in Construction Sector

Category	Challenges	Impact	Mitigation Strategies
Technological	✓ Lack of standardised & quality data ✓ Compatibility with the existing systems ✓ Data & cybersecurity threats	✓ Reduces AI accuracy & reliability ✓ High costs & technical barriers ✓ Loss of sensitive project data	✓ Establish data collection & protocols ✓ Gradual systems upgrades & middleware solutions ✓ Robust cybersecurity measures
Organisational	✓ shortage of professional skills ✓ AI decision-making bias	✓ Slows AI implementation ✓ Social & legal implications	✓ Upskilling training programmes ✓ Design ethical AI guidelines
Financial	✓ High initial investment for AI infrastructure ✓ Skilled personnel investments	✓ Limits adoption by small firms ✓ Slow down AI adoption	✓ Seek government incentives ✓ Adopt phased implementation ✓ Outsource personnel
Cultural/Environmental	✓ Compliance with data & legal standards ✓ AI adaptability to unstructured environments	✓ Delays in AI adoption ✓ Production of Inaccurate AI results and predictions	✓ Collaboration with regulatory bodies ✓ Refinement of the AI model

Korke et al. (2023), Obiuto et al. (2024), Oke et al. (2023), and Shakibaei (2024) underscore the importance of developing a comprehensive artificial intelligence implementation strategy specifically tailored to the construction industry, emphasising that such a strategy is essential for unlocking the full potential benefits that artificial intelligence offers to the construction and project management sectors.

4.3. Recommended Artificial Intelligence Implementation Strategy

At the heart of the digital transformation of the construction and project management sector through artificial intelligence is recognising the inherent complexity and variability characterising construction projects (Lu et at., 2024). From fluctuating material costs and labour availability to unpredictable weather conditions and regulatory changes, construction projects stakeholders face many challenges that demand precision, adaptability, and foresight.

The construction ecosystem is a complex and dynamic system encompassing various disciplines and stakeholders to ensure that projects are completed on time, within budget, and to the desired quality standards. A conceptualised construction and project management ecosystem is provided in Figure 1. Therefore, implementing artificial intelligence (AI) in this industry requires a well-designed strategy to maximise its benefits while minimising risks and challenges (Obiuto et al., 2024 and Shakibaei, 2024).

This study introduces a comprehensive AI implementation strategy tailored to the construction and project management industry. The conceptual

Construction and Project Management Ecosystem				
Project Partners	Project Financiers/Investors	Project Supervisors	Construction Software, Applications & Systems	ISO/Other Standards
Development & Procurement	Construction Management/ Project Consultants	Architectural/Engineering Designers		Building Inspectors
Materials and Equipment Suppliers	Construction Materials	Construction Equipment		Construction Tools
Off-Site Manufacturer	Construction Products Manufactured Off-Site by Specialized and Branded Product Houses			
Supply-Chain & Logistic	Logistics Coordinators	Suppliers/Public/Trade Associations		Subcontractors
Products Assembly	Site Engineers	Project Managers	Quality Controllers	Labourers/Vendors
Final Products	Heavy/Civil Construction	Industrial Construction	Building Construction	Residential/Housing
	Government Financing	*Private Sector Financing*		*Private/Personal Financing*

Figure 1: Construction and Project Management Ecosystem

framework for this strategy is illustrated in Figure 2, accompanied by a detailed description of its components.

4.3.1. Assess Needs and Opportunities

I. **Identify Pain Points:** Evaluation of the areas where AI can provide the most value, such as project scheduling, risk management, resource allocation, quality control, safety monitoring, and predictive maintenance, should be conducted.

II. **Set Clear Objectives:** Specify goals for AI adoption, like reducing project delays, improving safety compliance, or optimising material usage.

4.3.2. Build Awareness and Buy-In

I. **Stakeholder Engagement:** The stakeholders within the construction organisation, including project managers, engineers, and site workers, should be engaged and educated about AI's potential benefits and address concerns.

II. **Leadership Advocacy:** Support from the organisation's senior management should be secured to ensure alignment with organisational goals.

4.3.3. Develop a Pilot Programme

I. **Start Small:** Choose a manageable project or process to test AI tools, such as machine learning for predictive scheduling or drones for site inspections.

II. **Define Metrics:** Choose Key Performance Indicators (KPIs) to measure the pilot's success, like cost savings, time efficiency, or error reduction.

4.3.4. Choose the Right AI Tools

I. Evaluate Solutions: Selection of AI technologies suited to the construction industry is required, such as:

- ✓ **Building Information Modeling:** For design optimisation and clash detection.
- ✓ **Predictive Analytics:** This is used to anticipate delays and risks.
- ✓ **Computer Vision:** This is used to monitor site safety and progress.

II. **Vendor Collaboration:** A partnership with reputable, experienced AI providers in construction and project management should be established.

4.3.5. Build Infrastructure and Skills

I. **Data Readiness:** Ensure data collection systems have clean, structured data for AI training and analysis.

II. **Training Programmes:** Upskill employees to use AI tools effectively and understand their outputs.

III. **Integration with Existing Systems:** Seamlessly connect AI tools with existing construction and project management software and workflows.

4.3.6. Scale and Optimise

i. **Analyse Pilot Results:** Use insights from the pilot to refine AI applications and address challenges.

ii. **Expand Adoption:** Gradually implement AI solutions across more projects.

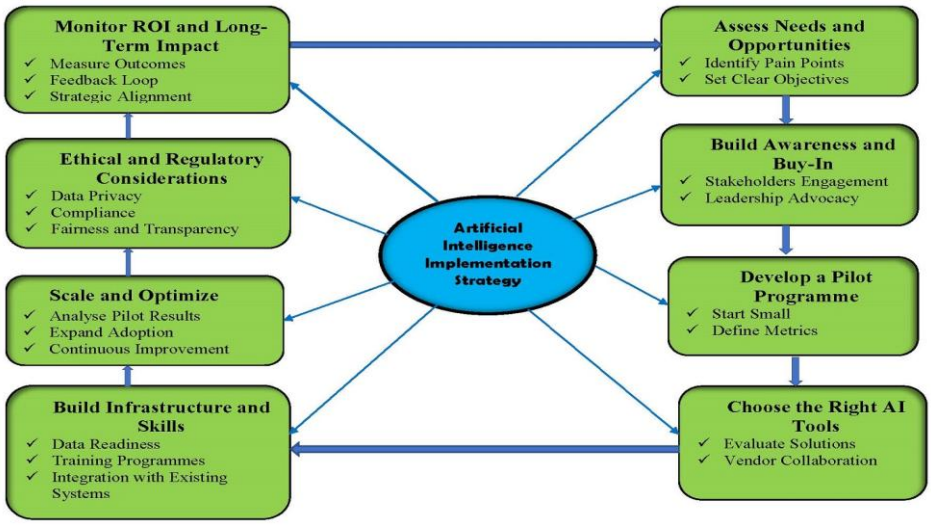


Figure 2: Conceptual Diagram of Artificial Intelligence Implementation Strategy

iii. **Continuous Improvement:** Monitor AI performance, update algorithms, and adapt to changing project requirements.

4.3.7. Address Ethical and Regulatory Considerations

i. **Data Privacy:** Implement measures to secure sensitive project and worker data.

ii. **Compliance:** Ensure AI tools comply with construction industry standards and regulations.

iii. **Fairness and Transparency:** Avoid biases in AI decision-making and maintain transparency with construction stakeholders.

4.3.8. Monitor Return on Investment and Long-Term Impact

I. **Measure Outcomes:** Regularly evaluate the impact of AI on project timelines, costs, safety, and quality.

II. **Feedback Loop:** Collect feedback from users, such as Architects, Engineers, and Project Managers, to enhance AI tool functionality and usability.

III. **Strategic Alignment:** Ensure AI adoption aligns with the organisation's long-term goals and vision.

By adopting this implementation strategy, construction and project management firms can harness AI to optimise processes, reduce costs and risks, strengthen safety, improve decision-making, and enhance productivity across the project lifecycle.

5. Conclusion and Further Research

The construction and project management industry has experienced a significant digital transformation, primarily driven by Artificial Intelligence (AI) integration. Through a systematic literature review, this study explored the applications of AI within the industry and highlighted its associated benefits.

However, despite its transformative potential, the adoption of AI in construction is not without challenges, which the study also examined. To address these, the study proposed an AI implementation strategy tailored to the construction industry, aiming to optimise processes, reduce costs and risks, enhance decision-making, and boost productivity throughout the project lifecycle. Additionally, the study emphasised the need for further research to establish standardised AI regulatory and ethical frameworks for the construction sector. This includes the development of standardised data collection processes that prioritise data privacy and cybersecurity strategies.

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A Systematic Review of the Current State of Artificial Intelligence Adoption in South Africa's AEC Sector

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Abstract

This study investigates the current state of artificial intelligence (AI) adoption within South Africa's Architecture, Engineering, and Construction (AEC) sector, with a focus on its implementation, associated barriers, and enabling factors. While AI holds significant potential to boost productivity, reduce costs, and drive innovation, its adoption remains limited due to financial constraints, inadequate digital infrastructure, and a shortage of skilled professionals. To ensure a comprehensive assessment of AI adoption trends, a systematic review was conducted using the PRISMA methodology to refine relevant literature. Additionally, bibliometric analysis was performed using VOSviewer to explore citation networks, key authors, and research clusters. The study also employed keyword co-occurrence analysis to map prominent themes related to AI integration. Findings reveal that AI use is largely limited to machine learning and predictive analytics, with advanced applications such as robotics and natural language processing significantly underutilized. The study highlights the urgent need for policy reforms, enhanced digital infrastructure, and targeted training initiatives to promote widespread AI adoption and improve competitiveness across South Africa's AEC industry.

Keywords: Artificial Intelligence, South Africa, Construction Industry, AI Integration, AEC

1. Introduction

The rapid growth of artificial intelligence (AI) has the potential to revolutionize the architecture, engineering, and construction (AEC) industry by enhancing efficiency, reducing costs, and improving decision-making (Abioye, et al., 2022; Pan & Zhang, 2021). However, AI adoption in South Africa's AEC sector remains inconsistent due to persistent barriers such as financial constraints, limited digital infrastructure, a shortage of skilled professionals, and inadequate policy frameworks (Felemban et al., 2024). These challenges are particularly acute in developing regions, where the AEC industry continues to grapple with project delays, cost overruns, and operational inefficiencies (Deng et al., 2022; Wang, et al., 2020). Despite the global momentum in AI-driven innovation, there is limited research specifically exploring the extent, barriers, and enablers of AI integration. This study addresses this critical gap by conducting a systematic review and bibliometric analysis to assess the current state of AI adoption in the local AEC sector (Balli & Guven, 2022; Rafsanjani & Nabizadeh, 2023).

2. Literature Review

This section provides a thorough review of the literature on AI adoption in the AEC industry, with a focus on South Africa. It begins by looking at global trends in the industry's use of AI and emphasizing how it may increase project efficiency, safety, and cost-effectiveness. This section provides a thorough review of the literature on AI adoption in the AEC industry, focusing on South Africa. It begins by examining global trends in the industry's use of AI and emphasizes how it may enhance project efficiency, safety, and cost-effectiveness. The chapter then shifts to the South African context, discussing the challenges facing the sector, the current state of AI integration, and opportunities for further AI adoption.

2.1. AI Adoption in the AEC Industry

Despite its significant economic contribution, the AEC sector has traditionally lagged in digital adoption due to its reliance on conventional methods and fragmented project structures (Felemban et al., 2024; Pan & Zhang, 2021). However, AI technologies are increasingly recognized for their potential to revolutionize the industry by improving efficiency in project management, cost control, safety, and productivity (Li, et al., 2025). Machine learning algorithms can analyse historical data to predict project delays and budget overruns, allowing proactive risk mitigation (Darko, et al., 2020). AI-powered solutions also enhance on-site safety by identifying hazards and enabling real-time data analysis to prevent accidents (Deng et al., 2022). In many developing regions, however, limited access to advanced technology and infrastructure slows AI adoption, while more developed countries benefit from tools like predictive analytics and automation. Financial constraints, a shortage of skilled professionals, and outdated systems further hinder widespread integration . Bridging this gap requires investment in training, improved funding, and supportive policies to ensure AI's benefits are accessible across the global AEC sector.

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2.2. The State of AI Adoption in South Africa's AEC Sector

AI adoption in South Africa's AEC sector is advancing unevenly, with larger firms leading in areas like project management, resource optimization, and predictive analytics to reduce risks and delays (Deng et al., 2022). While these advancements improve efficiency, they are often limited to select projects, and broader industry adoption remains slow. SMEs, which make up a large portion of the sector, face challenges such as high costs, limited skills, and outdated infrastructure, especially in rural areas (Abioye, et al., 2022). A lack of a unified AI strategy further hinders widespread integration (Bilal , et al., 2016).

2.3. Barriers of AI Adoption in South Africa's AEC Sector

AI adoption in South Africa's AEC sector is hindered by several key challenges, with financial constraints being the most prominent, particularly for smaller firms that struggle to invest in AI without immediate returns (Abioye, et al., 2022). Limited digital infrastructure, especially in rural areas with unreliable connectivity and outdated systems, further restricts implementation (Darko, et al., 2020). A significant skills gap in AI, data analytics, and machine learning also persists, as the industry lacks sufficient digital education and training (Felemban et al., 2024). Additionally, unclear policies and regulations, including data privacy concerns and the absence of AI ethics guidelines, create further hesitation among stakeholders (Ikudayisi et al., 2023). Addressing these challenges requires proactive government intervention. Targeted policies, including funding for digital infrastructure, tax incentives, and AI adoption programs tailored for SMEs, can help ease financial barriers and promote wider implementation. Investments in AI-related education and training will also be crucial in bridging the skills gap, ensuring that firms of all sizes can harness AI's potential (Bilal , et al., 2016). Without these efforts, AI adoption may remain concentrated within larger firms, deepening industry inequalities and limiting overall growth and innovation.

2.4. Enablers of AI Adoption in South Africa's AEC Sector

Despite existing challenges, several enablers have the potential to accelerate the adoption of AI within South Africa's AEC sector. The gradual enhancement of digital infrastructure, particularly in urban regions, has facilitated improved internet connectivity and cloud computing capabilities, thereby creating a supportive environment for AI integration and data-driven decision-making (Abioye, et al., 2022; Onososen & Musonda , 2022). Collaborative efforts among government entities, industry stakeholders, and academic institutions are essential in addressing the skills shortage through the implementation of AI-specific training programmes and the revision of construction-related curricula (Felemban et al., 2024). Moreover, governmental support in the form of tax incentives, subsidies, and grant funding can reduce financial barriers, particularly for small and medium-sized enterprises. Strategic investments in both technological infrastructure and human capital development are critical for fostering long-term growth, enhancing operational efficiency, and improving the global competitiveness of the sector. By leveraging these enablers, the South African AEC industry may be better positioned to harness the transformative potential of AI technologies in a sustainable and inclusive manner.

