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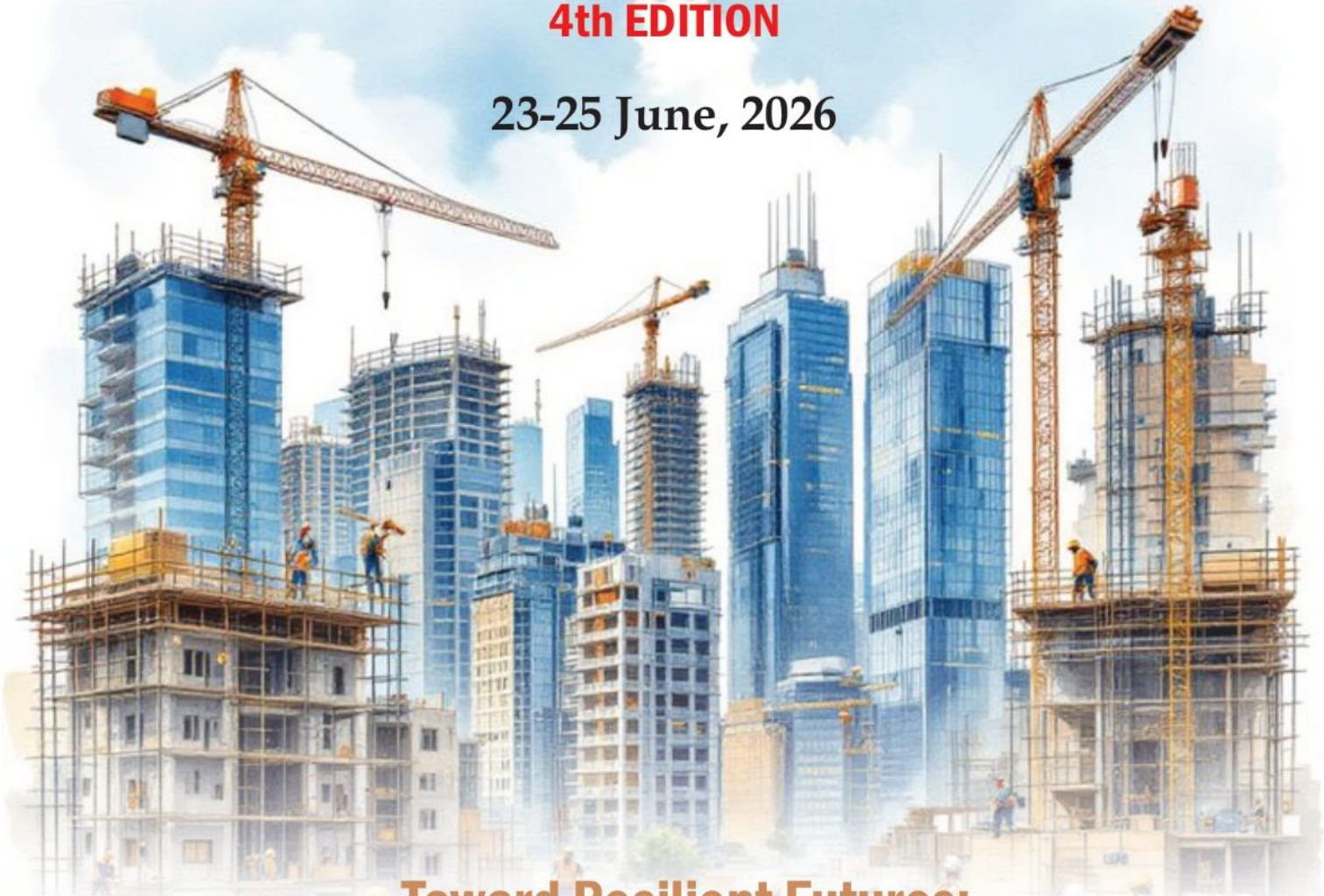
4th EDITION

23-25 June, 2026



Toward Resilient Futures:
Sustainable Construction and Innovation in the Built Environment

University of Cape Town · iYunivesithi yaseKapa · Universiteit van Kaapstad

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DECLARATION

One hundred and ten submissions were received, and 75 were accepted for presentation at the Conference from authors based in 39 Universities and institutions in South Africa, Ghana, Zimbabwe, Kenya, Nigeria, Malaysia, Turkey, Iran, the United Kingdom, and the United States. All full papers in this publication went through a double-blind peer-review process, which involves abstract 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.

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University of South Africa (UNISA), South Africa	9	8.0%
University of Texas at San Antonio, United States	1	0.9%
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University of the Witwatersrand (Wits), South Africa	5	4.5%
Walter Sisulu University, South Africa	1	0.9%
Total	**112**	**100%**

PREFACE

On behalf of the Construction Business and Project Management Research Group at the University of Cape Town and the CBPM 2026 Organising Committee, it is my pleasure to present the Proceedings of the 4th Annual Construction Business and Project Management Conference (CBPM 2026), held from 23-25 June 2026 at the UCT Graduate School of Business Conference Centre in Cape Town, South Africa.

The conference was convened under the theme "Towards Resilient Futures: Sustainable Construction and Innovation in the Built Environment." This theme reflected the growing need for transformative, inclusive and multidisciplinary responses to the challenges confronting the construction sector and the wider built environment. CBPM 2026 provided a platform for researchers, industry practitioners, policymakers, regulatory bodies, manufacturers, professionals, and emerging scholars to exchange knowledge, interrogate contemporary challenges, and explore practical pathways toward a more resilient and sustainable construction sector.

The conference programme reflected the important interface between research, policy and practice. The first day featured the Innovative Building Technologies (IBT) Advancement Workshop, which focused on advancing innovative building technologies beyond pilot applications to broader, scalable implementation. The subsequent conference programme included keynote addresses, plenary presentations, parallel academic sessions and focused discussions addressing the principal themes shaping construction business, project management, sustainability and innovation in the built environment.

CBPM 2026 was privileged to host distinguished leaders and experts from government, industry and academia. These included the Honourable Sihle Zikalala, Deputy Minister of Public Works and Infrastructure, South Africa; Mr Bongani Dladla, Chief Executive Officer of the Construction Industry Development Board; Dr. Lindelani Matshidze, Chairman of Agrément South Africa; Dr Martin Röck of GBDI; and Dr Shaun Lundy, together with the presenters, panellists and delegates whose contributions enriched the conference discussions.

The papers presented in these proceedings reflect the breadth of contemporary research in construction business and project management and the continuing effort to connect scholarly enquiry with the practical challenges facing the built environment. They address diverse but interconnected questions concerning sustainability, innovation, project delivery, construction management, technology, infrastructure, organisational performance and the resilience of the construction sector.

The publication of these proceedings would not have been possible without the commitment of the authors, members of the Scientific Committee, reviewers and the editorial team. I extend my sincere appreciation to all authors who contributed their research to CBPM 2026

and to the reviewers whose expertise and constructive feedback supported the scholarly review and development of the papers included in this volume. Their collective contribution is central to maintaining CBPM as a credible platform for research dissemination, scholarly exchange and industry engagement.

I also wish to express our deep appreciation to our platinum sponsorship partners, the Construction Industry Development Board (cidb) South Africa and the National Home Builders Registration Council (NHBRC), for their generous support. We further acknowledge the valued contributions of our institutional partners, professional bodies, participating manufacturers, speakers, presenters, panellists and delegates. Their continued participation and support strengthen the relevance and impact of the CBPM Conference.

We hope the research presented in these proceedings will extend the conversations initiated during CBPM 2026, inform future research and professional practice, support evidence-based policy and decision-making, and encourage new collaborations across academia, government and industry.

We are pleased to share this collection as a record of the scholarly contributions made to CBPM 2026 and as part of our continuing commitment to advancing knowledge in construction business and project management.

September 30th, 2026

Warm regards,

Professor Abimbola Windapo
Chair, Construction Business and Project Management (CBPM) Conference 2026

SCIENTIFIC COMMITTEE 2026

The success of the 4th edition of the CBPM Conference reflects 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.

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THE PEER REVIEW PROCESS

All full papers in this publication underwent a rigorous two-stage blind peer review by at least 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. Reviewers assessed each abstract for relevance to the conference theme and objectives, academic rigour, contribution to knowledge, originality of material, and research methodology. Authors whose abstracts were accepted received anonymous reviewers' comments and were asked to address them when developing their full papers.

The second stage of review
The submitted full papers were first checked for originality and inappropriate copying using Turnitin/Ithenticate software. Next, we assigned the papers to experts in the field based on their areas of expertise. Reviewers assessed the full papers for relevance to the originality of the material; technical writing; academic rigour; contribution to knowledge; pertinent literature review; research methodology and robustness of data analysis; empirical research findings; and overall quality and suitability 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. Authors were required to provide evidence of specific actions taken in response to the referees' suggestions. Final papers were accepted and included in the proceedings only after satisfactory evidence was provided. To be eligible for inclusion in the conference proceedings, these papers had to receive a unanimous endorsement from the Scientific Committee and Review Panel that they met all conditions for publication. Of 110 submissions, 75 papers were accepted and included in the CBPM 2026 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 editors and the scientific committee ensured the final papers incorporated the reviewers' comments and arranged them in the final sequence shown in the Table of Contents.

Professor Abimbola Olukemi Windapo
Chair, Conference CBPM 2026

CBPM 2026 CONFERENCE COMMUNIQUÉ

4th Annual Construction Business and Project Management Conference

"Towards Resilient Futures: Sustainable Construction and Innovation in the Built Environment"

University of Cape Town Graduate School of Business, Cape Town, 23-25 June 2026

Communiqué

The 4th Annual Construction Business and Project Management (CBPM) Conference was held at the University of Cape Town Graduate School of Business, Cape Town, from 23 to 25 June 2026 under the theme "*Towards Resilient Futures: Sustainable Construction and Innovation in the Built Environment*." The conference brought together researchers, government and regulatory representatives, industry professionals, manufacturers, students, sponsors and partners from South Africa and other countries in Africa and beyond.

The conference opened with an Innovative Building Technologies (IBT) Advancement Workshop. The workshop and subsequent conference discussions highlighted a common concern that innovation in construction will not achieve scale through technical solutions or pilots alone. Mainstream adoption requires an enabling system in which approvals are predictable, procurement can be innovative, projects are bankable and insurable, evidence is credible, risks are understood, and the construction industry has the skills and institutional capacity to deliver.

The conference recognised IBTs as practical approaches that can accelerate delivery, improve predictability, strengthen resilience to climate and other shocks, support industrialisation and localisation, reduce waste and improve life-cycle value, and create opportunities for SMEs, youth and women. At the same time, participants stressed that adoption must respond to local market realities, institutional capacity, community expectations and the existing construction value chain.

The conference further highlighted the importance of whole-life thinking in sustainable construction. Discussions on environmental life-cycle modelling highlighted the need to consider both operational and embodied emissions and to develop better building and material data to support evidence-based policy, planning and investment. The conference recognised that data availability, consistency, and willingness to share information are important constraints, and that collaboration among researchers, practitioners, and policymakers is needed.

Digital transformation emerged as a major enabler across the conference programme. Papers and discussions addressed digital twins, BIM, artificial intelligence, robotics, 3D printing, smart construction systems and other digital applications. The conference noted that technology adoption should be driven by value, appropriate skills, reliable data, safety, interoperability, and fit-for-purpose implementation.

Governance, procurement and financial performance were also identified as decisive conditions for successful project delivery. The conference called for procurement systems and specifications that can lawfully support innovation, allocate risk, enhance project governance, improve financial accountability, and use performance-based approaches where

appropriate. Participants also emphasised the need for financiers and insurers to better understand innovative and sustainable construction solutions, as well as the evidence required to support investment decisions.

Health, safety, wellbeing, inclusion and professional competence were central to the conference agenda. Contributions covered smart technologies for safety, leadership and workforce engagement, emotional intelligence, mental health, gender-sensitive safety, professional competence, and preparing future-ready built-environment graduates. The conference recognised that resilience depends on buildings and infrastructure, and also on the people, organisations and communities that plan, construct, operate and use them.

The conference also reaffirmed the importance of education, skills development and collaboration across institutions. Government, industry, professional bodies and universities were encouraged to strengthen partnerships that translate research into policy, procurement practice, professional competence and delivery outcomes. Participants noted the need for technical and artisan development, digital capability and continuing professional development to support the changing construction environment. The conference welcomed the emphasis on inclusive growth, localisation, youth and women's participation, and local enterprise development. It acknowledged that infrastructure investment should deliver physical assets, create jobs, build capability and generate opportunities for communities and local businesses.

The CBPM conference concludes that the path to resilient and sustainable construction requires a shift from fragmented initiatives to coordinated implementation. The Conference calls for continued collaboration among government, regulators, industry, professional bodies, financiers, academia, manufacturers and communities to develop practical pathways for innovation, strengthen evidence and confidence, improve procurement and project readiness, and build the skills required for future delivery. The Conference encourages stakeholders to incorporate these findings into their programmes, policies, research agendas, and project delivery practices.

Key Conference Resolutions

- Move from innovation declarations and pilots to implementation and measurable delivery outcomes.
- Create clearer, more predictable and coordinated approval and compliance routes for innovative construction solutions.
- Make procurement, contracting, risk allocation, and specifications conducive to innovation while maintaining accountability and transparency.
- Improve the evidence base for sustainability, safety, performance and whole-life impacts through better data and collaboration.
- Enhance project bankability and insurability by aligning technical evidence, risk information and financing requirements.
- Invest in digital capability, professional competence, artisan development and lifelong learning.
- Use infrastructure delivery to advance localisation, inclusive growth, youth and women's participation and community benefit.