3. Research Methodology

This section describes the research methodology, highlighting that the study is part of a broader project. While the overall research follows a positivist approach, this paper specifically focuses on a qualitative literature review. It includes bibliometric analysis using VOSviewer software to identify trends, factors, and barriers affecting AI adoption in South Africa's AEC sector, providing both qualitative insights and objective data analysis for a comprehensive understanding of the subject matter under investigation.

3.1. Research Design

The research design adopted in this study is qualitative and exploratory, whilst focusing on synthesizing existing literature knowledge related to AI adoption in the AEC industry, particularly in the South African context. The systematic literature review provides a structured and transparent framework for gathering relevant studies on AI adoption, barriers, and enablers (Petticrew & Roberts, 2006). Bibliometric analysis supplements the review, analysing the frequency, citation patterns, and relationships between key articles to uncover trends in AI research within the AEC sector (Moed, 2005).

3.2. Data Collection

To ensure a rigorous and systematic approach to data collection, a structured methodology was adopted to identify, screen, and select relevant studies on AI adoption in South Africa's AEC sector. The process involved searching academic databases and other sources using keywords such as "Artificial Intelligence," "AI adoption," "AEC sector," "Architecture, Engineering, Construction," "South Africa," "Barriers to AI," "Enablers of AI," "Machine learning," "Predictive analytics," and "Digital infrastructure."

This search aimed to gather peer-reviewed, high-quality literature that aligned with the research objectives. Following the identification of 160 records, the PRISMA methodology was applied to refine the data systematically (Figure 1). After removing duplicates, the screening phase resulted in the exclusion

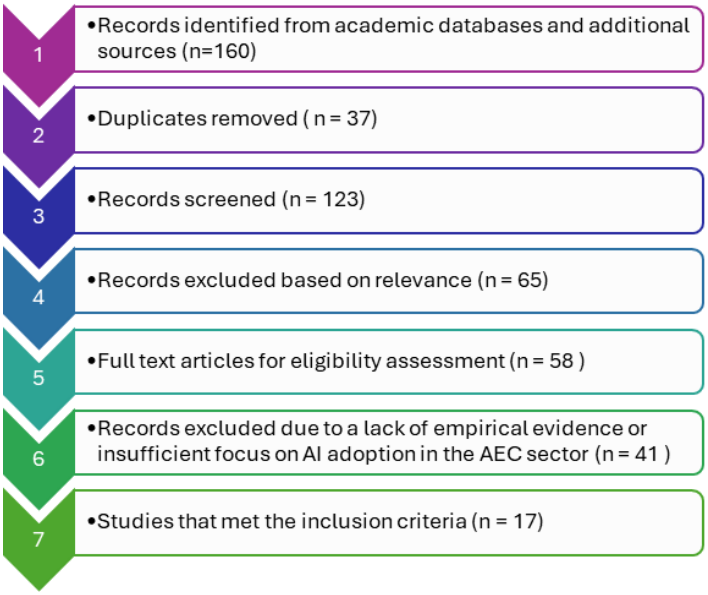


Figure 7: PRISMA flowchart displaying data collection process

of 65 records based on relevance, peer-review status, and alignment with the research objectives. The remaining 58 full-text articles were assessed for eligibility, with 41 excluded due to a lack of empirical evidence or insufficient focus on AI adoption in the AEC sector. Ultimately, 17 studies published between 2017 and 2024 met the inclusion criteria and were incorporated into the systematic literature review and bibliometric analysis, providing valuable insights into the trends, barriers, and enablers of AI adoption in South Africa's AEC industry.

The inclusion of 17 publications reflects the early stage of the current master's research, which aims to provide a foundational understanding of AI adoption in South Africa's AEC industry. As this paper is part of a broader project, the limited sample size ensures a focused analysis, with plans to expand the review as the research progresses, enhancing its depth and scope.

3.3. Data Analysis

Bibliometric analysis was conducted using VOS viewer software to map relationships between key articles and identify significant trends in the literature. Citation networks and keyword frequency analysis highlighted influential studies and knowledge gaps, helping to track the development of AI-related research within the AEC sector (Van Eck & Waltman, 2010). This approach provided a clear framework for categorizing and interpreting the findings.

3.4. Justification of the Methodology

The positivist approach is suitable for this research as it seeks to analyse objective, existing data to draw conclusions about AI adoption in South Africa's AEC industry. By employing a systematic literature review and bibliometric analysis, the study synthesizes the current body of knowledge and identifies patterns without requiring primary data collection. This approach aligns with the study's aim to explore the current state of AI integration in the sector (Petticrew & Roberts, 2006). The use of VOS viewer enhances the reliability of the findings by offering a structured, data-driven method for identifying trends and relationships within the literature.

3.5. Limitations of the Methodology

The limitations of this study include the reliance on published literature, which may not fully reflect real-time developments in AI adoption. The scope of available studies may also not capture all regional challenges or the specific experiences of industry practitioners. Additionally, the study is constrained using secondary data, limiting the ability to explore firsthand experiences of AI implementation by AEC professionals. Despite these limitations, the findings offer valuable insights into trends, barriers, and enablers of AI adoption in South Africa's AEC industry.

4. Findings and Discussion

This chapter presents the key findings from a bibliometric analysis of AI adoption in the AEC sector, highlighting an increase in publications and the growing recognition of AI's potential. Key themes include barriers to AI adoption, technological enablers, and regulatory concerns in South Africa. The findings emphasize the interdisciplinary nature of AI research in the AEC industry and stress the need for strategic approaches to address challenges and promote wider adoption in the sector.

4.1. Citation Networks and Key Authors

The citation network analysis demonstrated distinct clusters of influential authors in the domain of AI adoption within the AEC sector. Key contributors, such

as Oyedele, Lukmon, and Abioye, Sofiat, formed a prominent cluster, reflecting their foundational impact on the field. Other notable clusters include contributions by authors like Ahmed, Ashraf, and Akambi, Lukman, who have significantly shaped discussions on interdisciplinary applications of AI in construction. Interdisciplinary collaborations were evident, with connections spanning fields such as construction management, data science, and digital transformation (Figure 2). The network also highlighted emerging contributors, such as Schoeman, Franz, and Deng, Yichuan, who form smaller, yet pivotal clusters. These patterns underscore a growing emphasis on global and collaborative approaches to AI research in construction, providing a comprehensive perspective on technological advancements in the sector.

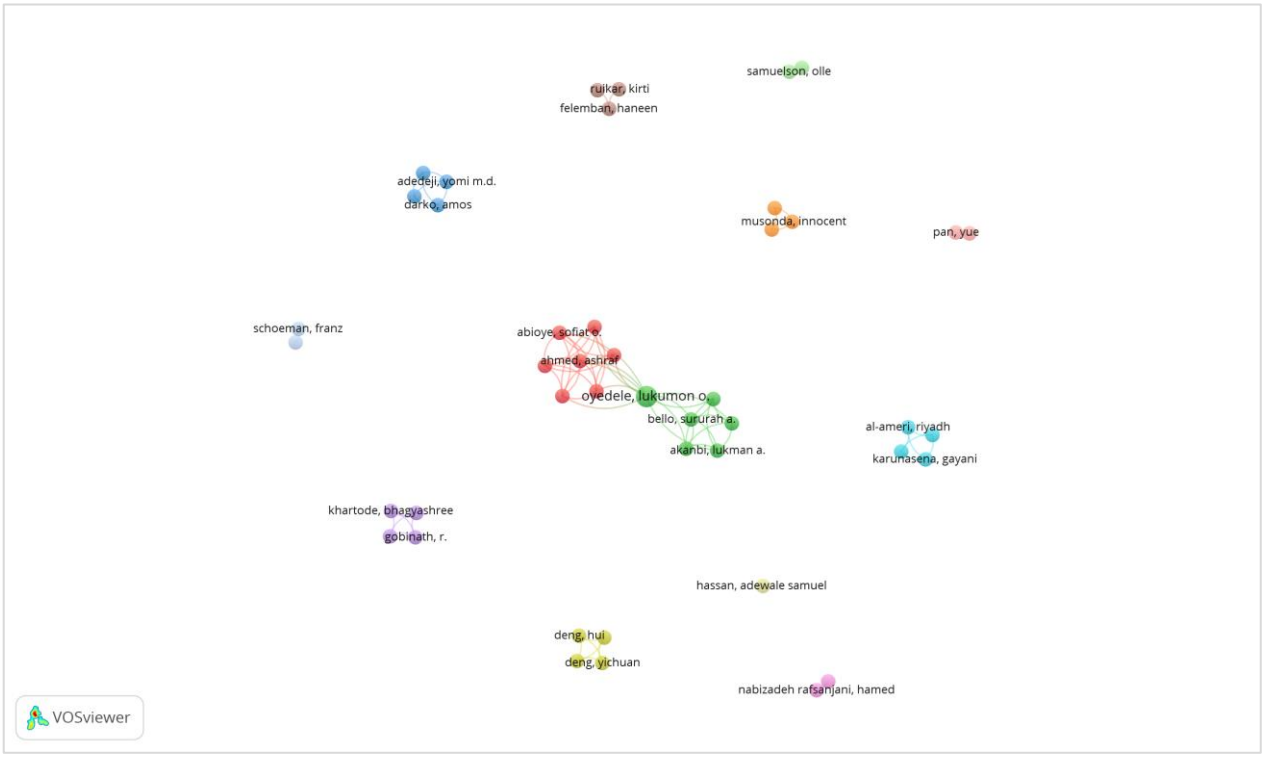


Figure 2: Citation Networks and Key Authors

4.2. Co-occurrence of key words

The co-occurrence of keywords in bibliometric analysis highlights the central themes and interconnected trends within AI adoption research in the AEC sector. The VOS viewer-generated map reveals distinct clusters representing recurring topics displayed in Figure 3 on the next page.

The red cluster emphasizes foundational themes like "AEC industry," "automation," "AI application," and "information," showcasing the role of AI in revolutionizing construction processes and project workflows. The green cluster focuses on challenges and facilitators, with keywords such as "barrier," "enabler," "efficiency," and "safety," pointing to discussions on overcoming obstacles and leveraging technological benefits. Meanwhile, the blue cluster centres on "AI adoption," "framework," "factors," and "South Africa," reflecting research addressing the local context and strategies to enhance adoption.

The purple cluster highlights organizational and regulatory considerations through terms like "organisation," "policy," and "maturity," while the yellow cluster explores conceptual and strategic discussions, with keywords like "concept," "advantage," and "digital technology." The interconnectedness between clusters, such as the link between "barrier" and "AI adoption," underscores the interplay between challenges and strategic interventions.

Overall, the analysis underscores an interdisciplinary approach that integrates technological, organizational, and policy-related dimensions. It also highlights a dual focus on addressing region-specific challenges, such as those in South Africa, while incorporating global insights into the adoption of AI in construction. This visualization provides a comprehensive understanding of the trends and gaps in the current research landscape. The bibliometric analysis using VOS viewer has provided valuable insights into the current state of AI adoption in South Africa's AEC sector. The findings indicate a growing body of literature that identifies key barriers, enablers, and trends shaping the adoption of AI technologies. Despite significant advances in AI adoption in certain sectors, there remains a need for more localized research, strategic policy interventions,

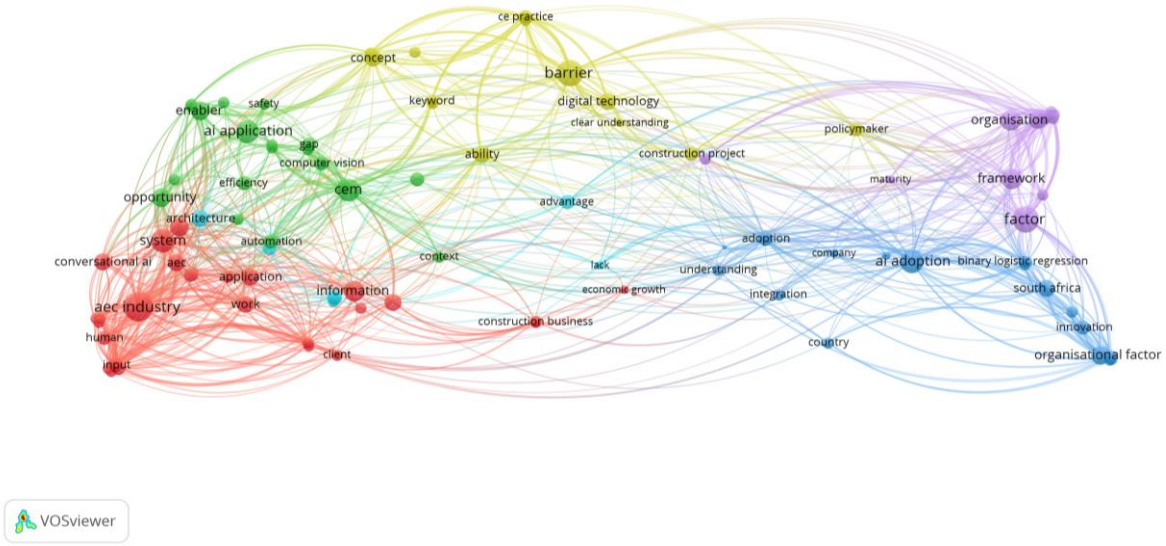


Figure 3: Co-occurrence of key words

and investments in digital infrastructure to support widespread AI integration in South Africa's construction industry.

4.3. Trends in AI Adoption in the AEC Sector

The bibliometric analysis revealed several key trends in AI adoption within the AEC sector, particularly in South Africa. Initially, the literature on AI adoption in the AEC industry was sparse; however, over the past seven years (from 2017 to 2024), a sharp increase in publications was observed. This surge, with over 17 papers specifically referenced in this study, highlights a growing recognition of AI's potential to enhance operational efficiency, project management, and safety in construction. The increased interest is particularly evident in urban areas with better-developed digital infrastructure, where AI applications such as predictive analytics, project risk management, and resource optimization are gaining traction (Abioye, et al., 2022). However, despite this growth in research, AI adoption in the South African construction sector remains limited, with only a small subset of studies specifically addressing its implementation within the local industry. This gap underscores the need for further investigation into the challenges and opportunities for AI adoption in the region.

4.3.1. Thematic Findings on AI Adoption in South Africa's AEC Sector

A detailed thematic analysis of the reviewed literature provides insights into the key focus areas of AI adoption in South Africa's AEC sector. Table 1 categorizes these findings into major themes, emphasizing the extent of AI adoption, barriers, enablers, applications, economic impact, and policy considerations shaping the sector. Notably, barriers to AI adoption were the most frequently discussed theme, appearing in 11 papers, underscoring financial constraints, lack of infrastructure, and limited AI expertise as major obstacles. Conversely, enablers of AI adoption, covered in 8 papers, highlight the role of government policies, digital infrastructure investment, and workforce upskilling in facilitating AI integration. The findings further indicate that AI's application in South Africa's AEC sector is mainly focused on predictive analytics, project risk management, and resource optimization, with limited use of advanced technologies such as robotics and natural language processing. Policy and regulatory challenges also remain a critical concern, as identified in 6 papers, emphasizing the need for structured AI governance, ethical considerations, and clearer guidelines to promote adoption. These insights demonstrate that while AI adoption is increasing, its implementation remains uneven, with larger firms leading the way while SMEs struggle due to financial and technical limitations. The data underscores the importance of targeted interventions, including policy reforms, financial incentives, and skills development initiatives, to bridge these gaps and drive AI adoption across the industry.