Editors, CBPM 2026 Conference

WORKSHOP AND PANEL DISCUSSION

The CBPM 2026 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 the theme "Towards Resilient Futures: Sustainable Construction and Innovation in the Built Environment" with construction stakeholders, academia and the professional community

CBPM 2026 INNOVATIVE BUILDING TECHNOLOGIES (IBT) ADVANCEMENT WORKSHOP

23 JUNE 2026

Workshop Report, Media Release and 180-Day Way Forward Action Plan

Date	23 June 2026
Time	08:30-16:30
Venue	UCT Graduate School of Business, Cape Town
Theme	From discussion to implementation: approvals, procurement, finance and confidence

PART A: WORKSHOP REPORT

1. Overview

The Innovative Building Technologies (IBT) Advancement Workshop was held on 23 June 2026 at the UCT Graduate School of Business in Cape Town as part of the 4th Annual Construction Business and Project Management (CBPM) Conference. It was designed as an implementation dialogue rather than a technology promotion event. The day brought together regulators, government and municipal representatives, built-environment professionals, academics, manufacturers, and other stakeholders to address the conditions that must change for IBTs to move from pilots to routine delivery. The programme explicitly targeted approvals, evidence, procurement, finance and market confidence.

The workshop built on the wider sector discussion, including the 2025 cidb National Construction Summit, the 2026 IBT Presidential Summit and the Agrément South Africa stakeholder engagement on the review of the Agrément SA Act, Cape Town, 2026. Recurring barriers across these engagements included certification and approval bottlenecks, fragmented institutional coordination, reliance on conventional procurement practices, limited confidence in the innovative systems, financing constraints, and skills gaps.

2. Workshop objectives

- A practical Cape Town IBT Advancement Action Plan.
- Align the regulatory routes and requirements across Agrément South Africa (ASA), NHBRC and municipal building control, including the evidence required at each stage.
- A procurement and contracting approach that allows innovation while protecting public-sector governance, accountability and audit requirements.
- A structured evidence and confidence process using manufacturer showcases, audience scoring, questions and a consolidated issues register.

3. Proceedings and participation

The workshop followed four linked stages. The opening session framed the shift from summit declarations to delivery and asked participants to identify the practical constraints that prevent uptake. The regulatory panel then examined what Agrément certification establishes, what NHBRC requires for enrolment and warranty, and what municipalities still need for project-specific approval. Three manufacturers - KwikFrame, Saint-Gobain, and Hydraform - presented technologies and evidence, followed by questions and audience scoring. The afternoon focused on public procurement, performance-based specifications, risk allocation, developmental contracting, project bankability and insurability. The closing session consolidated the main outputs and stressed that the dialogue should continue through measurable indicators instead of another cycle of discussion.

4. Key findings from the discussion

4.1 Regulation and approvals

- Agrément certification was explained as an assessment of non-standardised construction-related products and systems against performance criteria. It addresses areas such as structural strength and stability, fire resistance, water penetration, durability, thermal performance, and condensation, and incorporates quality management requirements.
- Agrément certification does not by itself replace municipal planning and building-control approval, nor does it remove the need for project-specific professional responsibility. Municipal officials stressed that site conditions, design, specifications and the competent professionals responsible for structural integrity are important.
- For NHBRC, an Agrément certificate can be accepted as evidence of compliance for the relevant product/system, but enrolment, registered builders, inspections and other applicable NHBRC requirements still apply.
- Municipal submissions would be robust when they include clear information on competent persons, installers, supply arrangements, factory/logistics, site-specific design, and evidence of previous applications or testing in real projects.
- The discussion supported early engagement or pre-application review with municipalities for larger or scalable projects, while recognising that other departments may still need to review the application.
- A recurring concern was the lack of a simple, shared evidence package to reduce repeated requests for different documents from various authorities.

4.2 Evidence, quality and confidence

- Participants distinguished technical certification from market confidence. Certification is necessary, but confidence also depends on demonstrated performance, competent installation, quality control, durability, maintenance, warranties and a visible track record.
- Pilot projects were described as important evidence because they allow professionals, regulators, financiers and communities to see how a system performs in real conditions.

- Manufacturers need to present not only product specifications but also implementation procedures, quality management systems, installer competence, supply capability, and evidence of performance at relevant scales.
- A central gap identified in the discussion was the absence of a recognised, easily accessible national database of IBTs and their certification/evidence status. Such a resource could make it easier for officials and professionals to verify products and systems.

4.3 Procurement and contracting

- The workshop found that procurement can unintentionally favour conventional construction when tenders prescribe specific materials or established methods, rather than clearly stating the required functional and performance outcomes.
- Participants supported the use of performance-based specifications and the controlled acceptance of alternative solutions, while retaining legal, technical and accountability safeguards.
- The market for some IBTs is still narrow. Procurement therefore needs to avoid creating unnecessary monopolies while also giving credible innovative suppliers a realistic route to compete.
- There was concern about the practical accountability of public officials and procurement teams. Performance-based procurement will only work at scale if officials understand how to evaluate innovation and can do so with confidence under public-sector audit requirements.
- Professional roles and responsibilities on site need clearer definition, particularly where innovative systems alter the normal relationships among designer, project manager, contractor, installer, and manufacturer.

4.4 Finance, insurance and bankability

- Financiers and insurers need evidence that an IBT is technically sound, insurable and capable of being delivered at scale. An Agrément certificate helps, but it is one element of a wider bankability case.
- Important evidence includes pilot-project performance, verified cost information, replacement values, risk allocation, maintenance obligations, sales pipeline, land/development arrangements and credible management capability.
- The discussion suggested that plot-and-plan and other development structures that reduce working-capital exposure can sometimes suit IBT developers better than relying only on conventional construction finance.
- The sector needs stronger engagement with commercial banks, development finance institutions, and insurers so certified and demonstrably performing IBTs can move from technical acceptance to practical financeability.

4.5 Skills, capacity and institutional coordination

- Participants identified skills gaps among clients, municipal officials, procurement practitioners, contractors and professionals as a practical barrier to adoption.

- Government departments were encouraged to understand their internal capacity before committing to IBT programmes. This points to the need for skills audits, targeted training and clearer technical support.
- The workshop repeatedly returned to the need for regulators, municipalities, manufacturers, financiers, professionals and academia to work as an integrated system rather than as separate approval or delivery silos.

4.6 Community, local participation and delivery context

- Community acceptance matters alongside technical compliance. Examples discussed during the workshop showed that users may compare IBTs with familiar brick-and-mortar construction and may need to see, understand and trust the technology before accepting it.
- Local labour, local supply capacity and the ability to maintain or repair an IBT were considered relevant to project readiness, particularly in housing and public-delivery contexts.
- The discussion also linked IBT adoption to broader development outcomes, including opportunities for local suppliers, SMEs, youth and women, consistent with the workshop programme.

5. Manufacturer showcase: practical lessons

The manufacturer presentations reinforced a common message that technology should be assessed as part of a delivery system, not as an isolated product. Presentations highlighted construction speed, lighter structures, reduced water dependence, factory-controlled quality, fire/thermal/acoustic performance, warranties, installer training, and system-level support. At the same time, the Q&A showed that commercial adoption depends on evidence beyond the factory, including site experience, maintenance, community acceptance, financing and the ability to scale supply.

The showcase also demonstrated the value of an evidence-based marketplace where manufacturers can respond directly to questions from regulators, professionals, financiers, and potential clients. The programme structure allowed audience scorecards and confidence questions to be captured for follow-up.

6. Findings from audience scorecards and confidence questions

The audience scoring was based on a 1–5 confidence scale, where 1 indicates *weak/unclear,* and 5 indicates *very strong/ready for scale*. The rubric covered 30 questions involving technical, regulatory, commercial, delivery, quality, developmental and bankability dimensions.

Twenty-four workshop attendees participated in the polls, and the results were aggregated. The manufacturer showcase generated generally positive but qualified confidence. The strongest scores related to the clarity of the IBT systems, construction speed, and

technical/fire/structural performance, while the lowest scores related to regulatory readiness, cost/lifecycle value, bankability/insurability, and quality assurance/installer training.

The results therefore suggest that the principal challenge to IBT adoption is whether the institutional and commercial environment is sufficiently prepared to approve, procure, finance and scale them, and not whether IBT systems have potential. The polling provides a clear signal for the next phase of the IBT agenda. Stakeholders have reasonable confidence in the technologies, but much less confidence in the institutional pathways surrounding them. The priority is therefore to move from demonstrating that IBTs can work to creating the approvals, procurement, quality-assurance, financing and insurance systems that allow them to work at scale.

7. Conclusions

1. IBTs can only move to scale when the full delivery ecosystem is aligned. Certification alone will not produce adoption.
2. The immediate regulatory priority is not a new layer of approval; it is a clearer, better-coordinated route from product/system evidence through NHBRC requirements to project-specific municipal approval.
3. Procurement should increasingly focus on required performance and outcomes, while preserving transparency, competition, professional responsibility and auditability.
4. IBT projects need a stronger bankability and insurability package, supported by real project evidence, reliable cost data, clear risk definitions, and early engagement with financiers and insurers.
5. A common evidence pack and a credible IBT database could reduce duplication and help decision-makers assess technologies more consistently.
6. Skills development and institutional capacity are implementation requirements, not secondary issues.
7. The workshop should be treated as the start of a 180-day implementation cycle. Progress should be progress by tangible outputs and pilot/project movement, not another round of declarations.

7. Proposed immediate outputs

- A consolidated IBT minimum evidence-pack/checklist for manufacturer submissions.
- A coordinated approvals pathway note covering Agrément, NHBRC and municipal building control.
- A practical performance-based procurement checklist and model tender guidance for public clients.
- A manufacturer evidence and confidence register, including the key questions raised during the workshop.
- A finance and insurance readiness template for IBT projects.
- A structured 180-day implementation tracker to be shared with Agrément SA, NHBRC, cidb, municipalities, professional bodies, financiers, manufacturers and other partners.

PART B: MEDIA RELEASE

MEDIA RELEASE

23 June 2026 | Cape Town

CBPM workshop calls for practical action to move innovative building technologies into mainstream delivery

Cape Town, South Africa - The Construction Business and Project Management (CBPM) 2026 Innovative Building Technologies (IBT) Advancement Workshop has called for a coordinated shift from repeated discussion and pilot projects towards a practical delivery system that can approve, procure, finance and implement innovative building technologies at scale. Held at the University of Cape Town Graduate School of Business on 23 June 2026, the workshop brought together regulators, government and municipal representatives, built-environment professionals, academics, and manufacturers. Its central question was to examine what must change for credible innovative building technologies to move into conventional construction and human-settlement delivery.

The discussion highlighted five immediate priorities. First, the approvals pathway needs to be clearer and better coordinated. Agrément certification provides important evidence of product or system performance, but project-specific municipal requirements, the competent professional's responsibility, and NHBRC processes must still be understood and aligned with. Early engagement with municipalities was identified as a practical way to reduce avoidable delays in IBT project implementation.

Second, procurement must create space for innovation. Participants supported clearer performance-based requirements and appropriate treatment of alternative solutions, while maintaining competition, transparency, accountability and audit confidence. The workshop also identified the need to improve the skills of procurement and technical officials who evaluate innovative solutions.

Third, IBTs need a stronger evidence base and greater confidence. Pilot projects verified cost and performance information, quality management systems, installer competence, maintenance arrangements, and actual track records are important to regulators, professionals, communities, financiers, and insurers. Participants identified a recognised database of certified and evidenced IBTs as a useful sector need.

Fourth, financing and insurance must be integrated into the innovation pathway. Participants noted that a technically acceptable system may still struggle to secure funding unless the developer can demonstrate a credible delivery structure, project evidence, risk allocation, sales or demand, insurance, and cost information.

Fifth, adoption requires people and institutions to work differently. Manufacturers, regulators, municipalities, professionals, contractors, financiers and communities all have a role. The workshop emphasised that local capacity, skills, community engagement and

realistic delivery conditions should be considered alongside technical performance. Three manufacturers - KwikFrame, Saint-Gobain and Hydraform - contributed practical technology showcases, allowing participants to question issues of evidence, performance, cost, readiness and delivery. The event closed with a commitment to develop a time-bound action plan to ensure the relevant organisations can take the workshop's work forward.

Prof. Abimbola Windapo, representing the CBPM conference, emphasised that no single institution can mainstream IBTs on its own. The workshop was intentionally positioned as a bridge between research and practice, regulation and implementation, manufacturers and procurers, and policy ambition and project delivery.

The CBPM conference will consolidate the workshop outputs into a post-workshop handout and implementation action plan for circulation to regulators, government, municipalities, industry, financiers and other stakeholders. The purpose is to ensure that future discussions show measurable progress in approvals, procurement, finance, skills, evidence and project delivery.

ENDS.

PART C: 180-DAY WAY FORWARD ACTION PLAN

Purpose
The following plan (Table 1) translates the workshop discussion into practical workstreams. It is intentionally framed as a planning proposal for Agrément South Africa and other participating organisations to consider and incorporate into their own work programmes. The time windows are proposed implementation milestones within the workshop's 180-day approach; they are not presented as formal commitments already approved by the respective organisations.