5. Conclusion and Further Research

This study provides an in-depth analysis of AI adoption in South Africa's AEC sector, identifying key trends, barriers, and enablers. Through a systematic literature review and bibliometric analysis, it reveals that AI usage is largely limited to basic applications like machine learning and predictive analytics, with more advanced technologies such as robotics and natural language processing underutilized. The primary barriers include financial constraints, inadequate digital infrastructure, and a shortage of skilled professionals. The research underscores the importance of strategic policy interventions, investments in digital

Table 3: Thematic Findings on AI Adoption in South Africa's AEC Sector

Theme	Number	Key Findings	Relevance to Study
Extent of AI Adoption in AEC	6	AI is primarily applied in automation, predictive analytics, and project management. More advanced technologies (robotics, NLP) remain underutilized.	Provides insight into the current maturity level of AI in South Africa's AEC industry.
Barriers to AI Adoption	8	Major barriers include financial constraints, lack of digital infrastructure, skills shortages, resistance to change, and regulatory uncertainties.	Identifies key challenges limiting AI adoption and informs policy recommendations.
Enablers of AI Adoption	7	Government policies, investment in digital infrastructure, targeted training programs, and financial incentives are crucial to accelerating AI adoption	Highlights opportunities and strategies to enhance AI integration.
AI Applications in Construction	9	AI is used for construction management, predictive risk analytics, safety monitoring, and resource optimization.	Demonstrates AI's functional role in improving project efficiency.
Economic Impact of AI	7	AI adoption reduces operational costs, improves productivity, and enhances project risk management.	Links AI implementation to financial and efficiency benefits.

infrastructure, and targeted training programs to overcome these challenges.

Further research is necessary to engage directly with industry stakeholders to explore practical implementation challenges and opportunities. Additionally, examining regional disparities in AI adoption and the potential of emerging AI technologies, such as robotics and AI-driven project management tools, could provide deeper insights into the sector's evolving capabilities. Addressing these areas will be critical to driving broader AI adoption, enhancing efficiency, sustainability, and competitiveness in South Africa's AEC sector.

6. Acknowledgement

This paper forms part of my master's study at the Durban University of Technology. I would like to express my sincere gratitude to my supervisor, Dr. Zakheeya Armoed, and my co-supervisor, Prof. Modupe Mewomo, for their invaluable guidance and unwavering support throughout the research process.

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Bringing Change in Construction: Analysing Strategies for Managing Cybersecurity Disasters in the South African Construction Industry

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Abstract

This study explored strategies for managing cybersecurity risks in the South African construction industry. Using a quantitative research methodology, the study targeted construction professionals and cybersecurity experts in Gauteng province through structured questionnaires, of which 150 were distributed and 90 were retrieved. The data was analysed using descriptive statistics, exploratory factor analysis (EFA), and correlation techniques to identify key cybersecurity risks and evaluate the effectiveness of existing strategies using Statistical Package for the Social Sciences (SPSS) software. The findings showed that companies prioritise adopting new technology and responding to cyber threats, but struggle to integrate cybersecurity into overall business strategies. Many firms focus on either strategic planning or cybersecurity, rarely balancing both due to resource limitations. The study concludes that bringing change requires a combined approach where cybersecurity measures align with strategic goals. Practical implications suggest that construction firms must invest in cybersecurity training, adopt stronger security policies, and use advanced technologies like AI and encryption. Companies should also improve stakeholder involvement to ensure that cybersecurity is a key consideration in project management. Future research should explore specific challenges preventing firms from fully implementing security measures and how government policies can support better cybersecurity practices. This study highlights the urgent need for a balanced approach to cybersecurity and strategic planning in the construction industry.

Keywords: Construction security, Technology adoption, Cyber threats, Risk management, Strategic planning

1. Introduction

The South African construction industry is undergoing significant transformation as it embraces digital technologies to improve efficiency and competitiveness (Jeza & Lekhanya, 2022). The industry is shifting from traditional methods to more innovative solutions with the growing adoption of Building Information Modelling (BIM), cloud-based systems, and advanced project management tools. These changes offer immense potential for cost savings, better collaboration, and faster project delivery. However, Jimmy (2021) noted that this change to digital integration also brings new challenges, particularly the risk of cybersecurity threats, which can disrupt operations and compromise sensitive data. To fully realise the benefits of digital tools, the industry must prioritise robust strategies to manage these emerging risks.

According to Stephen *et al.* (2024), cybersecurity has become a critical concern in construction, as the reliance on digital platforms increases the exposure to cyber risks. The study continued that construction companies now store valuable project data, financial records, and intellectual property on digital systems, making them attractive cyberattack targets. Möller (2023) and Stephen *et al.* (2024) noted that some cybersecurity disasters or threats, like data breaches, ransomware, and phishing attacks, can lead to financial losses, reputational damage, and project delays. Additionally, the studies explained further that weak cybersecurity measures can affect the entire supply chain, putting clients, contractors, and other stakeholders at risk. Addressing these vulnerabilities is essential to ensure the successful and secure adoption of digital technologies in construction.

Mantha and García de Soto (2021) and Mantha *et al.* (2021) stated that the lack of awareness about cybersecurity threats and the absence of comprehensive strategies to manage these risks are some of the challenges experienced in the digital construction industry. Many firms are unprepared for potential cyberattacks, which leaves their digital systems vulnerable. Pieterse (2021) gave examples of 74 cyber incidents, such as Johannesburg facing major cyberattacks in 2019, including a ransomware attack on City Power and a breach by Shadow Kill hackers, disrupting essential services. In 2020 and 2021, cyber incidents surged, impacting industries like finance, healthcare, and construction, highlighting vulnerabilities in South Africa's infrastructure. Therefore, the rationale for this research is to address this gap by providing insights into how construction companies can better prepare for and respond to cybersecurity disasters. The study's objectives are to examine the current state of cybersecurity in the construction industry, identify common vulnerabilities, and propose practical strategies for risk management.

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This research will benefit construction firms, project managers, Information Technology (IT) professionals, and policymakers by equipping them with tools and knowledge to safeguard digital systems. Ultimately, the study aims to analyse strategies for managing cybersecurity disasters in the construction industry, focusing on South Africa.

2. Cybersecurity Threats in the Construction Industry

Like many other sectors, the construction industry has embraced digital tools to enhance efficiency, collaboration, and project management (Jeza & Lekhanya, 2022). However, a growing risk of cybersecurity threats comes with increased reliance on digital systems (Mantha & García de Soto, 2021). Rane (2023) explained that construction companies often manage vast amounts of sensitive data, including project designs, financial records, and client information. This data, stored on cloud platforms or shared across digital networks, becomes a prime target for cybercriminals. According to McKane (2020) and Tanga *et al.* (2022), the South African construction industry has experienced several real-life cyberattacks, highlighting the industry's cyber risks. In 2019, a major construction company, Stefanutti Stocks, suffered a ransomware attack that disrupted its operations and delayed projects. The hackers tried to steal login details to access sensitive project data. In another case, malware infected a construction software system used by a subcontractor, causing delays in a large housing project in Gauteng. These examples show how cyberattacks can lead to financial loss, project delays, and damage to company reputations, highlighting the need for stronger cybersecurity.

One of the significant cybersecurity threats in construction is ransomware attacks, where hackers encrypt a company's data and demand payment for its release (Connolly & Wall, 2019). Such incidents can paralyse operations, delay projects, and result in financial losses. Phishing schemes are another common threat, where attackers trick employees into revealing sensitive information or downloading malicious software (Alkhalil *et al.,* 2021). Additionally, the construction industry is vulnerable to insider threats, as disgruntled employees or contractors with access to sensitive systems may misuse their privileges (Saxena *et al.,* 2020). These risks are compounded by the industry's complex supply chains, where third-party vendors or subcontractors may inadvertently introduce vulnerabilities.

Furthermore, the impact of cybersecurity threats extends beyond financial losses (Lee, 2021). A successful cyberattack can lead to reputational damage as clients lose trust in a company's ability to protect their data. For instance, a confidential project design breach can result in legal liabilities or competitive disadvantages. Moreover, Kure *et al.* (2022) stated that attacks targeting critical infrastructure projects pose national security risks, and Pieterse (2021) stated that 74 cyber incidents were identified occurring between 2010 and 2020. This emphasises the need for stringent cybersecurity measures. Kure *et al.* (2022) continued that despite these risks, many construction companies underestimate the importance of cybersecurity, focusing more on operational priorities like cost and deadlines. This lack of awareness leaves them unprepared for potential threats, making them easy targets for cybercriminals, as Mantha *et al.* (2021) explained.

2.1. Cybersecurity Frameworks and Standards

This section reviews key cybersecurity frameworks and standards developed by governments and international organisations, focusing on their relevance to the construction industry. These frameworks address the unique challenges of protecting operational technology (OT) systems on construction sites, which are crucial for on-site operations, as Sonkor and García de Soto (2021) explain. Shackelford *et al.* (2015) highlighted the role of organisations like the National Institute of Standards and Technology (NIST) and the International Organisation for Standardisation (ISO) in creating guidelines that help industries, including construction, strengthen cybersecurity. Examples include the UK's Minimum Cyber Security Standard (MCSS) of 2018, which sets baseline cybersecurity requirements (Srinivas *et al.,* 2019), and ISO/IEC 27001:2013, which provides universal guidelines for managing information security systems (Koza, 2022). In South Africa, the National Cybersecurity Policy Framework (NCPF) was influenced by global policies from the EU, NATO, and the US. Still, it raised concerns about its adaptation to local needs (Sutherland, 2017). Its goals include reducing threats, promoting cooperation, and building cybersecurity capacity (Djebbar & Nordström, 2023). In the construction sector, ISO 19650-5:2020 is an industry-specific standard focused on securing sensitive information in projects that use Building Information Modelling (BIM) and cybersecurity (Abbasnejad *et al.,* 2024). This standard addresses cybersecurity throughout the entire lifecycle of built environments, from design to operation. Unlike ISO/IEC 27001, which applies broadly across industries, ISO 19650-5 is tailored to the collaborative data-sharing processes in construction, making it a valuable resource for stakeholders.

According to Snail ka Mtuze and Musoni (2023), South Africa has a cyber framework called the Cybercrimes Act, which was signed into law in 2021. This law helps fight cyber threats by defining cybercrimes, setting punishments, and improving cybersecurity measures. It makes hacking, identity theft, and data breaches illegal while also giving authorities more power to investigate cyberattacks. For example, after the Experian data breach in 2020, where the personal data of 24 million

South Africans was exposed, the Cybercrimes Act now ensures stricter penalties for companies that fail to protect sensitive information. This framework helps protect industries like construction, which aim to fully rely on secure digital systems for project management and financial transactions.

2.2. Mitigating Cybersecurity Disasters in the Construction Industry

Mitigating cybersecurity disasters in the construction industry begins with building awareness and prioritising cybersecurity as a critical part of operations. Many construction firms underestimate the risks posed by cyber threats, often focusing more on traditional physical security. To begin with, Chagadama and Luamba (2022) stated that educating employees, contractors, and stakeholders about the potential dangers of cyberattacks and how to identify suspicious activities is essential. The authors continued that regular training sessions on safe online practices, such as recognising phishing emails and securely handling sensitive data, can significantly reduce human errors, which are a leading cause of cybersecurity breaches. Mantha and García de Soto (2021) concluded that construction companies can strengthen their first line of defence against cyber threats by creating an awareness culture.

Isakov *et al.* (2024) noted that another crucial step is the implementation of advanced technological measures to protect digital systems. The study explains that robust firewalls, up-to-date antivirus software, and data encryption should be standard practices. Additionally, companies should adopt multi-factor authentication (MFA) to add an extra layer of security when accessing systems and sensitive information (Cahyaningrum, 2024). The study explained that regular vulnerability assessments and cybersecurity audits can help identify and address weaknesses in existing systems. Ohueri *et al.* (2024) opined that investing in secure cloud-based platforms and adhering to internationally recognised standards, such as ISO/IEC 27001 and ISO 19650-5, can further enhance the security of critical systems and data, especially in projects relying on Building Information Modelling (BIM) and other digital tools.

Furthermore, collaboration and partnerships also play an important role in mitigating cybersecurity disasters (Bradshaw, 2015). The study explained that construction companies often work with multiple subcontractors, vendors, and external partners, making it vital to establish clear cybersecurity policies and protocols across the supply chain. It continued that these companies could collaborate with cybersecurity experts to develop tailored risk management strategies and incident response plans. In addition, Markopoulou and Papakonstantinou (2021) suggested that governments and industry bodies can support these efforts by providing resources, guidelines, and frameworks that address sector-specific risks. By integrating these efforts, the construction industry can build a united front against cyber threats, ensuring the protection of assets, data, and critical infrastructure. However, from the literature reviewed, a notable gap lies in the practical implementation and evaluation of cybersecurity frameworks specifically tailored to the construction industry's unique challenges. While existing standards like ISO/IEC 27001:2013 and ISO 19650-5:2020 provide comprehensive guidelines, limited evidence or case studies demonstrate their effective adoption within real-world construction environments, particularly in regions like South Africa.

Moreover, the literature highlights the industry's increasing digital integration but underscores a lack of widespread awareness and preparedness among construction firms.

3. Research Methodology

This study used a quantitative approach to examine how construction companies in South Africa are managing cybersecurity risks, following a descriptive research design to identify key issues and explore relationships. It focused on construction professionals and cybersecurity experts in Gauteng province, including architects, quantity surveyors, construction managers, engineers, and cybersecurity specialists. Cybersecurity experts were selected based on their qualifications and experience, while construction professionals were chosen from registered industry bodies such as the South African Council for the Quantity Surveying Profession (SACQSP). Aghimien *et al.* (2020) highlighted the role of professional bodies, with updates from the researcher showing that SACAP (2025) had 11,551 registered members, ECSA (2022) had 53,000 members, including 35,333 professional engineers, SACPCMP (2018) recorded 7,785 construction and project managers, and SACQSP (2018) had 4,339 members, rising to 4,539 by December 2018, totalling 59,208 professionals. According to Darling (2022), sample size depends on margins of error, where a ±10% margin at a 90% confidence level resulted in a sample size of 380 when Cochran's (1963) formula was used for the study. However, due to response challenges, 150 questionnaires were distributed via Google Forms, with 90 responses received, achieving a 60% response rate, which Sue and Ritter (2007) considered good. Bihu (2021) noted that questionnaires were chosen for most studies due to their cost-effectiveness, convenience, and the ability to overcome geographic barriers.

The data for the study were analysed using descriptive statistics, such as mean and standard deviation, using the Statistical Package for the Social Sciences (SPSS) software. This analysis helped understand construction companies' cybersecurity threats, as Grancharova and Aleksandrova (2023) noted. Exploratory Factor Analysis (EFA) was conducted to identify key

cybersecurity strategies further using the Kaiser-Meyer-Olkin (KMO) test and Bartlett's test, yielding a KMO value of 0.905, indicating the adequacy of the data. EFA was helpful in uncovering patterns, grouping related variables, and simplifying complex data.

4. Findings and Discussion

Stephen *et al.* (2024) illustrated that the cybersecurity adoption in South African construction is low despite Pieterse (2021) and Snail ka Mtuze and Musoni (2023) stating that numerous cyber incidents were identified occurring over time. To mitigate this, Table 1 shows measures to address cybersecurity risks in South African construction based on their mean scores and standard deviations (SD). "Readiness to incorporate technological innovations" ranks highest (Mean = 4.35, SD = 0.684), showing strong agreement and low variability among respondents. Close behind are "Response to data theft" (Mean = 4.31, SD = 0.693) and "Implementing strategic direction" (Mean = 4.30, SD = 0.727), both seen as highly important. Measures like "The validity of the strategy," "Usage of strategy control," and "Adopting zero-trust (ZTA)" also score

Table 1: Strategies to Address Cybersecurity Risk in Construction

Strategies	Mean	SD	Rank
Readiness to incorporate technological innovations	4.35	0.684	1
Response to data theft	4.31	0.693	2
The validity of the strategy	4.30	0.779	4
Implementing strategic direction	4.30	0.727	3
Usage of strategy control	4.30	0.689	5
Adopting zero-trust (ZTA)	4.26	0.865	6
Stakeholders' involvement in strategy implementation	4.26	0.750	7
Improving security software development	4.25	0.728	8
Availability of behavioural analytics	4.23	0.944	9
Adopting strategic formulation	4.23	0.742	10
Defensive AI and machine learning for cybersecurity	4.22	0.837	12
Infrastructure and security as code	4.22	0.719	11
Risk-based automation	4.18	0.839	13
Engaging usage of homomorphic encryption	4.17	0.849	14
Availability of elastic log monitoring for large data sets	4.17	0.801	15
Proper environmental assessment	4.16	0.796	16

(Source: Authors')

Table 2: Communalities

Pattern Matrix[a]		
	Component	
	1	2
Stakeholders' involvement in strategy implementation	0.811	
Usage of strategy control	0.809	
Proper environmental assessment	0.807	
Implementing strategic direction	0.793	
Readiness to incorporate technological innovations	0.791	
Adopting strategic formulation	0.762	
The validity of the strategy	0.747	
Response to data theft	0.571	
Infrastructure and security as code		-0.925
Defensive AI and machine learning for cybersecurity		-0.799
Availability of elastic log monitoring for large data sets		-0.769
Adopting zero-trust architecture (ZTA)		-0.750
Risk-based automation		-0.748
Improving security software development		-0.540
Engaging usage of homomorphic encryption		-0.536
Availability of behavioural analytics		-0.457

(Source: Authors')

high but with slightly more variation. Lower-ranked measures, such as "Proper environmental assessment" (Mean = 4.16, SD = 0.796) and "Availability of elastic log monitoring for large data sets" (Mean = 4.17, SD = 0.801), still have strong mean scores but less priority. Some measures, like "Engaging usage of homomorphic encryption" and "Defensive AI and machine learning," show higher variability, reflecting mixed opinions. Overall, the high mean scores indicate that all measures are important, with differences in ranking showing varying levels of emphasis.

The findings highlight the construction industry's prioritisation of technological innovations and strategic responses to cybersecurity risks, aligning with existing literature emphasising the growing need for advanced measures in this sector. For instance, Shopina *et al.* (2020) stress the importance of readiness for technological innovation to counter emerging threats, which supports the top-ranked measure in this study. Similarly, the focus on responses to data theft and strategic direction corroborates Oke *et al.* (2023)'s observation that organisations must integrate targeted strategies to manage risks effectively. However, the lower rankings of measures like "Proper environmental assessment" and "Elastic log monitoring for large data sets" contrast with recommendations by Upadhyay and Sampalli (2020), who argue that monitoring and environmental assessments are crucial for detecting vulnerabilities. This contrast may reflect practical limitations in implementing such measures in construction settings.

Table 2 shows the two main components influencing strategy and security measures. The first component, grouped as ***strategic measures***, has high positive values for factors related to strategic implementation, such as stakeholder involvement (0.811), strategy control (0.809), and environmental assessment (0.807), among others. This suggests that these elements work together in effective strategy execution. The second component, grouped as ***cybersecurity measures,*** has high negative values for cybersecurity measures like infrastructure security (-0.925) and defensive AI (-0.799), indicating that these factors are separate from or even inversely related to strategy implementation. This means organisations may focus on either strategic execution or cybersecurity, but not both simultaneously. According to Koza (2022), strategic implementation relies heavily on stakeholder involvement, structured control, and environmental assessment, which are crucial for achieving organisational goals. This can help mitigate cyber-attacks in the South African construction industry. Conversely, cybersecurity measures, such as infrastructure security and defensive AI, align with studies indicating that security concerns often compete with strategic priorities for resources and focus (Rane, 2023; Abbasnejad *et al.,* 2024). Putting in place simple cyber measures when planning construction can go a long way in addressing disasters over time. South African firms can prioritise strategic and cybersecurity measures to help combat further cyber incidents, as Pieterse (2021) noted.

Table 3 provides the results of the KMO and Bartlett's test of sphericity, which are essential assessments in factor analysis. The KMO is a value between 0 and 1, with higher values indicating better suitability for factor analysis. In this case, the KMO value is 0.905, which is close to 1. This high KMO value suggests that the dataset is highly suitable for factor analysis. In this specific analysis, Bartlett's test of sphericity yields an approximate chi-square value of 881.872 with 120 degrees of freedom. This suggests that the variables in the dataset exhibit significant intercorrelations, supporting the use of factor analysis to explore these relationships further, as Sharma *et al.* (2023) suggested.

Table 3: KMO and Bartlett Test

KMO and Bartlett's Test		
Kaiser-Meyer-Olkin measure of sampling adequacy.		0.905
Bartlett's test of sphericity	Approx. Chi-Square	881.872
	df	120
	Sig.	0.000

(Source: Authors')

5. Discussion and Conclusion

The current state of cybersecurity in the South African construction industry reveals a mixed level of preparedness, with companies recognising the risks but often struggling to implement effective measures. Key issues include low awareness of critical security steps, such as proper environmental assessments and elastic log monitoring for large data sets, which are often overlooked. Challenges such as high costs, limited technical knowledge, and resistance to adopting new systems hinder progress. Research by Shopina et al. (2020), Oke et al. (2023), Rane (2023), and Abbasnejad et al. (2024) show that firms tend to focus either on strategic planning or cybersecurity improvements, rarely balancing both. This disconnect limits their ability to integrate security into their operations fully. Factors like stakeholder involvement and resource allocation are crucial, as firms often face tough decisions between investing in strategic growth or enhancing security. Furthermore, effective strategies for improving cybersecurity should include better integration of security measures into everyday operations and prioritising innovations like

infrastructure security and defensive artificial intelligence (AI) while addressing resource challenges by aligning cybersecurity initiatives with overall business strategies. South African construction firms can build resilience against cyber threats and achieve sustainable growth.

The study's scope is limited to Gauteng. A broader geographic scope beyond the province and including qualitative insights from industry leaders could offer a more comprehensive understanding of the required strategies. Furthermore, future research should explore practical ways to help construction companies implement both cybersecurity and strategic planning together. Studies could also examine the specific barriers preventing companies from fully adopting advanced security measures and how government policies or industry guidelines can support better cybersecurity practices.

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A Systematic Literature Review on Emergency Response Systems and their Impact on Infrastructure Resilience

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Abstract

The purpose of this study was to assess existing literature on the impact of emergency response systems on infrastructure resilience, identifying optimal methodologies and highlighting obstacles in emergency response that affect stability during emergencies. Thus, the research design was based on a systematic review of 30 peer-reviewed English-language articles published between 2015 and January 2025 to analyze global trends and expert opinions on emergency response infrastructure, identifying best practices and knowledge gaps. Articles addressing emergency response systems and impact issues were given extra consideration. The study's research limitations include bias toward developed countries and potential outdatedness due to rapid advancements in emergency response technologies. Key findings are based on examinations of existing scientific knowledge regarding the state of emergency response on infrastructure and its economic and socio-political impacts. The identified key infrastructure includes early warning, situational awareness, technology and infrastructure, response efficiency, resources and capabilities, strategic framework, community engagement, preparedness and knowledge, and institutional communication. The impacts include global economic consequences, human and property loss, infrastructure deficiencies, and displacement issues. The socio-political impact includes demographic and urban challenges, infrastructure gaps, vulnerability, and economic stability. The review emphasizes the importance of decision-makers prioritizing emergency preparedness and uniform agency procedures. It highlights the need for coordinated response plans, community involvement, and strengthening infrastructure against future crises, which are considered key practical implications .

Keywords: Emergency, Emergency response, Impact, Infrastructure resilience, Natural hazard.

1. Introduction

Emergency Response Systems (ERS) face challenges in disaster management and healthcare infrastructure, requiring urgent enhancement due to the growing population and increased vulnerability to natural and man-made disasters. Global disasters pose significant risks to human life and property, limiting sustainable growth and affecting economic and social development in communities (Zulu & Shi, 2023). Natural and manmade hazards significantly impact every livelihood, causing significant losses to housing infrastructure (Vinokurova, *et al.,* 2022). Building resilient infrastructure is crucial for socio-economic stability and community well-being.

Critical infrastructure underpins the functioning of contemporary societies, enabling access to essential services such as transportation, energy, food, and education (Sharma & Gardoni, 2018). The rapid growth of urban environments has led to a higher concentration of people in buildings and facilities, increasing the potential risks during emergencies such as fires or other disasters (Matveev *et al.,* 2021). Effective disaster risk management (DRM) strategies are needed to address these vulnerabilities and ensure the safety of occupants. The increasing congestion of transportation systems poses safety risks, delays, and impeded emergency response times (Khalid *et al.,* 2021). Therefore, it is crucial to implement risk management and reduction strategies to mitigate these hazards.

Crowd management during evacuations is another critical concern. Human behaviour can shift rapidly from calm to panic in emergencies, leading to chaos and potential injuries (Yazdi & Zarei, 2024). Proper planning ensures safe and efficient evacuations, especially in crowded facilities. Fires remain a significant threat in public buildings, and many countries have established fire safety regulations to protect residents (Ahmed, 2024). The effectiveness of regulations varies, with high-profile incidents like the London Tower fire highlighting the need for robust emergency response infrastructures (Zualkernan *et al.,* 2019). Ghana experiences frequent residential fire incidents, causing significant loss of life and financial

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damage, causing fear and panic among the population. Adopting preventative measures, awareness, response, and rehabilitation or reconstruction activities can enhance facility resident safety through a comprehensive DRM cycle (Zulu & Shi, 2023). Among the research tasks conducted by researchers is an illustration of nature-based solutions for a sustainable African built environment.

Research tasks conducted by researchers have illustrated nature-based solutions for an African-built environment on sustainable emergency response by Aghimien *et al.,* (2024). Assessing the social, economic, and environmental challenges of veld fires in South Africa by Adom *et al.,* (2025). Mallick (2025) investigated climate resilience and smart cities. However, previous studies have shown that research on emergency response is crucial for enhancing infrastructure resilience in sub-Saharan Africa, especially in response to recurring emergencies. This literature review aim to assess these systems and their impact on infrastructure resilience, providing insights that can inform future improvements in emergency management strategies across the region and beyond.

This study adopted the following research questions (RQ): RQ1: What is the impact of ERS on infrastructural resilience? and RQ2: What are the key challenges of ERS on infrastructural resilience?

2. Literature Review

2.1. Emergency response system

A coordinated framework created to successfully handle emergencies and disasters is an emergency response system (Wang *et al.,* 2022). A successful emergency response system is essential for reducing casualties, safeguarding property, and guaranteeing a speedy recovery (Dwarakanath *et al.,* 2021).

Risk knowledge and management is one of the systems that involves identifying hazards, and assessing vulnerability while utilising available resources and systems for the safety and well-being of people, and properties. Street security, traffic, and disaster have advanced monitoring technologies to detect, manage, and provide early warnings for disaster preparedness. Crime watch monitoring systems use surveillance cameras, community reporting apps, and data analytics to enhance public safety and emergency response in infrastructure (Damaševi˘cius *et al.,* 2023). Data management, disaster risk analysis, community engagement, and religious institutions develop strategies by collecting, storing, and analysing disaster-related information and assessing impacts on infrastructure (Sutton *et al.,* 2024).

Forecasting for an emergency uses advanced tools to predict disaster events using meteorological, geological, and environmental data. Disaster risk reduction (DRR) uses thorough data analysis to identify patterns, develop strategies, and mitigate risks in infrastructure (Basher, 2006). Assessing pre-disaster management measures improves resilience and risk management. Predicting disaster trends involves analysing historical data, adjusting DRR strategies, and implementing proactive measures. Social media platforms enable rapid dissemination of disaster information, enhancing public awareness and preparedness. Regular briefings, updates, and training sessions integrate pre-disaster information into DRR strategies (Sibiya, 2022). A comprehensive database improves accessibility and coordination. Platformizing early warning systems (EWS) delivers timely alerts. Religious and social institutions contribute to DRR through awareness campaigns and training (Sutton *et al.,* 2024).

Emergency preparedness using stakeholder cooperation, gender and social inclusion, effective communication, and community participation are crucial for DRR management. Transforming high-level policies into detailed procedures enhances preparedness and community resilience (Perera *et al.,* 2020). Investment in DRR is crucial for disaster resilience, funding infrastructure improvements, EWS, and community-based projects. Capacity building, educational curricula, and community engagement enhance DRR effectiveness (Cvetkovi´c *et al.,* 2021). Sutton *et al.,* (2024) suggest that religious and social institutions can enhance DRR initiatives. Assessing emergency response capabilities involves enhancing disaster prevention and mitigation capacity, involving human resources, science, technology, organization, and promoting effective management of facilities (Damaševi˘cius *et al.,* 2023).

Disaster zones, damage assessment, and rehabilitation are crucial for disaster recovery. Germany's floods highlighted the need for cooperation, while risk assessment helps compare preventive measures and recovery costs. Assessing disaster damage aids in rebuilding plans and enhancing resilience through risk reduction, building standards, and infrastructure strengthening, requiring stakeholder collaboration for effective emergency response strategies (Cvetkovi´c *et al.,* 2021). Community engagement in emergency planning, investment in training, public education, and DRR incorporation in school curricula enhance preparedness, while effective communication is crucial for efficient response (Damaševi˘cius *et al.,* 2023).