Immediate priorities for the next 30 days
1. CBPM circulates this report and the proposed action plan to workshop stakeholders for comments and confirmation of institutional leads.
2. Agrément SA, NHBRC and municipal representatives identify existing guidance and agree what can be consolidated into a practical minimum evidence and approvals pack.
3. cidb/procurement stakeholders identify a suitable live or recent procurement case against which performance-based IBT guidance can be tested.
4. Interested financiers/insurers and IBT developers nominate one or more projects for a bankability/insurability readiness assessment.
5. CBPM establishes a simple progress register and schedules a first 30-day follow-up review.

Planning principle
The workshop's guiding principle is that the next stage should produce fewer repeated discussions and more visible movement in the system.

Table 1: Workshop Discussions Practical Workstreams

Workstream	Action / output	Lead / partners	Indicative timing	Success indicator
1. Evidence and approvals	Develop a single minimum IBT evidence-pack/checklist covering Agrément evidence, NHBRC enrolment information, competent-person inputs, site-specific design, quality control and municipal submission requirements.	Agrément SA + NHBRC + City/municipal building control + professional bodies + manufacturers	0-60 days	Draft checklist agreed for pilot use; fewer duplicated document requests.
2. Regulatory coordination	Prepare a simple end-to-end pathway note showing what is assessed by Agrément, what NHBRC requires, what municipalities approve, and where project-specific professional responsibility sits.	Agrément SA + NHBRC + municipalities	0-90 days	Shared pathway published and used in at least one pilot/scalable project.
3. Pre-application engagement	Institutionalise early consultation for scalable IBT projects so applicants can identify evidence and submission requirements before formal approval.	Municipal building control + applicants/manufacturers + professionals	0-90 days	At least one documented pre-application review completed for a qualifying project.
4. IBT evidence database	Assess and develop a recognised database/register of certified IBTs, evidence status, intended application, installer information and relevant contacts.	Agrément SA + research institutions + manufacturers + public clients	30-120 days	Agreed data fields and governance model; initial records loaded.
5. Procurement reform	Prepare a performance-based IBT procurement checklist and model wording that permits credible alternatives without compromising competition, accountability or auditability.	cidb + public procurement/SCM + municipalities + JBCC/professional bodies	30-120 days	Guidance tested against a real tender or procurement case.
6. Professional accountability	Clarify roles and responsibility across client, designer, project manager, contractor, installer, manufacturer and building control for IBT projects.	Professional councils + cidb + municipalities + industry	30-120 days	Role/responsibility matrix agreed and reflected in guidance.
7. Skills and capacity	Conduct targeted skills/capacity audits and design short practical training for municipal officials, procurement teams, professionals and contractors dealing with IBTs.	Government/municipalities + universities + professional bodies + manufacturers	60-150 days	Priority skills gaps identified; training package scheduled or delivered.
8. Finance and insurance	Develop an IBT bankability/insurability readiness pack covering certification, pilot evidence, QS cost data, risk allocation, maintenance, warranties, development structure and funding pathway.	Financiers/DFIs + insurers + developers + professional bodies	60-150 days	Readiness pack tested with finance/insurance stakeholders; at least one project reviewed.
9. Pilot projects	Identify credible pilot or demonstration projects that can generate real-world performance, cost, maintenance and user-acceptance evidence and can be used for learning.	Public clients + municipalities + manufacturers + developers + universities	60-180 days	Priority projects identified and monitoring framework agreed.
10. Community and local participation	Build structured community engagement and local labour/supply considerations into IBT project planning, particularly for housing and public delivery.	Municipalities + developers + community structures + manufacturers	60-180 days	Community engagement record and local participation plan included in pilot projects.
11. Financing the innovation pipeline	Engage banks and DFIs on suitable mechanisms for pilot-to-scale transition, including project structures that reduce working-capital barriers.	Banks/DFIs + developers + government + industry	90-180 days	At least one structured finance dialogue and documented financing options for IBTs.
12. Monitoring and accountability	Create a simple 180-day dashboard reporting completed actions, participating organisations, pilots, approvals, procurement reforms, training and finance outcomes.	CBPM as convening/coordination platform, with participating institutions	Immediate; review at 30/60/90/180 days	Progress report circulated at each review point; next-step actions agreed.

CBPM Conference Secretariat
September 2026

KEYNOTE SPEAKERS AND ADDRESS

The CBPM 2026 Organising Committee thanks our keynote speakers for accepting the invitation to share their presence and thoughts on the theme "Towards Resilient Futures: Sustainable Construction and Innovation in the Built Environment" with construction stakeholders and 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.

ADDRESS BY DPWI DEPUTY MINISTER AT THE CBPM CONFERENCE, GRADUATE SCHOOL OF BUSINESS, UNIVERSITY OF CAPE TOWN

25 JUNE 2026

INTRODUCTION: THE VALUE OF IBTs

Programme Director, Distinguished Delegates, Industry Leaders, Project Managers, and Esteemed Colleagues:

It is a profound honour to address this year's Construction Business and Project Management (CBPM) Conference under the theme *"**Towards Resilient Futures: Sustainable Construction and Innovation in the Built Environment**."*

With a special focus on Innovative Building Technologies (IBTs) and taking place here in the Mother City (Cape Town) which arguably leads South Africa in embracing IBT's, the 2026 CBPM conference is timely.

We applaud UCT's Professor Abimbola Windapo and the conference organizers for reminding us that IBTs are no longer merely alternatives.

Instead, IBTs are practical approaches that can strengthen resilience, support industrialisation and localisation, reduce waste, enhance lifecycle value, and create opportunities for SMMEs, youth and women in manufacturing and construction value chains.

This CBPM conference builds on the Innovative Building Technologies Summit which took place in February 2026 in Johannesburg.

Commending IBT's potential in addressing South Africa's housing backlog and impact in driving sustainable local economic development, His Excellency President Cyril Ramaphosa said:

"If we continue to build in the old way – on the same land, with the same vulnerabilities, using the same methods – then we are not solving the housing challenge.

We must make a change.

We must embrace the tide of technological progress to future-proof human settlements.

This is a social imperative and an economic necessity."

We agree with the President that Innovative Building Technologies offer our country a strategic opportunity.

Indeed, by ensuring that they are socially accepted and locally embedded, they will allow us to build faster, safely, and at scale.

In this regard, the President highlighted the crucial role currently played by DPWI's entity, Agrément South Africa (ASA) in providing technical certification of innovation products and systems.

REVIEW OF THE ASA ACT

Ladies and Gentlemen, the Department of Public Works and Infrastructure plays an important role in creating the policy and institutional environment in which innovation can support the delivery of public infrastructure.

This role includes encouraging performance-based approaches, strengthening coordination across the built environment, and ensuring that innovation is adopted responsibly in the public interest.

Agrément South Africa (ASA), as an entity of the Department of Public Works and Infrastructure (DPWI), contributes by assessing and certifying non-standardised construction products, systems and processes.

Agrément certification is a key part of the evidence base that can help municipalities, the NHBRC, professional teams, procuring institutions, financiers and end users understand whether an IBT system is safe, fit for purpose, or not.

Certification is not the end of the process. A certified system still needs to move through project-specific approval, municipal building plan processes, National Home Builders Registration Council (NHBRC) enrolment, quality assurance, inspection, and occupation.

Once again, we extend a word of appreciation to the conference organisers for ensuring that inclusive in the programme, is a workshop aimed at creating a practical opportunity to clarify what Agrément certification processes involves and the role of other regulators like the NHBRC and municipalities.

We also wish to take this opportunity to invite you to participate in the current review of the ASA Agrément South Africa Act, 2015, that is led by DPWI.

The proposed Amendments seek to move from voluntary certification and to provide for the mandatory certification of prescribed non-standardised construction-related products and systems before they are placed on the market.

The aim is to strengthen quality management, performance-in-use monitoring and provide for a digital register and public verification.

We have realized that the current voluntary nature of ASA's certification process allows non-compliant products to enter the market, posing health, safety, and environmental risks.

Making ASA a mandatory statutory body is intended to create clear regulations and enforcement, ensuring only safe building products and systems are used. It is our considered view that such a transition is crucial for closing compliance gaps and key in enhancing public safety.

ASA is currently streamlining its processes through a phased implementation of its revised operating model to facilitate enhanced certification processes and Quality Assurance activities for improved operational efficiency and sustainability.

The entity is also aligning standards and methodologies with international best practices to bolster the organisation's effectiveness.

Agrément South Africa (ASA) continues to champion research, innovation, and certification sustainable building materials. ASA's eco-labelling programme supports climate resilient construction methods.

DIGITILISATION AND BIM

Colleagues, in December 2023, the cidb published a Business Case and a Roadmap towards BIM adoption.

The cidb roadmap revealed that:

"*Global population will rise to approximately 9.7 billion people by 2050, with 75% of the population residing in cities…contractors will be required to build an estimated 3 600 more buildings per day by 2050. On the African continent, 1 327 buildings would need to be built per day in urban areas. To achieve these goals and meet the demands of the construction industry, innovative solutions such as digitisation of the industry should be considered.*"

With our cities rapidly getting hotter because of rapid urbanisation and population growth, we must drive resilient infrastructure development to mitigate climate change risks.

The adoption of Building Information Modelling (BIM) by the SA construction industry will contribute to rapid development which is safe, cost effective, and efficient.

Through the cidb Centres of Excellence at Wits, UJ, and Walter Sisulu University, DPWI is at the forefront of supporting 4IR technologies like BIM to support efficient, sustainable infrastructure delivery.

The Department is actively playing its part in reducing the carbon footprint through its Green Building Policy.

The National Infrastructure Plan (NIP 2050) supports the decarbonization of the economy through the gazetting of a number of SIPs by DPWI's ISA to supports SA's Just Energy Transition and clean energy sources.

To address service delivery challenges, municipalities will increasingly use renewable energy as a source to drive continuous functioning of water and wastewater treatment plants rather than the reliance on the grid energy.

Using renewable energy sources (including solar) should result in saving on electricity bills in the long run.

There are also opportunities in the manufacturing of battery energy storage systems (BESS) as these can be used both with the grid and solar power installations.

We are encouraged by the huge interest from investors on SA's multibillion Green Hydrogen Projects and Integrated Renewable Energy and Resource Efficiency Programme (iREREP).

RESILIENCE AS A NATIONAL IMPERATIVE

Compatriots, infrastructure is more than steel, concrete, and design.

When government proclaims its vision of turning South Africa into a construction site, it is because of the recognition that infrastructure is the backbone of our economy, the lifeline of our communities, and the bridge to a sustainable future.

DPWI's commitment to national infrastructure resilience is South Africa's vision to drive sustainable construction and accelerate innovation in South Africa's built environment.

Resilience means thriving and surviving despite shocks.

Our agenda must be about ensuring that all projects withstand the pressures of climate change, rapid urbanisation, and economic uncertainty.

To succeed, we must ensure that resilience is embedded into every stage of infrastructure delivery—planning, design, financing, and execution—so that our built environment is future-proof and adaptable.

DRIVING SUSTAINABLE CONSTRUCTION

Waste reduction, material reuse, and regeneration will define the next era of construction.

Working with our entities – Agreement South Africa, CIDB, CBE, ISA, IDT, the Department of Public Works and Infrastructure continues to work towards embedding eco-friendly standards into national frameworks, such as energy efficiency, renewable energy integration, and carbon footprint reduction.

By enhancing green building practices, we ensure that sustainability is not an afterthought, but the foundation of every project.

INNOVATION IN A VUCA WORLD

Ladies and Gentlemen, we live in a volatile, uncertain, complex, and ambiguous world, shaped by rapid technological change. This means that we must be steadfast in revolutionising how we design, build, and maintain our infrastructure using digital technologies, robotics, automation, and use of advanced materials.

In a world that faced disruption through COVID-19 and devastating flood disasters, the Construction Industry Recovery Plan led by the cidb had to be anchored around the pillars of green economy implementation, industry capacitation, and robust infrastructure project pipeline.

BANKABILITY AND PARTNERSHIPS

Under the leadership of President Cyril Ramaphosa, South Africa offers policy certainty, police coherence and is investment-ready.

We recognize that without alignment and investments, innovation can be imperiled and derailed.

For us to scale innovation in sustainable, green infrastructure, we must engender trust, predictability, and confidence in our innovation system.

As the President stated at the IBTs Summit, through our social compact, development finance institutions, banks and insurers have undertaken to align funding instruments, de-risk projects, and recognise certified IBT housing as financeable and insurable assets.

This provides an opportunity for all stakeholders to work together to drive inclusive growth, job creation, and skills development to meet the demands of a growing, sustainable built environment.

As DPWI, are committed to transparent governance and risk management to attract sustainable financing and develop bankable projects that are high quality, deliver returns, and uplift communities.

We need greater collaboration between government, industry, academia, and international partners to accelerate delivery and scale innovation.

INCLUSIVE INFRASTRUCTURE DELIVERY

Compatriots, projects must uplift local communities, create jobs, and empower women, the youth, and People With Disabilities.

Inclusivity is not a side goal.

We must remain focused on developing resilient and sustainable, people-centred infrastructure, ensuring that no community is left behind in the march towards progress.

HUMAN CAPITAL AND SKILLS

Working with you, let us encourage investments in training programs, innovation hubs, and partnerships with universities to prepare our workforce for the demands of sustainable construction.

Skills are the true foundation of resilient infrastructure. Without skilled engineers, artisans, and project managers, our vision cannot be realized.

Through Professional Services, the Department of Public Works and Infrastructure must continue to support black learners and female learners from our impoverished townships and rural villages in the STEM subjects.

To build a credible skills pipeline, DPWI has a duty to continue investing in its university bursary programme which supports a number of learners at our public universities.