2.2. Current state of emergency response infrastructure

Early warning systems are effective globally but may not always lead to emergency responses, causing casualties and property loss. Emergency operations centres provide situational awareness, but their reach is limited (Perera *et al.,* 2020). US authorities prioritise technology over training for effective communication,

highlighting a communication gap with at-risk individuals. Disaster response involves authorities, agencies, and the public mobilising resources, such as transportation administration, immigration, and customs enforcement, for airport security measures (Gilmore & DuRant, 2021). Similar technology and strategies can be adopted to enhance infrastructure resilience to combat disaster in facilities. Information on potential event impacts is crucial for adaptive governance, but gaps exist in urban planning, particularly in master plans and social housing plans, exacerbated by resource scarcity (Travassos *et al.,* 2021). Municipalities play a crucial in adaptation planning. Emergency broadcasts raise awareness and guide evacuations. DRM planning involves government, private sector, and civil society, focusing on risk identification, reduction, preparedness, and financial protection (Bello *et al.,* 2021).

Integrating DRM policy tools with a country's framework aids resource allocation, but issues in the Flood Early Warning System (FEWS), including community participation, are crucial (Perera *et al.,* 2020). Social media platforms aid in crisis management, providing timely information to disaster victims for quick decision-making and lifesaving (Dwarakanath *et al.,* 2021). Cities integrate ERS into urban development strategies to enhance policy coherence. The World Meteorological Organization (WMO) started a forecasting program based on the impact on many to enhance user-friendly services for science, technology development, and natural hazards management (Merz *et al.,* 2020). Facilities management must adopt new technologies for hazard management and early warning programs to improve infrastructural resilience. Agencies prioritise environmental management and hazard forecasting, while smart city business models in developing countries prioritise economic capacity, technology readiness, and citizen participation (Myeong *et al.,* 2020). Not as much has been placed on the FEWS's three non-technical elements. Cooperation between interested parties, including local government, disaster management committees, and civil society organisations, is crucial for FEWS but is often hindered by barriers (Perera *et al.,* 2020).

2.3. Impact of emergency response infrastructure

2.3.1. Economic effects

From 2001 to 2018, more than half of water-related disasters were floods, which resulted in 94,000 fatalities and USD 504 billion in worldwide funds shortfalls (Perera *et al.,* 2020). Combining EWS with impact forecasts provides informed emergency measures and focuses on common targets (Merz *et al.,* 2020). Economic factors influence disaster likelihood and their effects on the economy. The smart city concept enhances sustainable development and improves local living standards (Myeong *et al.,* 2020). Between 2001 and 2018, 2,309 disaster cases resulted in 510,204 deaths, 297 million affected persons, and $437 billion in damage (Bello *et al.,* 2021). Insecure housing increases disaster impacts, including death, injury, and homelessness, while inadequate residential infrastructure can prolong or worsen health effects. From 2010 to 2019, global natural disasters caused an average annual economic loss of over USD 187 billion and displacement of an average of 24 million people annually. Disasters cause direct and indirect losses to communities, including physical destruction, environmental degradation, and human injuries. Developed nations have reduced losses, but developing nations like Ghana still face significant challenges (Mensah-Bonsu, 2022).

2.3.2. Socio-political effects

The socioeconomic impact is estimated using local thresholds influenced by hazard frequency, population density, and season (Merz *et al.,* 2020). The 2010 super floods in Pakistan severely damaged homes, infrastructure, medical facilities, and schools (Deen, 2015). Research on social and political institutions during emergencies is limited, with fragmentation influenced by socio-political landscape factors, and stronger political and administrative infrastructures are needed. Disasters can reintroduce vulnerable groups, highlighting the need for sustainable and resilient development policies to mitigate the consequences (Bello *et al.,* 2021). Impact forecasts assess how physical and socioeconomic factors affect critical infrastructure, buildings, fatalities, displaced individuals, monetary shortfalls, and supply chain disruptions. (Merz *et al.,* 2020). Pakistan's 2010 floods severely impacted 18 million people, causing widespread destruction and poverty. Government and international efforts provided short-term relief and interventions to restore livelihoods (Deen, 2015). Disaster risk events consistently impact sustainability, threatening community social and economic livelihoods due to the persistent threat of natural hazards (Tanesab, 2020). Migration from rural to urban areas reflects social and economic inequality, causing government pressure to build new facilities (Mensah-Bonsu, 2022).

2.4. Theories underpinning the study

To create resilient, flexible infrastructure emergency response systems, it is essential to apply systems and resilience concept that emphasize interconnectedness, feedback loops, and overall system behavior (Bonaretti and Piccoli 2018; Chen *et al.,* 2017). AI, Internet of Things, and GIS systems are integrated by system theory and resilience theory for real-time monitoring, emergency alert creation, and drone use for aerial surveillance and disaster assessment (Son *et al.,* 2020).

3. Research Methodology

This literature review evaluates the impact of ERS on infrastructure resilience by synthesising existing research knowledge, identifying best practices, and pinpointing knowledge gaps to guide future policy and practice. A comprehensive literature search was carried out across multiple academic databases, including Scopus, and Google Scholar, to gather relevant peer-reviewed articles, conference papers, and reports published between 2015 and 2025. The focus centred on studies related to ERS, infrastructure resilience, disaster management, and crisis response. The initial search yielded 150 articles, which were subsequently screened for relevance based on their titles, abstracts, and alignment with the study's focus on ERS and infrastructure resilience. Following this screening, 30 articles were chosen for detailed analysis using a qualitative thematic approach. The analysis sought to identify recurring themes and patterns regarding ERS and its effect on infrastructure resilience. The articles were filtered using specific keyword combinations such as "emergency response infrastructure," "challenges," "impact," "developing countries," "barriers," "limitations," and "constraints." Only studies examining ERS issues across various disaster scenarios were included, while those concentrating solely on developed countries or unrelated infrastructure issues were excluded. From the selected 30 articles, key data was extracted, including descriptions of the challenges, their causes, and their effects on emergency response. These findings were organised into thematic areas, encompassing socioeconomic inequality, infrastructure deficiencies, governance issues, resource shortages, and technological limitations.

4. Findings and Discussion

The literature review highlights early warning, technology, response efficiency, resources, strategic framework, community engagement, preparedness, and institutional communication in assessing ERS's resilience for facilities. The impact of ERS on the resilience of infrastructure is illustrated in Figure 1. Ineffective EWS can delay disaster response due to poor communication, coverage, and technological constraints. Enhancing data integration and interagency communication can improve response effectiveness (Perera *et al.,* 2020; Kalogiannidis *et al.,* 2022). Modern technology, like geographic information systems, drones, and mobile applications, can enhance ERS by improving operational efficiency, reducing response times, and strengthening infrastructure resilience (Bello *et al.,* 2021; Merz *et al.,* 2020). Insufficient emergency response infrastructure, communication, and transportation networks hinder resource mobilisation and recovery efforts. Clear protocols, interagency collaboration, and training enhance readiness and resilience (Kalogiannidis *et al.,* 2022). The UN Office for DRR report highlights emergency response financial and human resource limitations, including outdated systems and inadequate funding, necessitating focused investments and collaborations (Bello *et al.,* 2021; Perera *et al.,* 2020).

The gap between disaster risk policies and their implementation is a major challenge, causing dispersed regional efforts and missed opportunities for resilience and recovery (Travassos *et al.,* 2021). Community involvement in emergency planning is crucial for resilience, but top-down approaches often lack ownership and understanding. Inclusiveness and gender perspectives can lead to more equitable outcomes (Perera *et al.,* 2020). Training and capacity-building programs are crucial for DRM, enhancing the preparedness and resilience of infrastructure (Binkley & Kemp 2022). Inadequate interagency communication hinders efforts and delays in information dissemination, affecting emergency management. Effective communication ensures stakeholders' collaboration during emergencies (Bello *et al.,* 2021; Perera *et al.,* 2020).

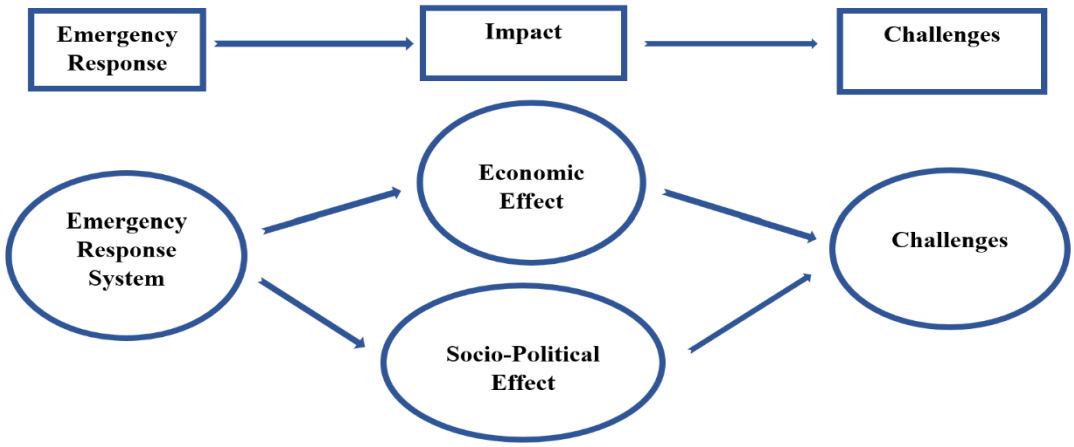


Figure 1: Conceptualised Emergency Response System. Author's construct (2025)

4.1. The economic impact of emergencies

The occurrences of natural and manmade hazards have been a global issue. Very little work has been reported on the economic impact of emergencies, which can lead to emergency response infrastructural challenges, as shown in Figure 1. Emergencies cause major disruptions to economic activity, resulting in large losses for the world economy (Perera *et al.,* 2020). Both developed and developing economies are significantly impacted financially by disasters (Bello *et al.,* 2021; Deen, 2015). Research shows short-term asset damage and long-term economic downturns due to lower investment and productivity, with natural disasters costing developing countries up to 10% of GDP annually (Tanesab, 2020; Mensah-Bonsu, 2022). Emergencies significantly impact human life and property, with loss of life being the most tragic outcome (Bello *et al.,* 2021). Disasters can kill thousands of people, especially in places with a high population density and poor infrastructure (Deen, 2015; Tanesab 2020). According to a UN report, property loss from disasters often leads to increased poverty and unstable economies, particularly in low-income areas (Mensah-Bonsu, 2022).

Most residential and healthcare facilities lack resilience to crises, leading to disastrous failures (Deen, 2015; Tanesab, 2020). Studies show that inadequate residential and medical infrastructure increases risks for residents and vulnerable groups, leading to physical damage and increased mortality rates during emergencies (Bello *et al.,* 2021). The COVID-19 pandemic's inadequate healthcare infrastructure led to overburdened systems due to lack of adequate infrastructure. Emergencies often lead to displacement, causing people to leave their homes and resulting in temporary or permanent homelessness (Deen, 2015; Tanesab, 2020). Cities face severe vulnerability due to housing shortages and population density, leading to social dislocation (Merz *et al.,* 2020). There is a need for improved ERS that considers housing and assistance for communities caused by disasters.

4.2. Socio-political impact of emergencies

The trend in emergency response and its socio-political impact needs to be addressed in ERS, as shown in Figure 1. Emergencies exacerbate existing urban and demographic issues, particularly in areas with high population densities (Merz *et al.,* 2020; Deen, 2015). Rapid urbanisation in informal settlements increases vulnerability to disasters due to a lack of infrastructure, necessitating creative solutions for ERS (Tanesab, 2020; Mensah-Bonsu, 2022). Communities' ability to withstand emergencies is greatly impacted by social amenities (Deen, 2015; Merz *et al.,* 2020). Communities lacking sufficient access to social services, healthcare, and education are more vulnerable to the impacts of natural disasters (Bello *et al.,* 2021; Tanesab, 2020). Insufficient social infrastructure can hinder emergency solutions (Mensah-Bonsu, 2022).

Emergencies frequently worsen societies' preexisting vulnerabilities and disparities (Merz *et al.,* 2020; Bello *et al.,* 2021). The literature highlights the disproportionate impact of disasters on marginalised groups, such as women, and the impoverished, who often lack the necessary tools and assistance (Deen, 2015; Tanesab, 2020). Children and women are especially at risk, with increased chances of exploitation and violence following disasters. Communities' economic stability is greatly impacted by emergencies (Merz *et al.,* 2020). Disasters often lead to low productivity, lower wages, and higher unemployment rates, making a recovery from economic instability challenging for communities (Bello *et al.,* 2021; Deen, 2015). Emergency-induced economic downturns often cause sluggish recovery, leading to ongoing social and economic issues, particularly in areas with weak economic infrastructure (Tanesab, 2020).

5. Conclusion and Further Research

ERS face challenges like ineffective early warning systems, outdated technology, funding, and poor community involvement, necessitating urgent reforms and unified national strategies for better response. Building emergency resilience requires community involvement, resource investment, and stakeholder training. Strengthening response systems, implementing reforms, and encouraging stakeholder cooperation can enhance disaster resilience. Emergencies significantly impact infrastructure resilience, causing economic losses, property damage, and displacement. Sociopolitical difficulties arise, particularly in urban areas, exacerbated by demographic pressures. To effectively prepare for future emergencies, a diversified strategy focusing on robust infrastructure, efficient early warning systems, and community involvement is crucial to fostering resilience and societal recovery.

This study contributes to the existing body of knowledge on ERS and raises awareness among emergency response stakeholders, facility users, and managers of their impact on infrastructure resilience. Future research should focus on understanding ERS and infrastructure resilience, integrating technology, focusing on community-centric approaches, conducting long-term studies, and evaluating policies for best practices and infrastructure impact assessment.

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A Literature Review of Construction Labour Productivity: A 30-Year Global Perspective

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Abstract

Construction labour productivity (CLP) is a critical determinant of project success, influencing cost, time, and overall efficiency in the construction industry. Despite extensive research, significant productivity variations persist due to diverse influencing factors. This scientometric review analyses the evolution of CLP research using bibliometric techniques to identify key trends, influential authors, prominent publications, and emerging themes. By utilising the Scopus and Web of Science databases, the study maps the intellectual structure of CLP research, employing VOSviewer and Biblioshiny for co-occurrence analysis, citation mapping, and network visualisation. The findings highlight an increasing focus on automation, digitalisation, and sustainable practices as key drivers of productivity enhancement. Additionally, the study identifies research gaps, including the need for interdisciplinary approaches, integration of advanced data analytics, and region-specific labour productivity assessments. The insights will aid researchers, policymakers, and industry professionals in developing strategies to enhance workforce efficiency and address productivity constraints. By synthesising current knowledge, this study provides a roadmap for future research and underscores the value of scientometric tools in advancing CLP.

Keywords: Bibliometric review, Construction labour productivity, Digitalization, Lean construction, Scientometric analysis

1. Introduction

Construction labour productivity (CLP) has been a global concern for three decades. This review explores bibliometric and scientometric analyses of CLP, highlighting trends, methods, findings, and gaps. Many studies use Scopus and Web of Science to analyse CLP data (Muhammad et al., 2015; Hamza et al., 2019; Umeokafor et al., 2022). Hamza et al. (2019) reviewed 88 papers, identifying regional CLP differences; Muhammad et al. (2015) analysed 644 documents on project complexity; and Umeokafor et al. (2022) noted research-output misalignment with regional needs. Scientometric tools also map knowledge domains (Nwaogu et al., 2019; Oladinrin et al., 2022), including ethics-innovation links (Oladinrin et al., 2022) and mental health (Nwaogu et al., 2018). Neve et al. (2020) linked direct work to CLP in North America, and Jarkas and Abdulaziz (2010) assessed buildability effects. While insightful, most studies are topic-specific, underscoring the need for broader, integrated research.

2. Literature Review

Systematic literature reviews (SLRs) synthesise existing research and identify gaps through structured database searches and critical study assessments (Muhammad et al., 2015; Naoum, 2016; Hamza et al., 2019; Ghaleb et al., 2022). Their reliability depends on the search strategy and selection criteria.

2.1. A synthesis of factors affecting CLP

The literature reveals a wide range of factors influencing CLP. These factors can be broadly categorized into several groups:

2.1.1. Project-level factors

Design and planning: poor design, inadequate planning, and design changes during construction significantly impact productivity (Ameh & Osegbo, 2011; Naoum, 2016; Mamlook et al., 2020). Naoum (2016) identified design errors, buildability issues, and poor project planning as critical factors. Similarly, Ameh and Osegbo (2011) highlighted inaccurate drawings and specifications as major contributors to time overruns. Mamlook et al. (2020) further emphasised errors in design drawings as key productivity constraints in Libya. The quality of design and planning directly influences construction efficiency.

Material management

Material shortages, supply delays, and poor planning negatively affect CLP (Enshassi et al., 2007; Naoum, 2016; Alaghbari et al., 2019). Enshassi et al. (2007) identified material shortages as a major challenge in Gaza Strip construction projects. Naoum (2016) ranked material mismanagement among the most significant productivity barriers. In Yemen, Alaghbari et al. (2019) identified material availability on-site as a top factor affecting CLP. Efficient material management is essential for minimising delays and ensuring a smooth workflow.

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Technology and equipment
The availability and utilisation of appropriate technology and equipment are crucial for improving CLP (Naoum, 2016; Jin et al., 2019; Chea et al., 2020). Jin et al. (2019) highlighted the role of BIM and other digital technologies in enhancing productivity and collaboration. Naoum (2016) stressed the need for greater investment in construction technology and innovation. Chea et al. (2020) noted the increasing adoption of automation and robotics, which enhance efficiency, accuracy, and safety.

Workforce
The skill level, experience, motivation, and health of the workforce are critical determinants of productivity (Barg et al., 2014; Muhammad et al., 2015; Naoum, 2016; Alaghbari et al., 2019; Gurmu, 2020). Muhammad et al. (2015) emphasised the importance of skilled labour for effective project management. Naoum (2016) found that project managers' experience and design errors significantly affect productivity. Alaghbari et al. (2019) ranked workers' experience and skills as the most influential factor in Yemen. Barg et al. (2014) and Gurmu (2020) highlighted worker motivation and human resource management as essential for enhancing CLP.

2.1.2. Management-level factors Supervision and leadership
Effective supervision, clear communication, and strong leadership are essential for maintaining high productivity (Enshassi et al., 2007; Naoum, 2016; Alaghbari et al., 2019; Nasirzadeh et al., 2020). Enshassi et al. (2007) identified misunderstandings between superintendents and workers as a negative factor. Naoum (2016) highlighted communication issues as a critical influence. In Yemen, Alaghbari et al. (2019) ranked leadership and site management efficiency as key productivity factors. Nasirzadeh et al. (2020) found inadequate supervision to be a major issue in Australia. Effective management practices are crucial for coordinating activities, resolving conflicts, and motivating workers.

Organisational factors
Organisational structure, communication channels, and procurement methods influence CLP (Naoum, 2016; Chen et al., 2022; Oladinrin et al., 2022). Naoum (2016) found procurement methods and communication styles to be significant productivity determinants. Oladinrin et al. (2022) highlighted the limited intellectual exchange and lack of cohesion between ethics and innovation research as an industry challenge. Chen et al. (2022) explored the integration of BIM, Construction 4.0, and Industry 4.0 in smart cities, demonstrating the impact of organisational context and technological integration on sustainable development.

Incentives and motivation
Financial and non-monetary incentives can significantly enhance worker motivation and productivity (Barg et al., 2014; Hiyassat et al., 2016). Hiyassat et al. (2016) found that financial incentives increased productivity in Jordan. Barg et al. (2014) emphasised the role of both intrinsic and extrinsic motivation in improving worker performance. A well-structured incentive system encourages workers to perform at their best.

2.1.3. External factors
Economic conditions: Inflation, interest rates, and credit availability influence construction investment and productivity (Jalal & Shoar, 2019; Kazemi et al., 2020). Jalal and Shoar (2019) identified inflation as a factor affecting labour productivity through increased execution costs. Kazemi et al. (2020) highlighted financial problems and payment delays as major causes of project delays in Iranian oil construction. Economic instability can lead to reduced investment and project disruptions.

Political and regulatory factors
Political instability, regulatory changes, and bureaucratic delays significantly impact construction projects and CLP (Alaghbari et al., 2019; Kazemi et al., 2020). Alaghbari et al. (2019) identified political and security issues as key factors affecting CLP in Yemen. Kazemi et al. (2020) pointed to sanctions and government management systems as major sources of delay in Iran. A stable political and regulatory environment is essential for efficient project execution.

Environmental factors
Weather conditions, site accessibility, and environmental regulations affect construction activities and CLP (Muhammad et al., 2015; Khaleel et al., 2018). Emerging trends and future directions in CLP research (Table 1) were identified through synthesis of recent studies (Jin et al., 2019; Chea et al., 2020; Marvila et al., 2022; Nazir et al., 2020; Guaygua et al., 2023).

Table 1: Emerging Trends and Future Directions in CLP Research

S/No	Trend	Key research areas
1	Industry 4.0 and digital technologies	BIM, IoT, AI integration
2	Sustainability and circular economy	Waste materials, energy efficiency
3	Prefabrication and modular Construction	Supply chain optimization, automation
4	Human factors and workforce development	Motivation, mental health, training
5	Risk management & safety	Proactive risk assessment, robotics

Muhammad et al. (2015) cited weather as a factor impacting labour productivity. Khaleel et al. (2018) ranked climate conditions as a major negative factor in Iraq. Adverse weather can delay construction and reduce productivity.

2.2. Geographic variations in CLP research

While CLP research follows a global trend, geographic variations exist in focus and findings. Studies from developed countries often explore advanced technologies and management practices, whereas those from developing countries emphasise challenges related to infrastructure, resources, and workforce limitations. For instance, Neve et al. (2020) examined North America, Enshassi et al. (2007) investigated the Gaza Strip, Alaghbari et al. (2019) focused on Yemen, and Khaleel et al. (2018) studied Iraq. These variations highlight the diverse challenges across regions and the need for context-specific research. Research output also varies by region, with studies from Asia and Europe benefiting from greater funding and higher publication rates (Olawumi et al., 2017). Recent literature from underrepresented regions has helped bridge the global perspective gap in CLP research. In **Canada**, Zhai et al. (2009) used survival analysis to model productivity in pipe installation, enhancing data-driven productivity assessment. From the **USA**, Thomas and Napolitan (1995) quantified the negative impact of design changes on construction labor performance. A study in **Germany** by Koch and Buser (2006) linked training systems and regulatory frameworks to productivity performance. In **Brazil,** Formoso et al. (1999) assessed performance measurement using lean construction tools across Latin America. Meanwhile, **South African** insights by Smallwood (2000) emphasized managerial influence and client perspectives on site productivity. These contributions underscore the importance of contextual factors and the growing breadth of CLP research across global regions.

3. Methodology

This study conducts a bibliometric analysis of CLP research from 1994 to 2024, using Scopus and Web of Science to examine publication trends, key authors, journals, and keywords. VOSviewer was employed to generate co-authorship, co-citation, and keyword co-occurrence networks, revealing research clusters and thematic linkages. The analysis highlights influential contributions, evolving themes, and research gaps. Despite limitations such as database bias and interdisciplinary coverage, this approach provides valuable insights into the intellectual structure and development of CLP research.

3.1. Emerging trends in CLP research

Industry 4.0 and digital technologies

The adoption of Industry 4.0 principles and digital technologies, such as Building Information Modelling, the Internet of Things, and artificial intelligence, is transforming the construction industry and enhancing CLP (Jin et al., 2019; Zabidin et al., 2020; Khan et al., 2021; Sepasgozar & Samad, 2021; Xiao et al., 2022; Omrany et al., 2023). Zabidin et al. (2020) examined the industry's shift towards digitisation and smart products. Jin et al. (2019) explored BIM applications in construction engineering and management, while Khan et al. (2021) studied its integration with immersive technologies. Xiao et al. (2022) investigated advances in robotics, and Sepasgozar and Samad (2021) along with Omrany et al. (2023) analysed the role of digital twins in construction. Further research is needed to fully assess these technologies' potential to improve CLP.

3.1.1 Sustainability and Circular Economy

Increasing concerns about environmental sustainability are driving research into sustainable construction practices that enhance CLP (Sandanayake et al., 2020; Norouzi et al., 2021; Marvila et al., 2022). Sandanayake et al. (2020) examine trends in using waste materials in concrete, while Norouzi et al. (2021) analyse the evolution of circular economy applications in construction. Marvila et al. (2022) examine the use of recycled aggregate for sustainable concrete production. Further research is needed to explore innovative approaches that minimise environmental impact while improving productivity.

Table 2 summarises publication details from 1994–2024, compiled from bibliometric analysis of Scopus and Web of Science records.

Table 2: Publication details (1994-2024)

Year range	Number of publications	Key research focus
1994-1999	50	Early studies, basic CLP models
2000-2005	120	Factor identification, survey-based studies
2006-2010	210	Quantitative modeling, case studies
2011-2015	350	Technological impacts, policy influence
2016-2020	540	Advanced methodologies, BIM, AI integration
2021-2024	670	Scientometric analysis, digital transformation

In addition to publication trends, Table 3 presents a categorisation of factors affecting construction labour productivity and their relative impact levels. These factors, derived from an extensive literature review, are grouped into project-level, management-level, and external domains (Naoum, 2016; Alaghbari et al., 2019; Enshassi et al., 2007; Muhammad et al., 2015; Gurmu, 2020).

3.2. Keyword co-occurrence network

To identify the most frequently used keywords in CLP research, we present the keyword co-occurrence network (Figure 1). This graph visually maps the connections between key terms, highlighting predominant themes in CLP studies.

Table 3: Factors category Vs Impact on productivity

S/No	Factor category	Factor	Impact on productivity
1	Project-Level Factors	Design & Planning	High
2	Project-Level Factors	Material Management	High
3	Project-Level Factors	Technology & Equipment	Medium
4	Project-Level Factors	Workforce	High
5	Management-Level Factors	Supervision & Leadership	High
6	Management-Level Factors	Organizational Factors	Medium
7	Management-Level Factors	Incentives & Motivation	High
8	External Factors	Economic Conditions	Medium
9	External Factors	Political & Regulatory Factors	Medium
10	External Factors	Environmental Factors	Medium

3.1.2 Prefabrication and Modular Construction

The increasing adoption of prefabrication and modular construction methods is providing new opportunities to enhance CLP (Chea et al., 2020; Nazir et al., 2020; Yang et al., 2020; Liu et al., 2021; Guaygua et al., 2023). Liu et al. (2021) review global research on prefabricated buildings, while Nazir et al. (2020) compare modular and traditional UK housing construction. Guaygua et al. (2023) examine seismic-resistant precast concrete buildings, and Yang et al. (2020) propose a conceptual framework for supply chain management in prefabricated construction. Chea et al. (2020) explore automation and robotic technologies for structural prefabrication. Further research is required to optimise these methods and address challenges in design, manufacturing, and assembly.

3.2.1 Human factors and workforce development

An increasing focus on human factors and workforce development highlights the role of skills, training, motivation, and well-being in enhancing CLP (Dai et al., 2007; Chan & Kaka, 2007; Barg et al., 2014; Nwaogu et al., 2019; Gurmu, 2020). Barg et al. (2014) examine construction worker motivation, while Gurmu (2020) applies fuzzy synthetic evaluation to analyse human resource management practices influencing CLP. Dai et al. (2007) assess craft workers' and foremen's perceptions of CLP factors, and Chan and Kaka (2007) compare the views of managers and workers. Nwaogu et al. (2019) examine global research on mental health in construction. Further research is needed to develop effective training programmes, improve working conditions, and promote worker well-being.

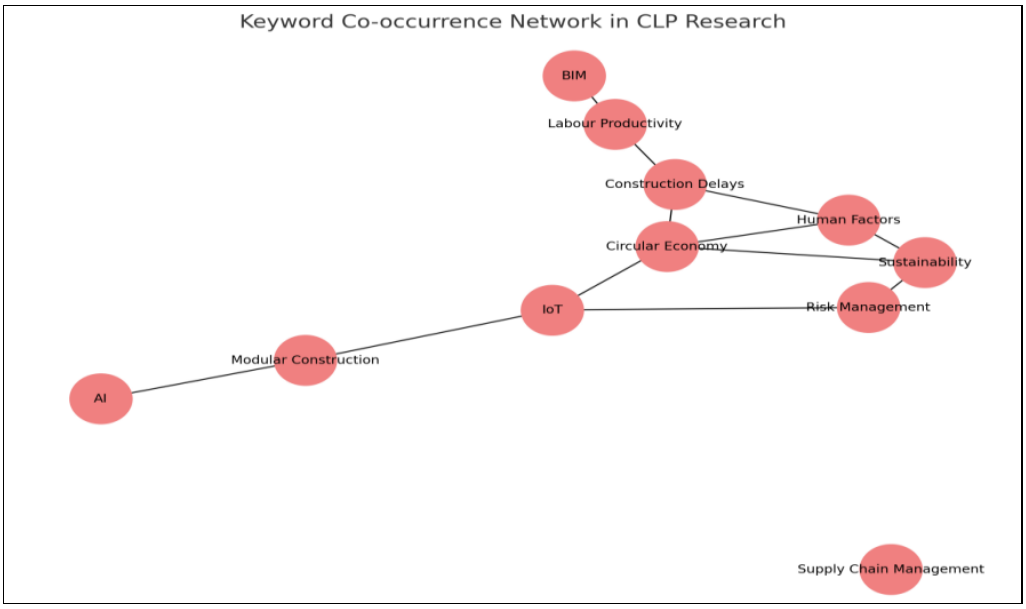


Figure 1: Keyword co-occurrence network in CLP research

3.2.2 Risk management and safety

Given construction's inherent risks, recent studies have focused on integrating risk management and safety practices to enhance CLP (Ganbat et al., 2018; Ibrahim et al., 2022; Akinlolu et al., 2020; Onososen et al., 2022). Ganbat et al. (2018) review BIM-based risk management, Ibrahim et al. (2022) address design-for-safety, Akinlolu et al. (2020) explore safety technologies, and Onososen et al. (2022) assess robotics and human-robot teams. Further research is needed to develop proactive strategies and strengthen safety protocols for improved productivity.