The Department of Public Works and Infrastructure also implements the Artisan Development Programme to contribute towards the country's target of producing 30 00 Artisans per annum as pronounced by President Ramaphosa during 2023 State of the Nation Address (SONA).

Our Artisan programme focuses on developing construction trades such as Bricklaying, Welding, Carpentry, Painting, Mechanical, Fitter and Turner, Electrical, Plumbing, Boiler Making.

We contribute to the building capacity for Facilities Management to comply with the National Immovable Assets Maintenance Management (NIAMM) standards.

The resuscitation of our technical maintenance workshops to in-house the maintenance of the department contributes in the capacitation of the state to respond to state building maintenance needs.

The pool of artisans within the Department is aimed at ensuring proper implementation of maintenance strategy and capacitate the Department to be able to respond to preventative maintenance and corrective maintenance.

DPWI Artisan Development Programme appoints TVET College students who have undergone the Nated qualification. The apprenticeship is for 36 months and students get an opportunity to be exposed to the construction trade work. They further undertake trade preparation. When they are ready and prepared, they go for trade tests at accredited centres.

Research shows that currently, our country produces too few artisans to meet the needs of the economy.

An estimated 26 000 artisan learners enter vocational training each year and only about 15 000 qualify.

We call on the private sector, academia, and SETAs to play a greater role to ensure that South Africa train enough artisans.

To address the low throughput, government offers various incentives including tax rebates, RPL grants to SETAs, and artisan development grants to employers to train artisans.

GOVERNMENT ROAD-MAP

The government's road map is clear:

Embed sustainability, resilience, and inclusivity into all infrastructure projects.

Align national standards with international best practices.

Foster innovation ecosystems that link industry, academia, and government.

Ensure that every project contributes to climate resilience, economic growth, and social equity.

No single institution can transform the built environment alone.

We therefore call for a compact among the government departments responsible for the built environment; municipalities; regulators; universities; professional councils; manufacturers; financiers; contractors; and communities.

The CBPM 2026 conference should be positioned, and remembered, as a platform for practical collaboration, not only academic exchange.

CONCLUSION

Colleagues, the future of South Africa's built environment depends on our collective resolve.

Together, we can build a nation where innovation drives sustainability, where resilience safeguards prosperity, and where infrastructure is not just built—but endures.

Let us construct beyond buildings and roads, but hope, opportunity, and lasting progress for generations to come.

I thank you!

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.

FROM SUMMIT DECLARATIONS TO DELIVERY:
THE 2026 IMPLEMENTATION AGENDA

BY CIDB CEO, BONGANI DLADLA

23 JUNE 2026

OPENING AND ACKNOWLEDGEMENTS

Conference Secretariat and Leadership:

- Prof. Abimbola Windapo of University of Cape Town,
- Prof. Ayodeji Aiyetan of Durban University of Technology,
- Mr Darmarajan Chinasamy of University of Cape Town,

Agrément South Africa Representatives,

Policymakers,

Municipal Building Control Officials,

Financial Institutions,

IBT Manufacturers,

Academics,

Practitioners,

Colleagues,

Programme Director,

Ladies and gentlemen, good morning!

It is an absolute pleasure to be back on the ground, and occasionally in the air, connecting with the people who are actively building the future of our country.

I must thank Professor Windapo and the CBPM team for convening this crucial dialogue.

Let’s give them a round of applause!

Looking around this room, I don't just see conference delegates; I see the architects of a modernised, resilient South African construction value chain.

The great African leader, Samora Machel, once said: *"International solidarity is not an act of charity: It is an act of unity between allies fighting on different terrains toward the same objective."*

Today, we are allies fighting on different terrains: regulatory, academic, financial, and practical. But we share a singular, non-negotiable objective: to modernise this sector and build a resilient future for our people.

We also meet today during a sacred month on the South African calendar, Youth Month. Today, in June 2026, the question we must ask ourselves is: *What are we legacy building for the youth of today?* The great Oliver Tambo famously said: *"A nation that does not take care of its youth does not deserve its future."*

If we want a resilient future for our built environment, we must acknowledge that this future belongs to our young people. But they cannot inherit an industry trapped in obsolete, slow, and carbon-heavy methodologies.

Modernising the construction industry through Innovative Building Technologies is our generation's responsibility to the next.

MOVING BEYOND THE SUMMIT

Let us be honest with one another. South Africa's construction and human settlements sector has reached an undeniable inflexion point. Behind us, we have a trail of declarations.

In November last year, the cidb National Construction Summit laid down the challenge: modernisation is no longer optional. It is the master key to unlocking rapid infrastructure delivery, strengthening governance, and raising performance across the board.

Just a few months later, in February, the IBT Presidential Summit reinforced our national marching orders: we must deliver public housing faster, better, and at a scale never seen before, all while maintaining absolute quality and public trust.

But declarations don't mix concrete. Resolutions don't shelter a family from the winter rains of the Western Cape.

We cannot remain professional tourists travelling from summit to summit, admiring the problem. Our people do not need more conclusions; they need commitments. They need an enablement system that actually works.

DISMANTLING THE BARRIERS

Innovative Building Technologies are no longer alternative or niche experiments. They are the structural tools we need to build resilience against devastating floods, fires, and extreme weather patterns.

They are our best vehicle to enable industrialisation, boost localisation, eliminate site waste, and vastly improve lifecycle value. Critically, for the cidb, IBTs represent a massive frontier for transformation. Traditional construction has high structural and physical barriers to entry.

But the IBT value chain from digitised component manufacturing and smart logistics to precision on-site assembly is inherently aligned with a digitally native generation.

Mainstreaming these technologies creates high-value, sophisticated entry points for youth-owned SMMEs, women, and local suppliers within the manufacturing and construction

supply chains. We aren't just changing how we build; we are changing who builds. We are shifting young people from the periphery of casual labour into the core of industrialised manufacturing.

Yet mainstreaming hasn't happened. Why? Because we have trapped innovation in a perpetual loop of pilot projects. As Agrément South Africa pointed out during their stakeholder engagement in February, the bottlenecks are clear:

- Fragmented institutional coordination.
- Procurement frameworks rigidly designed only for conventional brick-and-mortar.
- Risk-averse financial institutions and limited access to specialised skills.
- Approvals that stall within municipal building control systems.

We are asking innovators to build the future using a bureaucratic playbook from the past. It is time to change the rules of the game.

WHAT WE MUST FIX TODAY

This workshop is uniquely structured to do exactly that: to build a functional ecosystem in a single day. We are here to unlock three specific levers:

1. A fast-track regulatory pathway: We need an aligned, seamless conveyor belt stretching from Agrément SA certification, through NHBRC enrolment, straight to municipal building control approvals. Industry confidence grows when timelines are predictable.
2. Procurement fit for purpose: The cidb is deeply committed to performance, governance, and compliance priorities. We need to translate technical evidence into pro-innovation, performance-based specifications that public sector Supply Chain Management teams can legally and confidently implement without fear of audit irregularities.
3. Bankable project packaging: We must de-risk these projects so that funders and insurers don't view innovative as a synonym for hazardous.

OUR COMMITMENT

As the cidb, we are not just observers of this process; we are active partners. We are ready to align our performance standards and development priorities with the outcomes of today's workshop to ensure public sector delivery is both agile and compliant.

As we evaluate these manufacturer platforms and look to iron out the regulatory and procurement bottlenecks today, let us do so with the urgency that our demographic reality demands.

Without further ado, let this Youth Month be defined not by speeches and promises, but by practical access. Let us approach today's sessions with a spirit of radical collaboration.

Let’s interrogate the manufacturer evidence platform, score the solutions rigorously, and sign off on a Cape Town IBT Advancement Action Plan that guarantees young entrepreneurs, women, and local suppliers a permanent seat at the delivery table.

Let us give the youth of 2026 an industrialised, modernised, and accessible construction sector that they can proudly lead into the next half-century.

Thank you very much, and let’s get to work.

ENDS.

Dr Martin Röck

Dr. Martin Röck is a climate impact and eco-social transformation scholar exploring life cycle sustainability dynamics of the built environment. His practice focuses on assessing and improving the climate and environmental impacts of buildings and building stocks at national and transnational scales. Martin and colleagues use life cycle-based assessment methods such as Life Cycle Sustainability Assessment (LCSA), Building Information Modelling (BIM), Data Science and AI methods to support the development of benchmarks, targets, and policy pathways. Martin Röck has led policy-informing research projects for the European Commission and vairous national governments, as well as for leading private and public funders. Martin's insights help decision makers in industry and policy spaces identify and promote effective strategies for planning and implementing sustainable building design and regenerative spatial development. Martin advises policy makers and industry leaders at national, European, and global levels to support concrete actions to reduce environmental impacts and improve the life cycle performance of buildings. Martin received a Research Fellowship of the Austrian Academy of Sciences and previously researched and taught at KU Leuven (Belgium), ETH Zurich (Switzerland), UNICAMP (Brazil), and TU Graz (Austria). Today, Dr. Martin Röck is the Founder and Director of the RISE Institute for Regenerative Spatial Systems Science (Vienna, Austria) and Director of internationally-active GBDI, the Global Building Data Initiative (Lausanne, Switzerland).

TOWARDS REGENERATIVE SPATIAL SYSTEMS: ADVANCING ENVIRONMENTAL LIFE CYCLE MODELLING FOR SUPPORTING LOW/NO CARBON AND CLIMATE RESILIENT BUILDING STOCK DEVELOPMENT

BY DR MARTIN RÖCK

24 JUNE 2026

Abstract

The imperative to expand housing and infrastructure worldwide collides with the equally urgent requirement to achieve deep-scale climate mitigation and adaptation. Although a range of low-carbon and climate-resilient technologies has been identified, their successful implementation is contingent upon a multitude of context-specific factors—including local climate conditions, material supply chains, market readiness, spatial development patterns, and prevailing building cultures.

This talk showcases how advanced, high-resolution spatial and life-cycle modelling of individual buildings and whole-stock evolution can serve as a decision-support platform for navigating this complexity. Presenting the learnings from integrating climate and population projections, detailed building modelling and material-flow inventories, market readiness and adoption dynamics, and transnational climate policy levers into a unified building stock development modelling framework.

The framework enables to:

- Quantify both operational and embodied carbon trajectories for existing and future building stocks.
- Identify the most effective retrofit and new-construction strategies for distinct geographic and socioeconomic contexts.
- Evaluate trade-offs among carbon performance, climate resilience, economic viability, and implementation feasibility under realistic adoption scenarios.

Illustrative case studies demonstrate how these insights enable planners, developers, and policymakers to prioritize interventions that are technically feasible, financially sound, and culturally appropriate. Ultimately, such data-driven analysis is essential for progressing from conventional “green” building practices toward regenerative spatial systems—built environments that actively restore ecosystem services, sequester carbon, and adapt to a changing climate while delivering affordable, high-quality housing.

Dr Shaun Lundy

Dr Shaun Lundy is an experienced Chartered Safety and Health Practitioner and Chartered Building Engineer with over 25 years of national and international professional practice. He has a strong track record of driving innovation in health and safety, developing practical and creative solutions that deliver meaningful improvements without unnecessary bureaucracy. Dr Lundy regularly collaborates with professional bodies and regulatory organisations, contributing to policy development and helping to shape national agendas for change. He is also a confident and engaging presenter, with extensive experience speaking at conferences, chairing professional meetings, briefing board-level audiences, and engaging effectively with employees across all organisational levels.

TOWARDS BEYOND COMPLIANCE: THE GOLDEN THREAD AND THE FUTURE OF BUILDING SAFETY RISK MANAGEMENT.

BY DR SHAUN LUNDY

25 JUNE 2026

Abstract

Effective building safety requires more than compliance with individual regulations at particular stages of a project. This presentation explores the "golden thread" as a continuous, reliable body of information that supports building safety decision-making throughout the asset life cycle. It considers how information, accountability and risk management can be connected from design and construction through handover, occupation, maintenance and change. The presentation highlights the role of digital information, clear responsibilities and evidence-based decision-making in improving the visibility and management of safety risks. It also considers the implications for clients, designers, contractors, building operators and regulators, arguing for a more proactive and integrated approach in which safety information is maintained, accessible and used throughout the life of the building.

CONFERENCE GUESTS SPEAKERS AND PANELISTS

The CBPM 2026 Organising Committee would like to thank our conference guests for accepting the invitation to come and share their presence and thoughts on Towards Resilient Futures: Sustainable Construction and Innovation in the Built Environment debacle with construction stakeholders, the academic and professional community.

Dr Luyanda Mpahlwa

A Cape Town-based Architect & Urban Design practitioner, pursuing socially relevant architecture with a focus on the transformation of urban environments, in particular reimagining our cities as inclusive, affordable and liveable environments, accessible to all. He obtained his Masters' in Architecture at the Technical University of Berlin, Germany. He is the Director of Architecture & Design Network and has been in practice since relocation from Berlin in 2000. His education in South Africa was interrupted when he was incarcerated on Robben Island Prison in 1981 for his role in the anti-apartheid struggle. After his release in 1986, he left for Germany, where he spent 15 years in exile.

He was awarded an Honorary Doctorate in Science and Technology from the Walter Sisulu University in 2010 for his contribution to innovative, socially relevant design and technology. Currently he is an Adjunct Professor at the UCT, African Centre for Cities. He is former President of the South African Institute of Architects (SAIA). He is a member of SACAP (South African Institute for the Architectural Profession) and UDISA,(Urban Design Institute of South Africa).