3.2.3 Co-citation network

The co-citation network illustrates the connections between frequently cited research papers (Figure 2), helping to identify key research clusters and influential studies that have shaped the field of CLP over time. Another important gap in the literature is the lack of regional comparative studies. While many studies examine individual countries or regions, few compare CLP research findings across different areas.

4. Results - Research trends in CLP

To illustrate the growth of research in CLP, we present the **research trends in CLP graph (Figure 3),** which visualizes the publication trends over the last three decades. This figure highlights the increasing volume of studies focused on CLP and the key areas of interest that have evolved over time.

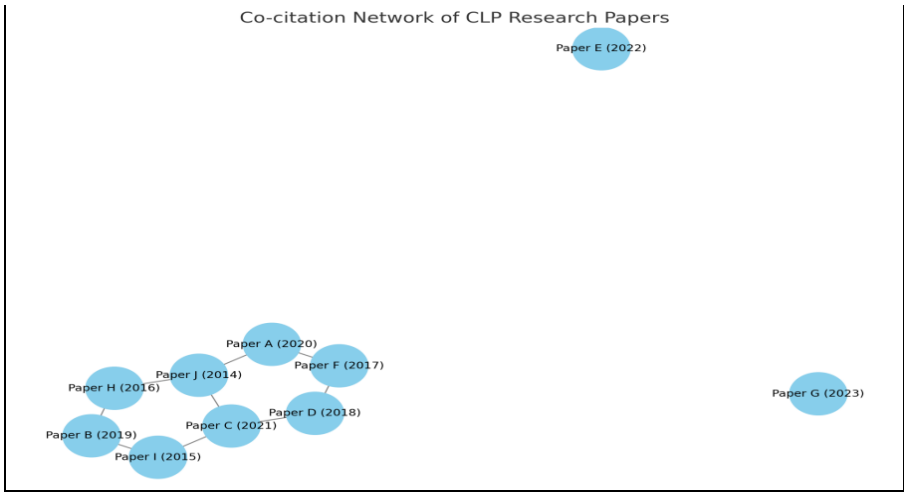


Figure 2: Co-citation network of CLP research papers

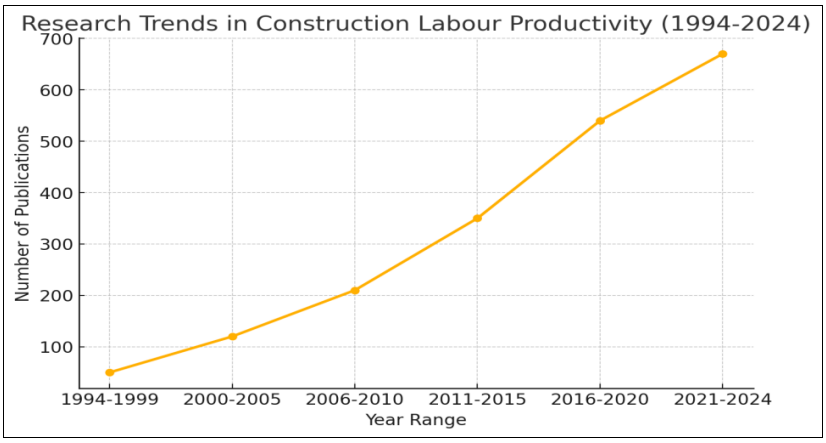


Figure 3: Research trends in CLP (1994-2024)

5. Conclusion

This review offers a comprehensive 30-year analysis of CLP research through bibliometric and scientometric methods, identifying key trends, influential scholars, and research gaps. It categorises CLP factors into project-level, management-level, and external domains, and explores methodologies and geographic variations. Emerging trends include Industry 4.0, sustainability, prefabrication, workforce development, and safety. Advancing CLP requires technological innovation and better management. Future research should address challenges in developing countries, propose context-specific strategies, and integrate qualitative and quantitative methods to improve predictive models and deepen understanding of CLP dynamics.

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Assessment of the Perceived Impact of Flooding and Climate Change on Construction Projects in Nigeria

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Abstract

Since the Paris Agreement (PA) in 2015, there has been an increasing focus on assessing the impact of flooding and climate change. The study assessed the impact of flooding and climate change on construction projects in Nigeria. Data were collected through questionnaire and semi-structured interview to address the research objectives. Primary data were collected by applying tools for eliciting local knowledge and perceptions, such as interviews and questionnaire administration. Nigerian town planners, architects, quantity surveyors, engineers, construction managers, contractors, and project managers were sampled and administered copies of the questionnaire. The findings revealed there is a high level of impact (76.8%) of flooding on the construction industry in Nigeria. The many (55.1%) of the respondents agreed that they experienced financial implications due to inadequate implementation of risk-mitigating methods for unforeseen flood and weather events. The identified key causing some of structure/ building collapse are attributed to issue of flood events and climate change such as heavy rainfall and overflow of rivers in accordance of 64.4% of the respondents. The study concluded that flood events are not the primary cause of structural or building collapses in the industry and also identifies key causes of flooding in Nigeria, including the release of water from the Ladgo Dam in Cameroon and the overflow of the Rivers Niger, Benue, and Meme due to heavy rainfall. To navigate these challenges, a proactive and well-informed construction key stakeholders and manager should consider active integration of flood risk mitigation strategy from the tender phase to operation stage thereby; ensuring adequate information is available to justify project decisions.

Keywords: Construction project, Climate change, Flood, Management, Mitigation

1. Introduction

In recent times, academic and political discussions have increasingly focused on the issues of flooding and climate change effects, recognizing their significant impact on construction projects. As a result, the effects of flooding and climate change on construction have become an international concern. Construction professionals working for clients, contractors, and consultants agreed that flood and climate change incidents affect construction projects (Okosun *et al.,* 2021). According to Aje *et al.* (2014), a project may be delayed (cost and time overrun) in part or whole due to inclement weather. As the variations in weather patterns become too extreme, their impact becomes puffed up, and construction projects become unprofitable (Hegeman, 2019). This emphasizes that construction industry managers are responsible for mitigating these impacts by accurately applying their expertise and skills.

The 2022 flood in Pakistan affected about 72 million people. It caused about 149 billion US dollars in damages, while in Nigeria, the 2022 flood affected 34 of the 36 states, displaced over 1.4 million people, and killed 612 people. Over 200,000 homes and 110,000 hectares of farmland were entirely or partially destroyed. Buba *et al.* (2021) also reported that extreme flood events had increased the number of collapsed structures/buildings in Nigeria. Efforts must be harnessed to mitigate this extreme weather event, which occurs more frequently due to climate change. Construction managers should know how they could mitigate climate change's impact on the construction industry and continuously develop and cultivate profitable businesses while meeting client needs. Floods can be caused by anthropogenic activities, which are human intervention in the natural processes which may include an increase in settlement areas; population growth in low-lying plains prone to flooding leading to alterations in the natural drainage and river basin system; deforestation and urbanization (Nharo, 2016).

Science communicators favor the term flooding and climate change over global warming due to the growing concern in the construction industry based on its impacts, such as storm damage, power outages, and loss of biodiversity that come to play. According to Okosun *et al.* (2021) a two percent (2%) increase in the construction work stoppage due to unexpected inclement weather has a major impact on the bottom line. The impacts of climate change events on

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construction projects' atmosphere have increased exponentially in the past 28 years. Attempts by man to harness available water resources have resulted in the construction of dams and other water control structures. The failures of these structures have resulted in flood risk in Nigeria. Similarly, Oluwajana *et al.* (2022) observed that flood and climate change impact the cost and time performance of construction projects in Nigeria.

Rising temperatures, flooding, and environmental pollution have become serious concerns to men when they exceed their coping capacities, damaging lives and property (Abhas *et al.,* 2012). As reported in NIMET (2015), economic losses due to flooding and climate change in states have increased in folds and have also resulted in major loss of human lives and livelihoods, destruction of economic and social infrastructure, and environmental damages (John-Nwagwu *et al.,* 2021). This further justifies the need for a policy framework to explore the impact of flooding and climate change on construction projects in Nigeria. Thus, research gaps exist; that informed participatory approach.

The following research objectives are set out to be achieved by this study: i) to determine the most rational approach to mitigate the risks experienced by flooding and climate change, ii) to determine the financial (cost) implications on construction projects experienced due to flooding and climate change, iii) to determine the major concerns raised by flood events and climate change in Nigeria, iv) to determine the extent to which contractors have implemented methods to adapt to the effects of flooding and climate change, v) to determine how does flooding and climate change impact the construction project lifecycle and vi) to determine the different methods to safeguard a contractor against the impacts of flooding and climate change.

2. Literature review

Construction projects in Nigeria are significantly challenged by flooding and climate change, which have an impact on schedules, expenses, and structural integrity. Nigeria's geographical susceptibility, along with bad urban design and insufficient drainage systems, aggravates the effect of floods on building operations (Unegbu *et al.,* 2024). Particularly in coastal and low-lying areas like Lagos, Port Harcourt, and Kano, climate change has changed rainfall patterns, causing more regular and severe floods (Chang and Ross, 2024). Increasingly, construction companies and stakeholders see these environmental hazards as significant barriers to the completion of projects, thereby requiring adaptive plans to minimise disturbances. Research shows that floods caused by climate change postpone projects, raise maintenance expenses, and shorten the life of infrastructure (Olanrewaju *et al.,* 2020). Drawing on empirical research and industry sources, this literature review investigates the perceived effects of floods and climate change on Nigeria's building business. Flood causes work stoppages, material damage, and restricted access to project locations, hence upsetting construction timelines. Nkwunonwo *et al.* (2020) estimate that more than 60% of Lagos construction companies experienced project delays caused by seasonal floods, with some projects suffering delays of up to three months. Flood-induced erosion and waterlogging can compromise foundations, hence requiring expensive corrective actions.

2.1. To determine the most rational approach to mitigate the risks experienced by flooding and climate change

Flooding and climate change pose significant challenges to the construction industry, particularly in regions like Nigeria where inadequate infrastructure, such as drainage systems, exacerbates the situation (Unegbu *et al.,* 2024). Among the many ideas put out to reduce these hazards are contracts, technology, insurance, and research-based planning. Ajayi *et al*. (2024) claim that only a tiny percentage of Nigerian building firms integrate flood risk evaluations in their project design, suggesting that the construction sector's method of reducing climate change risks is reactive rather than proactive. Though their use in the Nigerian setting is yet underexplored, contracts are becoming more acknowledged as a way to control these risks (Alabi, 2016). A more integrated strategy that incorporates modern technologies like Geographic Information System (GIS) would thus be the most logical way to reduce the hazards connected to climate change and floods.

2.2. To determine the financial (cost) implications on construction projects experienced due to flooding and climate change

Flooding and climate change have a major financial effect on building projects as these natural phenomena often cause delays, higher project costs, and material damage (Olanrewaju *et al.,* 2020). Construction expenses in flood-prone locations may surpass first estimates by as much as 20-30% (Nicholas *et al.,* 2022), with projects experiencing longer timeframes caused by work halts, material damage, and site access concerns (Adelekan & Asiyanbi, 2016). In Nigerian construction, where the effects of floods go beyond direct damage to buildings and include loss of production, higher maintenance expenses, and the need for expensive redesigns, this has been a major problem (Ibem *et al.,* 2021). Rising temperatures, floods and other climate-related events also may greatly shorten the life of infrastructure, which would increase long-term maintenance and operating expenses (Okoye *et al.,* 2021). Given these financial consequences, building firms have to include thorough financial planning to include climate-related hazards and get suitable insurance to offset such losses.

2.3. To determine the major concerns raised by flood events and climate change in Nigeria

Heavy rain and river overflow are the main causes of structure damage, so flood occurrences and climate change have generated many worries in the Nigerian building sector (Oluwajana *et al.,* 2022). Particularly in low-lying places like Lagos and Port Harcourt, where flood-induced erosion and soil instability endanger the integrity of buildings, the rising frequency of severe weather events has put great pressure on construction methods (Ezeokoli *et al.,* 2019). Many city areas' poor drainage systems aggravate these hazards and increase the susceptibility of building sites to weather-related disturbances (Nkwunonwo *et al.,* 2020; Adeleke et al., 2018). Moreover, the absence of strong rules and policies to control flood risk in the building sector has aggravated these worries (Agbola *et al.,* 2012). Many projects are left vulnerable to financial and structural damage as construction managers are usually unready for the abrupt beginning of these dangers. This emphasises the need of a more strategic approach to flood and climate risk management, including environmental impact assessments (EIA) into the project lifecycle and supporting more robust public-private partnerships (Adedeji *et al.,* 2023).

2.4. To determine the different methods to safeguard a contractor against the impacts of flooding and climate change

Various strategies, including the use of weather derivatives, insurance, better contracts, and the adoption of resilient building techniques, help contractors protect themselves against the effects of floods and climate change. Though being a relatively recent idea in the Nigerian building sector, weather derivatives have shown to be successful means of controlling financial risks connected to weather (Isang, 2023). Though only some of contractors are aware of its function in reducing climate change risks, insurance coverage is still lacking in Nigeria. Though studies show this is underused in Nigerian construction projects, using contracts to distribute weather-related risks among stakeholders is another efficient approach (Ajayi *et al.,* 2020). Reducing the long-term effect of climate change on construction projects also depends on using climate-resilient building methods such as raised foundations, flood-resistant materials, and sustainable design principles (Ibem *et al.,* 2021; Hegeman 2019 A mix of these techniques, guided by thorough study and planning, may enable contractors to create resilience to climate-related hazards and guarantee the long-term viability of their initiatives.

3. Research Methodology

Exploratory research design and survey research methods were adopted for this study. Data were derived from both primary and secondary sources. A mixed-methods approach was used to collect data from participants, combining surveys and interviews. A total of 130 WhatsApp/emails with questionnaires were sent out to a convenient purposive sample, of which 74 well-completed questionnaires were retrieved and analyzed. Additionally, 15 professionals were interviewed to gather further insights. The questionnaire included both closed-ended and open-ended questions to generate both statistical and textual data. The survey was administered via the Survey Monkey platform, with links distributed through WhatsApp or email due to COVID-19 restrictions. “This circumstance requires a few events, individuals, or objects to be identified, chosen, and examined to determine the population from which it was chosen (Salaria, 2012). This helps select a subset of a population to represent the entire population of interest. Stratified and cluster sampling techniques guided the distribution of the sets of the questionnaire. Data for the research population (Nigerian construction industry) were derived from the records of real estate construction, professional bodies in Nigeria, and the Cooperate Affairs Commission.