Luyanda has received various design Awards, including SAIA/Corobrik Award of Excellence in 2006 for the South African Embassy building in Berlin, Germany. He was the recipient of USA based Curry Stone Design Prize in 2008 for the Design Indaba Sandbag Low-Cost House in Mitchells Plein, Cape Town. This project was investigating alternative building systems and materials. He was part of the Technical Team of advisors for providing oversight and monitoring of the construction of the 2010 FIFA World Cup Stadia in South Africa.

He has served on various Boards & Councils, including the South African Heritage Resources Agency (SAHRA), the National Heritage Council (NHC), and previously, the Robben Island Museum Council and the Board of the South African Institute of Architects (SAIA). He also previously served in the Councils of UCT and the Walter Sisulu University (WSU).

SCALING INOVATIVE BUILDING TECHNOLOGIES THROUGH MARKET ACCEPTANCE AND DEVELOPMENT FINANCE

BY DR LUYANDA MPHALWA

23 JUNE 2026

Abstract

South Africa's housing and infrastructure challenges require approaches that can improve delivery speed, affordability and resource efficiency while remaining technically credible, commercially viable and acceptable to end users. The presentation examined these issues through practical experience with alternative and innovative building technologies (IBTs), with particular attention to how innovation can help address the country's housing backlog and the realities of delivery in township and informal-settlement contexts.

The presentation highlighted the importance of moving beyond small-scale demonstration projects towards IBTs that can be replicated and implemented at scale. Drawing on a practical low-cost housing project involving a sandbag and timber-frame system, the presentation demonstrates how innovation can respond to land constraints, affordability, local participation and construction practicality. The project also illustrated the importance of designing for municipal approval, integrating local labour and suppliers, and maintaining construction quality through appropriate professional oversight and prefabrication.

A central argument was that successful IBT adoption depends not only on the technology itself but also on the wider development and regulatory ecosystem. Certification, municipal approvals, NHBRC requirements, professional responsibilities, quality assurance, financing, insurance, contractor capability and end-user acceptance must operate coherently. The presentation identified ambiguity in professional and regulatory responsibilities, limited sector knowledge, bureaucratic processes and weak confidence among clients and users as barriers to wider adoption of alternative and innovative building technologies. It also emphasised the role of universities and professional education in building confidence and strengthening capacity across the built environment.

The presentation concluded that IBTs must be positioned within viable development and procurement models that can move beyond isolated projects. Greater collaboration among architects, engineers, project managers, regulators, financiers, manufacturers, and communities is essential to build confidence, strengthen market acceptance, and create pathways to scale innovation. Ultimately, successfully mainstreaming IBTs requires not simply innovative products, but an enabling system that supports approval, professional confidence, finance, quality, market acceptance, and scalable delivery.

MR. DAVID OLIPHANT

Mr. David Oliphant is a University of Cape Town graduate and an accomplished built environment professional with more than ten years of experience spanning construction, quantity surveying, project management, investment analysis and impact investing. He began his career with Group Five Construction, where he spent five years working on government infrastructure projects, before joining Old Mutual as an Investment Analyst. During his four years at Old Mutual, he focused on building and infrastructure investments designed to generate both financial returns and broader social and economic impact.

David currently works in the impact investment space as a consultant and also serves as Chief Executive Officer of Teach the Nation, where he contributes to leadership development through education-focused programmes. His professional interests sit at the intersection of infrastructure development, investment, social and economic mobility, and impact research.

Drawing on his experience as both a construction professional and investment analyst, David is particularly interested in how sustainable development can be advanced through systems thinking, sound investment decisions and meaningful investment in people.

MAKING IBT PROJECTS BANKABLE AND INSURABLE: DE-RISKING, READINESS PACK, AND FUNDING NAVIGATION

BY MR. DAVID OLIPHANT

23 JUNE 2026

Abstract

Innovative Building Technologies (IBTs) offer significant potential to improve the sustainability, efficiency and scalability of housing delivery in South Africa. However, these technologies can achieve widespread market adoption only if projects meet the requirements of regulators, insurers, mortgage providers, and investors. This presentation examines the conditions required to make IBT projects both bankable and insurable, drawing on practical experience from an anonymised South African IBT development case.

The presentation identifies certification as central to the commercialisation pathway. Agrément certification, together with NHBRC enrolment, provides a basis for demonstrating technical compliance, supporting mortgage eligibility and facilitating access to commercial insurance. The case further illustrates the importance of pilot projects, quality management systems, supply-chain readiness, verified cost information and evidence of market acceptance in reducing perceived technology and delivery risks.

A structured readiness framework is proposed, incorporating technical certification, insurance pathways, mortgage eligibility, pilot performance data, quantity-surveyor-verified cost models, scalability evidence, risk allocation and appropriate development structures. Particular attention is given to land availability and plot-and-plan models, which can reduce investor exposure by linking construction to confirmed end-user demand and mortgage finance.

The presentation concludes that bankability should be considered from the early stages of IBT development, not only when external finance is sought. Certification, insurability, mortgage eligibility, development structuring and investor confidence need to be approached as an integrated de-risking pathway if IBT housing solutions are to progress from demonstration projects to commercially scalable delivery.

Mrs. Thamini Nyide

Mrs. Thamini Nyide is the Chief Executive Officer of the Joint Building Contracts Committee and has over a decade of experience in the built environment. She holds a BSc Honours in Quantity Surveying, an MSc in Construction Management, obtained Summa Cum Laude, and is a Green Star Accredited Professional with the GBCSA. Her expertise lies in construction contract development and implementation, where she contributes to improving practice within the South African construction industry. Drawing on her academic background from the University of KwaZulu-Natal, she focuses on innovative construction methods, transformation, and workplace wellbeing. Thamini is also an active academic, contributing to research on public sector procurement through conferences and journal publications. She is committed to advancing women in construction through her PhD research and transformation committee work. She recently launched the JBCC's "Beautifully Built" campaign, creating a platform for important conversations among women in the built environment.

Professor Justus 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.

Mrs. Dominique Geszler

Ms. Dominique Geszler is a Professional Architect (PrArch) with more than 30 years of experience in architectural practice, building regulations, research, and sustainability innovation. She is the Technical Group Leader for Research and Development at Agrément South Africa, where she manages the R&D portfolio, strategic planning, stakeholder engagement, and research outputs supporting innovation and performance-based evaluation in the built environment. She holds a Master of Architecture by research with distinction from the University of the Witwatersrand, focused on low-carbon housing pathways, and a Bachelor of Architecture from the University of Pretoria. Her expertise spans energy efficiency, innovative building technologies, regulatory frameworks, sustainability research, and design. Dominique previously held senior roles at NHBRC and SABS, contributing to national building standards and regulatory advice. Registered with SACAP and PIA, she continues advancing sustainable, climate-appropriate, innovative housing in South Africa**.**

Mr. Fabio Companie

Mr Fabio Companie is the Head Construction Manager at the City of Cape Town, where he contributes to the planning, coordination, and delivery of construction-related projects within the municipal environment. His work supports infrastructure implementation, project oversight, stakeholder coordination, and the effective management of built environment activities. With practical experience in construction management and public-sector project delivery, Mr Companie brings valuable insight into the challenges and opportunities associated with urban infrastructure, service delivery, and sustainable development. His leadership perspective adds important value to discussions on construction innovation, implementation readiness, and strengthening collaboration between government, industry, and built environment professionals.

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ACADEMIC PAPERS: THEME 1 -
Digital Transformation, AI, BIM, Robotics and Smart Construction

Assessing Critical Success Factors for Implementing Artificial Intelligence (AI) in Public Procurement

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Abstract

Artificial intelligence (AI) offers significant potential to enhance efficiency and accountability in public procurement, yet its implementation remains limited, particularly in developing economies. Drawing on Institutional Theory and the Technology-Organisation-Environment (TOE) framework, this study identifies and clusters critical success factors (CSFs) for AI implementation in Nigerian public procurement. A quantitative survey of 71 procurement professionals across federal Ministries, Departments, and Agencies (MDAs) assessed 38 CSFs derived from literature. Data were analysed using descriptive statistics and exploratory factor analysis (EFA) with principal component extraction and Varimax rotation. Results identified appropriate team skills and knowledge, adequate technical know-how in AI tools, and adequate knowledge of AI applications as the top three CSFs. EFA revealed a ten-component model explaining 76.13% of variance, comprising: internal process coordination, data infrastructure, strategic leadership, vendor partnership, early-stage planning, user competence, data governance, project clarity, executive support, and technical compatibility. All components demonstrated acceptable reliability (Cronbach's α = .623–.891). The study contributes an empirically derived ten-factor model to guide evidence-based policymaking for AI adoption in public procurement. Limitations include the exploratory nature of the findings and the Nigeria-specific context, requiring validation in other settings.

Keywords: Artificial intelligence, critical success factors, public procurement, implementation, factor analysis, developing economy
Paper type: Research paper

1. Introduction

Public procurement plays a vital role in how governments deliver goods, works, and services to citizens. Yet, the process is often hindered by inefficiencies, lack of transparency, and outdated manual procedures (Allal-Chérif et al., 2021; Rejeb et al., 2018). Among technological innovations, Artificial Intelligence (AI) stands out as a tool with strong potential to transform procurement practices (Constant et al., 2022; Cui et al., 2022).

Research on digitalisation in procurement suggests that technologies such as AI can bring significant value (Kosmol et al., 2019). AI has proven useful in cost estimation, supplier evaluation, auctions, and risk management (Jahani et al., 2021; Niyazbekova et al., 2021). Similarly, AI shows promise in improving planning, strategy development, and contract management (Buchholz & Grabbe, 2022; Schulze-Horn et al., 2020).

Despite these benefits, AI use in public procurement remains very limited (Andersson, 2025). Unlike private procurement, public procurement is bound by stricter requirements for openness, ethical considerations, and complex regulations (Sanchez-Graells, 2024; Nowicki, 2020). These factors create unique challenges, including data protection concerns, need for high-quality datasets, limited digital skills, and uncertainty about AI applications (Nowicki, 2020; Guida et al., 2023).

Recent studies have examined barriers to AI adoption and developed AI-based decision support systems (Rejeb, 2018; Siciliani et al., 2023; Andersson, 2025). However, there remains a lack of research focused on assessing the Critical Success Factors (CSFs) necessary for successful AI implementation in public procurement.

This study bridges this gap by identifying and categorising the success factors required for AI adoption in public procurement within a developing economy context.

2. Literature Review

2.1. Defining AI in Public Procurement

This study adopts a functional definition of AI in public procurement, encompassing three primary use cases: (a) automated supplier pre-qualification and risk assessment, (b) intelligent contract monitoring and anomaly detection, and (c) predictive analytics for

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demand forecasting and price optimisation. These use cases span multiple stages of the procurement lifecycle, including planning, preparation, contract award, and contract management. Implementation success is defined as the effective integration of these AI capabilities into procurement workflows, resulting in measurable improvements in efficiency, compliance, or cost savings.

2.2. Critical Success Factors

Several studies have contributed to understanding determinants of AI implementation. Wuni (2025) investigated CSFs for AI in construction projects, identifying organisational readiness, data quality and technical competence as fundamental enablers. Makarius et al. (2020) emphasised employee skills, leadership support and organisational culture. Solaimani and Swaak (2023) highlighted interdependence between strategy, structure and technology readiness. Merhi (2023) focused on AI readiness in public organisations, identifying data management, regulatory alignment and digital competency as core determinants.

The 38 CSFs presented in Table 1 were derived through systematic literature synthesis of these four key studies. Overlapping factors across studies were merged into single items. For example, "top management commitment" (Merhi, 2023) and "leadership commitment" (Wuni, 2025) were combined into "Top management commitment and support" (CSF9).

This study draws on two complementary theoretical lenses to interpret the CSFs. Institutional Theory (DiMaggio & Powell, 1983) explains coercive (regulatory), mimetic (peer adoption), and normative

Table 1: Success factors for implementing AI

Code	Critical Success Factor
CSF1	Clear strategy and business model for AI
CSF2	Managerial competence and capabilities in AI
CSF3	Effective risk management for AI technologies
CSF4	Effective AI leadership and governance
CSF5	Adequate financial resources allocation
CSF6	Conducive organisational culture for AI
CSF7	Sufficient organisational readiness for AI
CSF8	Clear assignment of roles and accountabilities
CSF9	Top management commitment and support
CSF10	Extensive front-end planning for AI
CSF11	Effective change management strategy
CSF12	Clear vision and clarity of business case
CSF13	Alignment of AI with strategy and needs
CSF14	Clear and realistic AI objectives
CSF15	Supportive organisational infrastructure
CSF16	Robust supportive technological infrastructure
CSF17	Appropriate AI techniques and tools
CSF18	Adequate computing capabilities
CSF19	Adequate knowledge of AI applications
CSF20	Adequate technical know-how in AI tools
CSF21	Strong expertise of AI developers
CSF22	Robust integration into workflow
CSF23	Appropriate team skills and knowledge
CSF24	Appropriate integration with legacy systems
CSF25	Appropriate AI algorithms and models
CSF26	Technical compatibility with infrastructure
CSF27	Familiarity with AI tools
CSF28	Support from qualified AI vendors
CSF29	Early client commitment to AI
CSF30	Early involvement of AI consultants
CSF31	Early cross-functional team collaboration
CSF32	High quality and integrity of data
CSF33	Effective data management and governance
CSF34	Cyber security of data and algorithms
CSF35	Availability of high-value data
CSF36	Robust data ecosystems
CSF37	Sufficient quantity and flow of data
CSF38	Adequate data storage and cloud resources

(professional standards) pressures shaping AI adoption. The Technology-Organisation-Environment (TOE) framework (Baker, 2012) provides a multi-level categorisation of factors influencing technology adoption across technological, organisational, and environmental contexts.