A total of 130 WhatsApp/emails with questionnaires were sent out to a convenient purposive sample, of which 74 well-completed questionnaires were retrieved and analyzed, with a response rate of 57.0%. According to Survey Town (online), a standard response rate would be 10–15%. Hence, it is recommended that a reliable analysis be run. The questionnaires were presented logically, while the semi-structured interviews (qualitative approach) were carried out on several Nigerian construction industry professionals. To achieve the needed social survey, a convenient and purposive sample included construction managers and

Table 1: Questionnaire administration schedule

Respondents	**Number Administered**	**Number retrieved**
Architects	15	7
Quantity surveyors	12	6
Town planners	10	4
Construction Managers	20	11
Contractors	39	30
Engineers	13	5
Project Manager	21	11
Total	***130***	***74***

Source: Author’s field survey, 2020

contractors to gain reliable insight and an in-depth view of their opinions, beliefs, and thoughts regarding flooding and climate change and its impact on the Nigerian construction industry. Data collected from the semi-structured interviews (Key Informant Interviews) were recorded and stored in a password-protected system to ensure confidentiality and access to the researchers only; SPSS version 21 was used in analyzing the data.

4. Findings and discussion

The questionnaire data were analyzed to determine the impacts of flooding and climate change on construction projects in Nigeria. The sub-sections below present details of these impacts.

4.1. Discussion of results

4.1.1. Are you aware of floods and climate change in Nigeria?

Regarding awareness, nearly all respondents (98.7%) acknowledged the occurrence of flood events. A significant majority (89.4%) were aware of climate change, while the remaining 10.6% had only a basic awareness. This aligns with findings by Chang and Ross, (2024), who reported heightened awareness of flooding due to recent extreme weather events. However, the remaining 10.6% with only basic awareness underscores the persistent knowledge gap, similar to Oluwajana *et al.* (2022), who observed limited climate literacy among professionals.

4.1.2. Does flood and climate change in Nigeria currently impact the Nigerian construction industry?

A majority (76.8%) confirmed that flooding has significantly impacted construction activities. This finding supports Hegeman (2019) and Alabi (2016), who emphasized that extreme weather causes substantial cost and time overruns in construction projects. Conversely, the 23.2% who were uncertain reflect the regional and project-specific variability discussed by Unegbu *et al.* (2024), where differing exposure levels to flooding create varied perceptions of risk. Similarly, 60.0% believed climate change impacts the industry, while 22.2% remained uncertain indicating an ongoing need for awareness.

4.1.3. Have you witnessed any impact on weather-related delays, the safety of workers on-site, a change in construction materials design, structure/building collapse, project construction delay, cost and time overruns, manufacturing, or increased insurance costs due to the impact of flood and climate change?

Forty six percent of the respondents identified worker safety, material deterioration (14%), delays (12%), increased insurance costs (11%), structural collapses (10%), and cost overrun ns (7%). These concerns echo research by Olanrewaju *et al.* (2020), who found that flooding causes substantial maintenance burdens and infrastructure decay, and by Okoye *et al*. (2021), who documented structural weakening due to prolonged waterlogging. The discrepancies in perceptions around climate change's effects suggest influences such as geographical disparities and inconsistent professional experience, consistent with the observations of Nicholas *et al.* (2022).

4.1.4. Do you experience project construction delays due to flood and climate change?

Only 50.2% of respondents confirmed experiencing project delays due to extreme weather. While this is a lower percentage than the literature might suggest, it validates Nkwunonwo *et al.* (2020), who reported seasonal flooding leading to 3-month delays in Lagos-based projects. It also indicates a gap in proactive delay mitigation strategies, reinforcing the point made by Ibem *et al.* (2021) about limited adoption of climate-resilient construction practices due to cost and weak enforcement.

4.1.5. Is it true that most financial implications experienced on-site are due to weather-related delays?

Most construction contractors are held responsible for project delays. About 28.6% of the respondents in the research environment agreed that most financial implications experienced on-site were due to weather-related delays. Only 55.4% disagreed with this submission, while 16.0% refuted the assertion. Respondents largely agreed that weather-induced delays contribute significantly to financial losses, affirming literature by Nicholas *et al.* (2022), which reported construction cost overruns by 20–30% in flood-prone areas. Construction firms often face the burden of these losses, which discourages further investment in vulnerable zones, stalling urbanization efforts a theme echoed in the work of Chang and Ross (2024).

4.1.6. Does the contractor's Out-of-Pocket Costs Rise Proportionally to Flooding and Climate change's Impact On-Site?

Findings reveal that 57.4% of respondents agreed that out-of-pocket costs rise proportionally with climate-related disruptions, while 42.6% disagreed. The majority response supports the assertion made by Okoye *et al.* (2021) that environmental uncertainties such as flooding often lead to unbudgeted expenses, including emergency material replacement, equipment repairs, and temporary work stoppages all of which are borne by the contractor.

4.1.7. Have your previous executed projects experienced financial implications due to inadequate implementation of risk-mitigating methods for unforeseen flood and weather events?

The results indicate that a significant portion of respondents (**55.1%)** acknowledged experiencing financial implications on previously executed projects due to inadequate implementation of risk-mitigating methods for unforeseen flood and weather events. This finding aligns with literature of by **Adeleke *et al.* (2018),** which emphasize that poor risk assessment and weak adaptation strategies often leave construction projects financially exposed to climate-related disruptions. In contrast, **26.7%** of respondents reported no such experiences, while **18.2%** were uncertain suggesting variability in awareness or effectiveness of risk mitigation frameworks across projects. The data reinforces the critical role of proactive climate risk management in safeguarding project budgets, especially in flood-prone regions like Nigeria.

4.1.8. Have your experience of flood and climate change amounted to time and cost overruns in construction projects?

The majority of respondents (65.2%) confirmed that time and cost overruns are frequent occurrences in the construction industry due to Nigeria's unpredictable weather conditions and climate change. These natural events have a direct impact on both the initial project cost and the timely delivery of construction projects. This finding is consistent with previous studies by Adeleke *et al.* (2018), which highlighted that extreme weather events, including floods, disrupt construction schedules and increase costs. On the other hand, 27.0% of respondents were unaware that climate change contributes to such overruns, and 7.8% were unsure, pointing to a gap in awareness and knowledge of climate-related risks within the industry. Overall, the data suggests that floods and climate change are significant factors leading to time and cost overruns in construction projects.

4.1.9. Are you aware of using contracts to mitigate the impacts of weather conditions due to climate change on construction projects?

The study reveals that only 47.3% of respondents were aware of using contracts to mitigate the impacts of floods and weather-related conditions, while 52.7% were unaware, indicating a significant knowledge gap in the Nigerian construction industry. This aligns with *Ajayi et al.* (2020), who found limited integration of flood risk assessments in project design despite high awareness of climate risks. As highlighted in the literature, floods delay projects, increase costs, and compromise structural integrity (Nkwunonwo *et al.,* 2020), yet the absence of climate-adaptive clauses in most contracts shows that responses remain reactive rather than preventive. Lack of proactive contract use such as force majeure and indemnification clauses points to institutional and policy shortcomings.

4.1.10. Are you aware of using insurance to mitigate the impacts of weather conditions due to climate change on construction projects?

The findings show that 49.7% of respondents are aware that insurance can be used to mitigate the impacts of weather conditions caused by climate change on construction projects, while 34.3% are unaware and 16.0% remain unsure. This indicates a moderate level of awareness, suggesting that although insurance is recognized as a risk mitigation tool, its practical application in construction projects may still be limited or poorly understood. This gap aligns with existing literature that highlights the underutilization of structured climate risk management tools, such as insurance, in Nigeria's construction sector (Isang, 2023). Given the growing frequency and severity of climate-induced disruptions, there is a pressing need to enhance industry knowledge on tailored insurance policies and integrate them more formally into project planning and risk management strategies to ensure financial resilience against environmental uncertainties.

4.1.11. What is your opinion on the major cause(s) of structure/building collapse due to flood events and climate change?

The discussion of results aligns closely with the literature review, highlighting the considerable impact of flooding and climate change on construction projects in Nigeria. The majority of respondents (64.4%) identified heavy rainfall and river overflow as major causes of structural collapse, which supports findings by Unegbu *et al.* (2024) and Nkwunonwo *et al.* (2020) that point to extreme weather and poor drainage as critical risks. However, a significant percentage (35.6%) were unaware of such incidents, indicating a gap in awareness and documentation. Moreover, only 47.3% of respondents acknowledged the use of contracts for mitigating climate-related risks, and just 49.7% recognized the role of insurance, underscoring Ajayi *et al.* (2020) and Isang's (2023) observations that contractual and insurance-based adaptations are underutilized in practice.

4.1.12. Are you aware of using technology to deal with the impacts of weather conditions due to climate change on construction projects?

The analysis reveals that a significant majority (60.5%) of respondents are aware of the application of technology to mitigate the impacts of weather conditions on construction projects, with 27.6% unaware and 11.9% uncertain. This finding supports the literature's emphasis on the increasing importance of technology in enhancing resilience to climate-related disruptions in construction (Okoye *et al.,* 2021; Ibem *et al.,* 2021). It aligns with ongoing industry efforts to

adopt innovative tools such as flood modeling, real-time weather monitoring, and water-resistant construction techniques. The high level of awareness among respondents suggests growing recognition of technology's role in controlling aspects of the construction process traditionally deemed uncontrollable. However, the gap in full adoption, underscores the need for broader sensitization, training, and investment in climate-resilient technologies across the sector.

4.1.13. Are you aware of using weather derivatives as a risk assessment tool for weather conditions due to flood and climate change on construction projects?

The rationale behind this question was to assess respondents' awareness of weather derivatives as a tool for mitigating the impacts of weather conditions caused by climate change on construction projects. Unlike traditional insurance, weather derivatives do not require proof of loss only evidence of adverse weather making them a flexible financial risk management tool. The findings reveal that 45.3% of respondents were aware of weather derivatives, while 33.4% were unaware and 21.3% were unsure, indicating limited familiarity within the Nigerian construction sector. This aligns with the literature, which notes that weather derivatives are a relatively recent introduction to the industry and are still underutilized (Isang, 2023). Given their potential to support construction firms in minimizing weather-related financial risks and exploration of this instrument could significantly enhance climate resilience in construction project planning and execution.

4.1.14. In your opinion, what is the most logical approach method available to mitigate the risks imposed by flood and climate change?

This question sought to identify the most logical method for safeguarding contractors against the impacts of floods and climate change on construction projects. The findings reveal that 44.5% of respondents considered the use of contracts as the most logical approach, while 18.7% emphasized the importance of research and accurate planning, and 15.1% pointed to the use of technology. Only 11.3% believed that a combination of all available methods would yield the best outcome. These results suggest a fragmented understanding among professionals in the Nigerian construction industry regarding comprehensive climate risk mitigation strategies. The dominance of contract-based responses indicates some awareness of formal risk allocation, yet the relatively low recognition of integrated approaches highlights the need for further education, policy development, and knowledge dissemination in this evolving field.

4.1.15. Do you think the construction manager is in a position to safeguard the contractor against the impact of climate change on construction projects?

The majority of respondents (51.6%) believe that a construction management practitioner is in a position to safeguard the contractor against the impacts of climate change on construction projects, while 33.2% disagree, and 15.2% are unsure. This aligns with the literature, which stresses the critical role of construction managers in mitigating climate-related risks (Muller & Eli, 2021). The results suggest that construction managers are seen as key players in managing climate change risks, but further training and awareness are needed to ensure they are equipped with the necessary tools and strategies to effectively safeguard contractors and projects.

4.1.16. What are the future methods of dealing with risks imposed by flood and climate change?

In response to the question, the following suggestions were received to address a serious issue that will explore and identify possible future methods of dealing with the risks imposed by flood and climate change based on the beliefs, experience, and knowledge of the respondents.

The responses are;

I. Historical flood and climate data for the specific location (sites) in construction projects in Nigeria must be considered and incorporated into the contract. This will avoid the possible loss of person-hours due to flood events or climatic conditions. This alarming situation is becoming more challenging as flood events and climate change are changing different geological locations.
II. To mitigate climate change's impact on projects, a contingency sum should be included in the estimated contract value, reflecting the likelihood of remedial actions necessary to fix the damages caused by such adverse climate conditions.
III. Thinking for contingency planning for future flood events. In developed countries, information on the severity of flooding measured by its impact is key to insurance claims. Affected contractors should be involved in a participatory and bottom-up manner in drawing up measures to mitigate the impacts of flooding and, indeed, in flood management strategies.
IV. The contract should document all current and future flood and inclement weather data. The planners must also ensure the programme allows adequate float to cover adverse weather delays.
V. Historical flood and climate data for the specific location (sites) in construction projects in Nigeria must be considered and

incorporated into the contract. This will avoid the possible loss of person-hours due to flood events or climatic conditions. This alarming situation is becoming more challenging as flood events and climate change are changing different geological locations.

VI. Amending current and future contract documents to cover flood and climate change based on unpredicted events.

VII. All flood and inclement weather data is documented in the contract; the planners must ensure adequate float is allowed in the programme to cover any adverse flood events and weather delays.

VIII. Technology plays an interesting key role on sites. It allows the construction manager to better predict flood events and inclement weather at the tender phase so that the program can allow sufficient downtime.

IX. Neither a single solution nor a combination is the perfect answer to flooding and weather. Preparing during the tender phase and having ample information to justify his position requires a proactive and well-versed construction manager.

5. Conclusion and Further Research

This research examined the Nigerian construction industry's challenges due to flooding and climate change. The findings are crucial for contingency planning, management response, and strategic decision-making by construction managers, disaster managers, and other relevant authorities. These insights help implement effective measures to mitigate the impact of flood events and climate change on construction projects in Nigeria. The study revealed discrepancies between its findings and some of the literature reviewed. Most respondents disagreed with the assertion that financial implications on-site were primarily due to weather-related delays and time and cost overruns in Nigerian construction projects. In addition, the study shows that flood events are not the primary cause of structural or building collapses in the industry.

Climate change increasingly affects construction projects; it is not yet systematically reflected in contract practices underscoring the need for regulatory reforms, professional training, and the development of standard contract provisions that address environmental risks. A well-informed construction manager should integrate flood risk considerations from the tender phase; ensuring adequate information is available to justify project decisions. Therefore, while climate change increasingly affects construction projects, it is not yet systematically reflected in contract practices underscoring the need for regulatory reforms, professional training, and the development of standard contract provisions that address environmental risks. Future research should be explored on scientific investigation by professional practitioners in the built environments on the cost and implications of flooding and climate change impacts on construction projects in Nigeria.

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