3. Methodology

3.1. Questionnaire Design and Administration

A structured questionnaire was developed based on the literature review. To enhance content validity, the questionnaire was reviewed by a senior lecturer with over 10 years of industry and academic experience. The questionnaire comprised two parts: demographic information, and 38 Likert-scale items (1=strongly disagree to 5=strongly agree) measuring CSFs.

Respondents were procurement professionals from Nigerian federal MDAs. Using Yamane's (1967) formula, 109 MDAs were sampled. Of 109 questionnaires distributed, 71 (65%) were retrieved and analysed. Table 2 presents respondent demographics.

Table 2: Demographic information

Table 2. Demographic Information of Respondents		
Main variable specific variable	Frequency	%
Nature of procurement		
procurement services	32	45%
procurement goods	24	34%
procurement works	15	21%
Years of experience		
Less than 5 years	27	38%
6-10 years	29	41%
10-15 years	11	15%
more than 15 years	4	6%
Educational qualification		
HND	12	17%
B.Sc.	45	63%
M.Sc.	14	20%
Rank		
Senior management	11	15%
Middle management	27	38%
Low management	22	31%
Operational level	11	15%
Total	71	100%
Source: Author's own work		

3.2. Data Analysis

Data were analysed using SPSS version 22. Descriptive statistics (mean, standard deviation) ranked the 38 CSFs. Exploratory Factor Analysis (EFA) identified underlying latent structure using Principal Component Analysis (PCA) with Varimax rotation. Factor retention used eigenvalues >1.0 and scree plot inspection. Factor loading threshold of |0.5| was applied.

The Kaiser-Meyer-Olkin (KMO) measure was .772, exceeding the 0.6 threshold. Bartlett's Test of Sphericity was significant ($\chi^2 = 1880.108$, df = 703, $p < .001$), confirming data suitability for EFA.

Regarding sample size, while the 71:38 variable ratio (1.9:1) is below conventional heuristics, simulation studies (de Winter et al., 2009) demonstrate that EFA can yield stable solutions with smaller samples when communalities are high (>0.6) and factor loadings are strong (>0.7). Results should be interpreted as exploratory.

4. Results

4.1. Ranking of Critical Success Factors

Table 3 (Appendix 1) presents mean scores and ranking of all 38 CSFs (top 10 and bottom 10 shown for brevity). The three factors perceived as most critical were: Appropriate team skills and knowledge (CSF23, M=4.04), Adequate technical know-how in AI tools (CSF20, M=4.02), and Adequate knowledge of AI applications (CSF19, M=4.00). This emphasises human capital and technical competence as immediate prerequisites.

4.2. Exploratory Factor Analysis

EFA extracted ten components with eigenvalues >1.0, explaining 76.13% of total variance. Table 4 presents the rotated component structure.

Table 4: Exploratory factor analysis results

Component	Proposed Theme	Eigenvalue	Variance%	α
1	Internal Process & Team Coordination	12.434	32.72	0.891
2	Data Infrastructure & Ecosystems	3.237	8.52	0.867
3	Strategic Leadership & Governance	2.49	6.55	0.799
4	Vendor Partnership & System Integration	1.998	5.26	0.845
5	Early-Stage Planning & Alignment	1.949	5.13	0.812
6	User Competence & Workflow Adoption	1.627	4.28	0.784
7	Data Governance & Algorithmic Quality	1.52	4.00	0.741
8	Project Clarity & Organisational Readiness	1.358	3.57	0.784
9	Executive Support & Financial Resources	1.196	3.15	0.623
10	Technical Compatibility & Vendor Reliance	1.123	2.95	0.705

Note: Extraction Method: Principal Component Analysis. Rotation: Varimax with Kaiser Normalization. KMO = .772. Bartlett's Test: $\chi^2 = 1880.108$, df = 703, $p < .001$. Factor loadings <0.5 suppressed.

4.3. Interpretation of the Empirical Model

The ten-component model offers a granular structure for AI implementation. Component 1 (Internal Process & Team Coordination, α=0.891) captures organisational mechanisms including role clarity, team collaboration, and change management. Interpretation: Respondents saw internal processes, team coordination, and technological infrastructure as inseparable—addressing technology alone without clear roles is insufficient.

Components 2 (Data Infrastructure, α=0.867) and 7 (Data Governance, α=0.741) distinguish having data from managing data properly. Interpretation: In Nigerian MDAs, fragmented databases mean data infrastructure and governance require different capabilities.

Components 3 (Strategic Leadership, α=0.799) and 9 (Executive Support, α=0.623) address leadership dimensions. Components 4, 5, and 10 capture external collaboration. Components 6 and 8 focus on human and project dimensions. The model reveals that success requires simultaneous attention to strategic, organisational, human, collaborative, and technical fronts.

5. Discussion

The finding that human capital factors (CSF23, CSF20, CSF19) rank as top three CSFs underscores that in the Nigerian public procurement context, workforce readiness precedes technological investment. This aligns with Makarius et al. (2020), who argued that AI adoption fails without corresponding investment in employee skills. However, it diverges from Merhi (2023), who found data management primary in private sector adoption. This contrast likely reflects Nigeria's public sector reality where basic digital literacy remains limited.

The ten-component EFA model provides empirical support for the TOE framework, with components distributed across technological (Components 2, 7, 10), organisational (1, 3, 6, 8, 9), and environmental (4, 5) dimensions. The separation of Data Infrastructure (Component 2) from Data Governance (Component 7) is a novel contribution not explicitly identified in prior studies (e.g., Wuni, 2025). This likely reflects a specific challenge in Nigerian MDAs: fragmented legacy databases mean having data and managing data require different capabilities.

The relatively low loading of financial resources (Component 9, α=0.623, 3.15% variance) suggests financial constraints, while present, are not perceived as the primary barrier. This contradicts assumptions that funding is the main obstacle in developing economies. Instead, human capital and process factors appear more critical.

A limitation of the current model is the modest reliability of Component 9 (α=0.623), containing only two items. Future research should expand measurement of executive support and financial resources.

6. Practical Applications and Recommendations

The ten-component model serves as a diagnostic tool for public procurement agencies.

For policymakers at federal MDA level:

Prioritise AI skills training programmes over immediate technology procurement. Invest in certified AI literacy courses for procurement officers before purchasing AI software.

Establish a national data governance framework for public procurement, including mandatory data quality standards.

For procurement agency heads:

Conduct readiness assessments using the ten components as a checklist. If Component 2 (Data Infrastructure) scores low, prioritise data cleaning before AI vendor selection.

Require AI vendors to demonstrate knowledge transfer and training plans to avoid vendor reliance (Component 10).

For quantity surveyors and procurement officers:

Develop internal AI competency working groups addressing Component 6 (User Competence) through peer learning.

Document early planning decisions (Component 5) to ensure alignment between AI objectives and procurement strategy.

For international readers, the ten-component model is transferable but requires local calibration.

7. Conclusion and Limitations

This study assessed critical success factors for AI implementation in Nigerian public procurement. The top three CSFs prioritise human capital (team skills, technical know-how, AI knowledge). The empirically derived ten-component model (76.13% variance explained) provides a structured blueprint distinguishing technological, organisational, and environmental dimensions.

Limitations: The sample (N=71) is modest for EFA, and findings are specific to Nigeria's federal MDA context. The cross-sectional design captures perceptions, not actual implementation outcomes.

Future research: Validate the ten-component model using confirmatory factor analysis with a larger, cross-national sample. Conduct longitudinal studies testing whether these CSFs predict actual AI adoption success. Investigate causal relationships among components (e.g., does Strategic Leadership predict Internal Process Coordination?).

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Appendix 1

Table 3: Descriptive statistics (top 10 and bottom 10 CSFs)

Descriptive statistic					
Code	Critical Success Factors	N	Mean	Std. Deviation	Rank
CSF23	Appropriate team skills and knowledge	71	4.04	1.075	1
CSF20	Adequate technical know-how and skills in AI tools	71	4.02	0.965	2
CSF19	Adequate knowledge of AI applications and requirements in the project	71	4.00	1.056	3
CSF17	Appropriate AI techniques and tools	71	3.97	1.171	4
CSF21	Strong expertise and experience of the AI developers	71	3.92	0.89	5
CSF24	Appropriate integration of AI with legacy systems	71	3.89	1.008	6
CSF18	Adequate computing capabilities and infrastructure in the project	71	3.76	0.992	7
CSF13	Alignment of AI with project strategy and business needs	71	3.70	1.101	8
CSF12	Clear vision and clarity of business case for AI	71	3.58	1.009	9
CSF30	Early involvement of AI consultant and vendors	71	3.58	1.051	10
CSF29	Early commitment of the client to AI in the project	71	3.56	1.092	11
CSF22	Robust integration of AI into workflow and processes	71	3.59	0.994	12
CSF34	Cyber security of data, infrastructure and algorithms	71	3.59	0.979	13
CSF38	Adequate data storage capacity and cloud resources	71	3.46	1.012	14
CSF33	Effective data management and governance strategy	71	3.48	1.054	15
CSF32	High quality and integrity of data for AI models	71	3.52	0.939	16
CSF25	Appropriate AI algorithms and models	71	3.51	1.026	17
CSF35	Availability and accessibility of high-value data	71	3.51	1.081	18
CSF31	Early commitment and collaboration of a cross-functional team	71	3.49	1.132	19
CSF15	Supportive organizational infrastructure	71	3.31	1.129	20
CSF10	Extensive font-end planning for AI integration	71	3.31	1.116	21
CSF26	Technical compatibility of AI with existing infrastructure	71	3.31	1.064	22
CSF16	Robust supportive technological infrastructure	71	3.42	1.009	23
CSF11	Effective change management strategy for AI integration	71	3.42	1.078	24
CSF37	Sufficient quantity and flow of data for AI models	71	3.44	1.131	25
CSF6	Conducive organisational culture for AI	71	3.44	1.038	26
CSF7	Sufficient organisational readiness for AI	71	3.37	0.989	27
CSF14	Clear and realistic objectives of AI in the project	71	3.39	0.948	28
CSF8	Clear assignment of roles, responsibilities and accountabilities for AI	71	3.21	1.054	29
CSF4	Effective AI leadership and governance	71	3.14	1.257	30
CSF3	Effective risk management for AI technologies	71	2.99	1.153	31
CSF2	Managerial competence and capabilities in AI	71	2.99	0.978	32
CSF1	Clear strategy and business model for AI	71	2.85	1.499	33
CSF9	Top management commitment and support	71	3.31	1.129	34
CSF27	Familiarity of the project team with AI tools in the project	71	3.27	1.121	35
CSF28	Support from qualified AI vendors	71	3.27	1.183	36
CSF36	Robust data ecosystems	71	3.44	1.119	37
CSF5	Adequate financial resources allocation for AI technologies	71	3.35	1.255	38

Digital Twins: Implications for Construction Material Supply Chain in Sub-Saharan Africa

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Abstract

Fragmentation, inefficiency, and poor performance are salient matters affecting the building sector. This research explores the role of Digital Twin Technology (DTT) in mitigating inefficiencies in the construction material supply chain. DTT plays a crucial role in improving the efficiency of the construction materials supply chain. This study outlines the critical roles of DTT in the construction supply chain. This exploratory research reveals the significance of DTT in the construction materials value chain and the implications for sub-Saharan Africa. This research adopts a quantitative research design. A Bibliometric-Systematic literature review was conducted by sourcing peer-reviewed articles from selected databases, including Web of Science and Scopus. Relevant themes on the role of DTT in the CMSC were generated. With the use of Vos Viewer, five critical themes (Management, Efficiency, Performance, Digital Transformation, Safety, Systems, Networks) were generated and explored on the pivotal role of DTT in the CMSC. These themes show the importance of the application of DTT in enhancing construction material supply chains. Findings of the research provide the need to expedite the implementation of DTT within Africa, since there is a lag in implementation due to several factors, such as the unawareness of the capabilities of DTT for strategic decisions in the construction sector. This study is significant because it shows how DTT can improve the construction supply chain management and enhance digital transformation.

Key Words: Construction Supply Chain, Digital Twin Technologies, Sub-Saharan Africa, Bibliometric Analysis, and VOSviewer

1. Introduction

DTT originated in 2002, when the white paper authored by Grieves (2016) was published. Grieves (2016) elucidated that DTT is a "digital informational construct of an actual and existing structure, which is based on the information derived. This digital information would be a 'twin or the duplicate' of the information that was embedded within the physical system itself. This information can be linked to that physical system throughout the system's lifecycle (Grieves, 2016). Although the concept of Digital Twin has been in existence since 2002, it began to gain traction at the beginning of the 21st Century (Grieves, 2023). Hence, the digital twin is still an emerging technology whose application has extended beyond manufacturing to various sectors of the economy. This research explores the capabilities of DTT in the Construction Supply Chain.

In the construction industry, even though building projects occur serially, it is discovered that relevant stakeholders continue to work in silos (Riazi et al., 2020). This segmented circumstance has prevented the industry from performing efficiently (Riazi et al., 2020; Liet al., 2026). Delayed information and even the lack of the correct and relevant information at the right time along the construction supply chain impedes efficiency. DTT transforms business functionality and operations (Attaran and Celik 2023). Based on several studies, the following are some of the challenges that emanate in the building sector: resilience, risks, and performance failure (Ding and Jie 2025). Fragmentation and operational silos in the Construction supply chain necessitate the need to probe the implications of DTT in the construction space (Riazi et al., 2020). The main objective of this research is to explore the potential of DTT in the construction material supply chain, specifically in mitigating inefficiencies. The main research question is, what is the role of Digital Twin Technology (DTT) in mitigating inefficiencies in the construction material supply chain?

Databases such as the Web of Science, Scopus, and Google Scholar were used to search for peer-reviewed articles, book chapters, and conference proceedings that included words such as "Digital Twin" or "Construction Supply Chain" in the title and abstract. These literary resources were explored due to the wideness of their scope. Section 2 discusses the review of the literature. Section 3 explains the methodology, while the findings and discussion are discussed in Section 4. The conclusion and further research are outlined in Section 5

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2. Review of Literature

DTT has transformed the process of monitoring, simulating, and optimizing the construction value chain (Bhatia and Khumar, 2026). Riazi et al. (2020) are of the view that the building value chain has generally been confronted with issues such as delays, cost overruns, and several others. Ineptitude surrounds some functions in the construction value chain (Riazi et al., 2020). Ahmadi et al. (2026) state that digital twin (DT) technologies streamline data management via virtual representations and real-time updates across the supply chain. Therefore, creating alerts wherever there might be hitches or delays in the value chain. DTT continuously updated with real-time data has the capability for dual interaction and engagement (Zhang et al., 2026). Fuller et al (2019) further describe DTT as the unification of data between reality and cyberspace. Over time, there has been an increase in the application of DTT in different industry fields (Hu et al., 2021). Companies in any sector, including construction, are quick to detect and solve physical problems, design and build better products, and realize value and benefits faster than previously possible (Attaran and Celik 2023). DTT allows companies, irrespective of their industry, to have a twin of their product in their full lifecycle, respond expeditiously to physical issues sooner, prognosticate situations before it occurs, and better serve their customers (Hu et al., 2021). Despite the several benefits of DTT, there is still a lag in its implementation in sub–Saharan Africa. The critical issue with the application of DTT is that it has not been implemented extensively in sub–Saharan Africa. One of the several reasons for the lack of implementation in Sub-Saharan Africa could be a lack of awareness (Awodele et al., 2025). This study, therefore, delves into the potential of DTT in CMSC, hence contributing to the body of knowledge on the pivotal role of DTT in CMSC.

2.1. Theoretical Framework

This section examines the underlying theoretical framework that governs this research. The digital transformation theory relates strongly to this research as it describes how the combination of technology, people, and process transforms organisations (Elia et al., 2024). The application of this theory is that DTT can be used as a tool to transform and enhance the CMSC processes and procedures. This theory implies that it mitigates the underlying risk that emanates from supply chain failure.

3. Research Methodology: Bibliometric Systematic Literature Review

The bibliometric systematic review (B-SLR) adopts the pillars of critical analysis and proffers the need for relevant theoretical contributions (Marzia et al, 2025). Lame (2019) attests that systematic literature reviews (SRs) include the process of applying empirical answers to respond to research questions. Furthermore, De Sousa et al. (2024) define bibliometrics as a procedure that enables the quantitative mapping of scientific information found in scientific literature. According to Marzia et al (2025), there are 10 steps involved in the B-SLR process. This is captured in Table 1 (Appendix 1). This study applies the Bibliometric-Systematic Literature Review (B-SLR) framework

The entire research process is captured in Table 1. Step 1 includes selecting a Research Topic; Step 2 involves Formulating Research Questions; Step 3 includes establishing the Study Boundaries. Steps 4 and 5 are data collection and cleaning, respectively. Step 6 involves the application of bibliometric methods, in this case, Vosviewer. Vos Viewer is a bibliometric mapping computer software that enhances the ability to examine the trends in DTT. Vos Viewer reveals the author, publication, keyword, journal, country, and citation variables (Van Eck and Altman, 2009). Van Eck and Altman (2009) further reiterate that VOSviewer builds maps of authors or journals based on co-citation data, or constructs maps of keywords based on co-occurrence data. Figure 1 shows the mapping of keywords on DTT. The data set was synthesized in step 7 to generate themes and clusters. The themes are outlined in Table 2. The themes generated aligned with the theoretical framework. Steps 8 and 9 deal with alignment to the theoretical framework. This is discussed in section 4. Section 10 is the last step that deals with the report findings. In this final stage, the themes were systematically generated and coalesced into categories. The final stage of the systematic content analysis was discussed in Section 4.

3.1. Intense use of Databases

This section outlines the Journal sourced from the database. The 95 Journals examined are reflected in Table 2 (Appendix 1). The Journal on Buildings had the most publications.

3.2. Bibliometric Mapping

VOSViewer is adapted for bibliometric mapping, and the search was conducted on the Scopus databases. Keywords with (“Construction industry” OR “Construction Supply Chain”) AND (“Digital Twin Technology”), AND (“Implications for Future”), for 2018-2026 were searched for on 19th February 2026. Peer-reviewed articles were sourced from the selected document type “article” or “review”. 1107 papers. The network analysis is depicted in Figure 1. The set of items included in the map is referred to as the cluster (Van Eck and Altman, 2009). The bibliometric mapping network has 5 clusters with 64 items. This is a map of terms related to DTT. These clusters are depicted with colors such as purple, yellow, green, red, and blue. Cluster red has the most keywords. The following keywords emerge from the mapping of DTT's role in the construction supply chain:

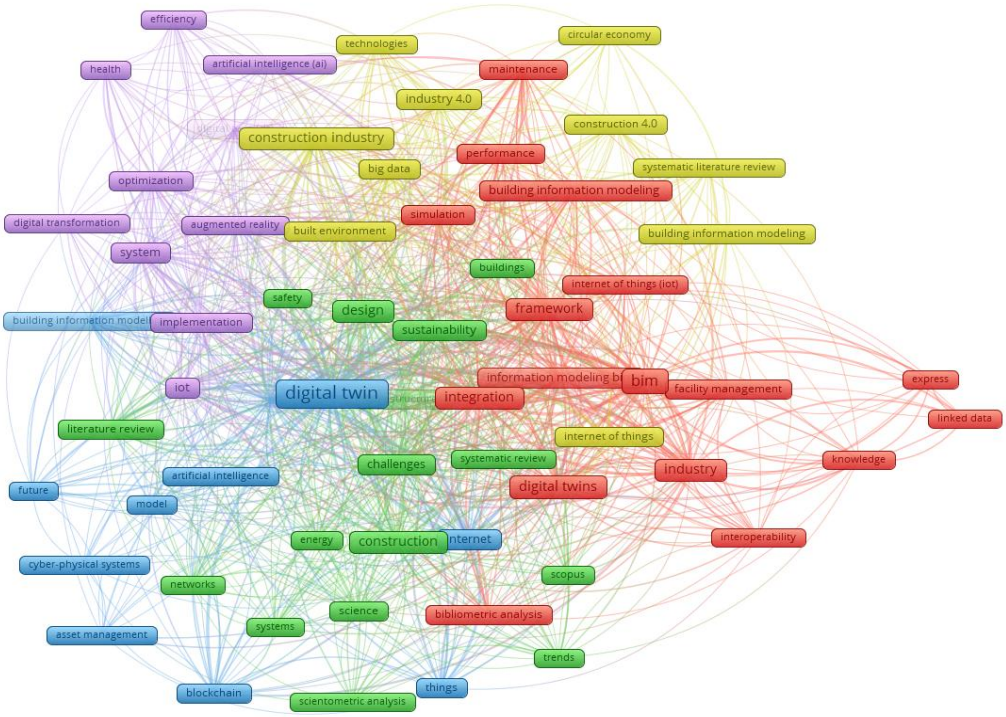

Figure 1: Map of Key Words on DTT
Source: Osundiran, 2026

Management, Efficiency, Performance, Digital Transformation, Safety, Systems, Networks. For instance, performance is a key term that emphasises the importance of DTT in improving the construction supply chain (Omrany et al., 2023; Hu et al., 2022; Qi et al., 2021). Managing the construction supply chain involves planning, controlling, and monitoring the entire process.DTT provides the manager the opportunity to identify possible gaps or problems that can emanate, therefore ensuring that the necessary action is taken to forestall the gap. DTT enhances efficiency in the process by reducing waste and delays. Performance is quickened when the manager can assess the value chain and prevent any situation that can lead to lags or hindrances. Digital transformation occurs when there is a shift from traditional procedures to digital, as DTT streamlines data management via virtual representations and real-time updates across the supply chain. Integrating these tools presents significant opportunities to support circular strategies in the building sector (Ahmadi et al., 2026).

4. Findings and Discussion

Five clusters are generated. These are named as Cluster 1 (Red) with 17 items, Cluster 2 (Green) with 16 items, Cluster 3 (Blue) with 11 items, Cluster 4 (Purple) with 10 items, and Cluster 5 (Yellow) with 10 items. The clusters explain the roles of DTT in the CMSC, as supported by the literature. Please refer to Table 3. Table 3 indicates the themes and the supporting literature. The first theme is facility management; DTT improves the efficiency of existing systems and structures (Wang et al., 2024). Efficiency borders on cost reduction and the ability to reduce waste in terms of time and resource allocation. Efficiency is another dominant theme in the role of DTT because it simulates and tests structures even before they are built (Wang et al., 2024).

For instance, when potential problematic situations are identified before they occur, improvements are enabled, hence leading to higher efficiency and higher delivery time (Wang et al., 2024). Performance is critical in construction. Non-performance affects buildings and, therefore, can lead to the demise of people. DTT is capable of predictive maintenance, which allows for early detection of faults, thereby promoting safety. DTT creates dynamic, evolving digital replicas of physical assets (Badenko et al., 2024). DTT enables just-in-time information (Preut et al., 2021). The themes generated align with the Digital Transformation theory because it shows how technology, in this case, a digital twin, can transform the construction material supply chain.

4.1. Implication of DTT for the Construction Supply Chain in Sub–Saharan Africa

The implication of the lack of adoption and slow implementation of DTT in Sub-Saharan Africa is that there will continually be delays in the overall supply chain. DTT provides the opportunity for transformation in the CSC. Nevertheless, many sub-Saharan African nations are yet to adopt DTT (Awodele et al., 2025).

Table 3: The Role of DTT in the Construction Supply Chain

The Dominant Theme	Clusters				
	1 Red	**2 Green**	**3 Blue**	**4 Purple**	**5 Yellow**
Facility Management	Facility Management Bhatia, and Kumar (2026) Badenko et al., (2024)	Infrastructure Broo et al., (2022)	Asset Management Attaran and Celik (2023)	Built Environment Wang et al (2024)	Digital Transformation Zhang et al., (2026)
Efficiency	Integration (Moshood et al., 2024)	Sustainability (Badenko et al., 2024 Moshood et al., 2024)	Building Information Management Wang et al (2024)	Construction Industry (Hu et al., 2021).	Efficiency (Hu et al., 2021). Liet al., 2026
Performance	Performance (Omrany et al., 2023)	Construction (Moshood et al., 2024)	Future Wang et al (2024)	Technologies Ahmadi et al. (2026)	Optimization Ahamadi et al., (2026)
Digital Transformation	Interoperability Mia and Haque, 2023)	Buildings Wang et al (2024) Avireneni et al., 2023)	Cyber Physical Systems Omrany et al., 2023	Digital Transformation Avireneni et al., 2023)	Implementation Fuller et al, (2019
Safety	Simulation Ahmadi et al. (2026) Agnusdei et al., 2025)	Safety Luo et al., (2025)	Management Ahmadi et al. (2026)	Circular Economy (Preut et al., 2021)	Artificial Intelligence Avireneni et al., 2023)
Systems	Predictive Maintenance (Hu et al., 2021). Wang et al (2024)	Systems Iliuță et al. (2024)	Artificial Intelligence Avireneni et al ., 2023)	Building Information Management (Mia and Haque, 2023)	System Avireneni et al., 2023)
Networks	Building Information Management Badenko et al (2024)	Networks Mashaly et al., (2021)	Model (Mashaly et al., 2021)	Construction 4.0 (Moshood et al, 2024)	Augmented Reality Wang et al (2024)

(Source: Osundiran, 2026)

There are many barriers to the adoption of DTT, hence, explaining why the adoption of DTT in the construction environment has not been smoothly implemented (Ibrahim et al., 2026). Some of the barriers include costs, lack of relevant skill set, infrastructure etc. Meanwhile, the construction industry is in dire need of a change due to the inherent challenges such as waste, delays, safety etc.

The implication of DTT for the construction supply chain in sub-Saharan Africa is that DTT can produce the change that is critical to ensure efficiency and accelerate performance. Therefore, there is an urgent need for stakeholders in the construction sector to be deliberate in transitioning from the traditional way of doing things to Industry 4.0(Moshood et al., 2024). The transformation is slow; however, there is an urgent need for stakeholders in the construction sector to continue conversations on how the processes and procedures can be improved. The potentials and benefits of DTT should be harnessed to accelerate the transformation to construction 4.0.

5. Conclusion and Further Research

The construction material supply chain sector is in dire need of an effective and efficient supply chain. This research advocates for the adoption of DTT in the construction sector. This research contributes to the body of knowledge by examining the pivotal role of DTT in enhancing the construction material supply chain.

This research focused on the role of digital twin technology in enhancing the construction supply chain. Even though the postulation of DTT has existed for over three decades, it has great significance in the

construction sector. A systematic literature review was done, and several themes emerged. The dominant themes included Facility Management, Efficiency, Performance, Digital Transformation, Safety, Systems, and Networks. These themes were threshed and discussed. The implementation of DTT in the sub-Saharan Africa construction industry should be examined since it has been successfully adopted in developed nations. Moshood et al al (2024) attest that DTT enhances efficiency and productivity in construction through increased innovation and improved collaboration, ultimately reducing information gaps and data discrepancies. The pivotal motivation of this research is to throw more light on the significance of DTT in the construction sector. Further research can be done on how the adoption of DTT can be enhanced in sub-Saharan Africa.

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Appendix 1

Table 1: Bibliometric Systematic Literature Review: The 10 Steps

Steps	Action Taken
Step 1: Selecting a Research Topic	The researcher scrutinized the existing literature on 'Digital Twins: Implications for Construction Material Supply Chain in Sub-Saharan Africa', to build an overview of the research stream. Key words such as: ("Construction Industry" OR "Construction Supply Chain") AND ("Digital Twin Technology"), AND ("Implications for Future"), from 2010 to 2026 were used. The search was conducted on 19th February 2026. Peer-reviewed articles were sourced from the selected document type "article" or "review".
Step 2: Formulating Research Questions	The main research question is, what is the role of Digital Twin Technology (DTT) in mitigating inefficiencies in the construction material supply chain? How can DTT enhance the construction material supply chain?
Step 3: Establishing Study Boundaries	The search query is defined as follows: ("Construction Industry" OR "Construction Supply Chain") AND ("Digital Twin Technology"), AND ("Implications for Future"), between 2010 and 2026. We ran the search query in the Web of Science. The literary publications were limited to those published in English and included Journal articles and Conference proceedings.
Step 4: Data Collection	The query generated 175 results with 77 Conference Proceedings and 98 Journal articles published in Web of Science. Three journal articles were removed because they were not in English. This means a total of 172 pieces of literature.
Step 5: Data Cleaning	Duplicates and ineligible documents were removed This has resulted in a final dataset of 172 literary pieces
Step 6: Applying Bibliometric Methods	Next, we moved to bibliometric analysis in VOSviewer version 1.6.20. (van Eck & Waltman, 2010). Section 3.2 captures the Bibliometric mapping
Step 7: Synthesizing Data	After independently reading the extracted documents, five clusters were identified with 64 items
Step 8: Alignment to theoretical framework	The following themes were generated: Efficiency, Management, Performance, Digital transformation, systems, safety and networks. This aligns with the digital transformation theory.
Step 9: Theoretical Findings/ Development	The clusters have been reviewed, and the keywords have been mapped in Figure 1.
Step 10: Report Findings	Based on the themes generated, DTT can enhance and improve the construction supply chain

Source: B-LS Framework adapted by Osundiran, 2026

Table 2: Journals Examined

Journals	Number of Selected Publications	References
Advanced Engineering Informatics	4	Su, SM; Zhong, RY; Jiang, YS; Song, JD; Fu, Y; Cao, HR Liu, Y; Feng, J; Lu, JM; Zhou, SY Jung, S; Jeoung, J; Kong, M; Jung, D; Hong, T Zhang, C; Wang, ZH; Zhou, GH; Chang, FT; Ma, DX; Jing, YZ; Cheng, W; Ding, K; Zhao, D
Advances in Civil in Engineering	2	Hosamo, HH; Imran, A; Cardenas-Cartagena, J; Svennevig, PR; Svidt, K; Nielsen, HK Hosamo, HH; Hosamo, MH

Journals	Number of Selected Publications	References
Architectural Engineering And Design Management Architecture-Switzerland	2	Jin, ST Chatsuwan, M; Moriwaki, A; Ichinose, M; Alkhalaf, H
Automation in Construction	12	Tuhaise, VV; Tah, JHM; Abanda, FH Jiang, F; Ma, L; Broyd, T; Chen, K Zhong, BT; Pan, X; Ding, LY; Chen, Q; Hu, XW Saif, W; Razavialavi, S; Kassem, M Bakhshi, S; Ghaffarianhoseini, A; Ghaffarianhoseini, A; Najafi, M; Rahimian, F; Park, C; Lee, D Li, T; Li, XJ; Rui, Y; Ling, JX; Zhao, SC; Zhu, HH Mai, TG; Nguyen, M; Ghobakhlou, A; Yan, WQ; Chhun, Nguyen, H Naderi, H; Shojaei, A XW; Liu, YP; Huang, LZ; Onstein, E; Merschbrock, C Marocco, M; Garofolo, I
Buildings	33	Zhang, ZC; Wei, ZK; Court, S; Yang, LC; Wang, SZ; Thirunavukarasu, A; Zhao, YF Shishehgarkhaneh, MB; Keivani, A; Moehler, RC; Jelodari, N; Laleh, SR Hu, W; Lim, KYH; Cai, YY Zahedi, F; Alavi, H; Sardroud, JM; Dang, HT Mêda, P; Calvetti, D; Hjelseth, E; Sousa, H Liu, WH; Lv, YH; Wang, Q; Sun, B; Han, DC Lauria, M; Azzalin, M Sepasgozar, SME Keles, C; Rios, FC; Hoque, S Peng, H; Wang, XL; Wu, H; Huang, B Sokic, D; Dolacek-Alduk, Z; Galic, M Alnajjar, O; Atencio, E; Turmo, J Cheng, FC; Bier, H; Wang, NZ; Andrasek, A Zohourian, M; Pamidimukkala, A; Kermanshachi, S; Almaskati, D Olimat, H; Alwashah, Z; Abudayyeh, O; Liu, HX Hauer, M; Hammes, S; Zech, P; Geisler-Moroder, D; Plörer, D; Miller, J; van Karsbergen, V; Pfluger, R de Souza, ASC; Debs, L Yan, JK; Zheng, Z; Zhou, YC; Lin, JR; Deng, YC; Lu, XZ Wang, J; Ma, YC; Li, R; Zhang, SX Li, YN; Li, YC; Ding, ZK Siccardi, S; Villa, V Adewale, BA; Ene, VO; Ogunbayo, BF; Aigbavboa, CO Ali, KN; Alhajlah, HH; Kassem, MA
Built Environment Project and Asset Management	1	Aklashie, S; Agyekum, K; Tachao, ET; Adinyira, E; Nani, G
Construction Innovation England	3	Radzi, AR; Azmi, NF; Kamaruzzaman, SN; Rahman, RA; Papadonikolaki, E Ghansah, FA; Lu, WS Gondak, MD; Hluszko, C; Moretti, V; Zeni, GLF; de Francisco, AC
Energy and Buildings	2	Liew, EFY; Ong, DEL; Peerun, MI Geng, LN; Li, SP; Farsangi, EN; Xu, XX; Tam, VWY

Journals	Number of Selected Publications	References
Engineering Application and Artificial Intelligence	1	Zhang, LM; Li, YS; Pan, Y; Ding, LY
Engineering Construction and Architectural Management	5	Omrany, H; Al-Obaidi, KM; Ghaffarianhoseini, A; Chang, RD; Park, C; Rahimian, F Lu, MQ; Antwi-Afari, MF Luo, QM; Sun, CS; Li, Y; Qi, ZQ; Zhang, GZ Yao, YL Ohene, E; Nani, G; Antwi-Afari, MF; Darko, A; Addai, LA; Horvey, E
Frontiers in Built Environment	1	Hosamo, HH; Nielsen, HK; Alnmr, AN; Svennevig, PR; Svidt, K
Infrastructures	2	Oditallah, M; Alam, M; Ekambaram, P; Ranjha, S Wangchuk, J; Banihashemi, S; Abbasianjahromi, H; Antwi-Afari, MF
Intelligent Buildings International	1	Krishna, USR; Kumar, NVP; Tadi, C; Badiger, MH
Journal of Building Engineering	7	Opoku, DJ; Perera, S; Osei-Kyei, R; Rashidi, M Zhang, AS; Yang, J; Wang, FL Arsecularatne, BP; Rodrigo, N; Chang, RD Osadcha, I; Jurelionis, A; Fokaides, P Alhadi, A; Tom, B; Yacine, R Khan, H; Bin Zahid, Z; Malik, UJ; Ahmad, J Wang, X; Wang, SQ; Xiao, F; Luo, XW
Journal of Computing in Civil Engineering	1	Davletshina, D; Reja, VK; Brilakis, I
Journal of Construction Engineering and Management	5	Manzoor, B; Antwi-Afari, MF; Alotaibi, KS; Edwards, DJ; Posillico, JJ Ahmadi, L; Bilal, M; Olumo, A; Mollaei, A; Jalaei, F; Ebrahimi, N; Mozaffari, H; Kim, J; Haas, C Yue, HZ; Wang, Q; Zhao, MR; Yang, ZZ; Lu, L Liu, HX; Han, S; Zhu, ZH Assaf, M; Al-Hussein, M; Li, XM
Journal of Construction Innovation and Management	1	Yildirim, M; Giran, O
Journal of Information Technology in Construction	5	Madubuike, OC; Anumba, CJ; Khallaf, R Palihakkara, AD; Osorio-Sandoval, CA; Tizani, W Getuli, V; D'Ascenzi, E; Fiesoli, I Deng, M; Menassa, CC; Kamat, VR Begic, H; Galic, M; Dolacek-Alduk, Z
Journal Of Science And Technology Policy Management	1	Dhamak, P; Aital, P; Daftardar, A
Nordic Concrete Research	1	Saback, V; Popescu, C; Blanksvärd, T; Täljsten, B
Smart And Sustainable Built Environment	1	Sarigul, FH; Gunaydin, HM
Sustainable Cities And Society	1	Xia, HS; Liu, ZS; Efremochkina, M; Liu, XT; Lin, CX
Transportation Geotechnics	1	Tan, J; Koohmishi, M; Jing, GQ; Kaewunruen, S; Guo, YL

Source: Osundiran, 2026

ASSESSING THE INTEGRATION AND UTILISATION OF ROBOTICS IN THE SOUTH AFRICA CONSTRUCTION INDUSTRY

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Abstract

Purpose: This study assesses the integration and utilisation of robotics in the South African construction industry by examining the major operational, technological, and cost-related barriers affecting adoption, as well as strategies for improving effective implementation.
Design/Methodology/Approach: A qualitative research approach was adopted using a systematic literature review (SLR). Fifty-five peer-reviewed journal articles, industry reports, and policy documents were analysed using thematic analysis to identify recurring patterns relating to robotics adoption, cost implications, and implementation strategies within the South African construction context.
Findings: The findings reveal that robotics utilisation in South African construction remains limited and largely pilot driven. Economic and financial barriers emerged as the most significant challenge, cited in 54.5% of reviewed studies, followed by skills and organisational readiness constraints (49.1%) and technological and infrastructural limitations (41.8%). Cost-related impacts were dominated by upfront capital investment (50.9%) and maintenance and lifecycle costs (47.3%). The study further identified key adoption strategies, including financial incentives, skills development initiatives, technological infrastructure readiness, and regulatory reforms to support Construction 4.0 implementation.
Practical Implications: The study provides actionable insights for policymakers, contractors, and professional bodies by highlighting the need for funding support, workforce upskilling, infrastructure improvement, and supportive regulatory frameworks.
Originality/Value: The study contributes context-specific evidence on robotics adoption in South Africa, addressing a gap in African construction research by integrating operational, technological, and financial perspectives.
Research Limitations: The study relies on secondary data and lacks empirical validation from live construction projects. Future research should incorporate quantitative surveys and case studies to evaluate the performance and return on investment of robotics in construction projects.

Keywords: Automation in Construction, Construction Robotics, Robotics Adoption, South African Construction Industry

1. Introduction

The construction industry has traditionally been labour-intensive, heavily reliant on manual processes and often challenged by inefficiencies, safety concerns, and time overruns. Globally, the advent of robotics and automation has started transforming construction operations, offering solutions that can improve productivity, precision, and worker safety. Robotics has been increasingly utilised in developed countries for tasks such as bricklaying, concrete dispensing, demolition, 3D printing of building components, and site monitoring, reflecting significant strides in Construction 4.0 (Bock, 2015). However, in many developing countries, including South Africa, and particularly in the province of South Africa, the integration of robotics in construction remains minimal, sporadic, and poorly documented (Aghimien et al., 2020).

In the recent time, the global construction industry is experiencing a paradigm shift with the integration of robotics and advanced automation technologies aimed at improving productivity, safety, and efficiency. In countries such as Japan, Germany, and the United States, robotics are being increasingly employed to perform repetitive, hazardous, or precision-based tasks (Olatunde et al.2023). Recent literature has emphasized the global benefits of robotics in construction, such as reductions in workplace accidents, enhanced quality control, and better time management (Zhou et al., 2013). However, most existing studies focus on technologically advanced regions, with limited empirical data available for emerging markets like South Africa. Moreover, while theoretical discussions exist about Construction 4.0 in Africa, the actual evidence of implementation, challenges, and drivers for adopting robotics is scarce (Oesterreich and Teuteberg, 2016).

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Despite growing awareness of digital transformation in the South African construction industry, there remains a gap in the understanding and practical implementation of robotic technologies, especially at the provincial and municipal project levels. South Africa, as one of the country's major construction hubs due to ongoing infrastructure development, faces constraints such as limited technological capacity, high costs of robotic systems, and lack of skilled personnel to operate advanced tools (Harty et al., 2020). These limitations hinder the sector's ability to adapt to technological innovation, leaving opportunities for robotics underexplored in terms of enhancing efficiency and reducing project risks. There is a pressing need to investigate the extent to which robotics is being integrated and utilised within this specific regional context (Aibinu and Venkatesh, 2014).

Despite the global evidence of productivity improvements through robotics, the construction industry in South Africa continues to face persistent challenges including labour inefficiencies, safety incidents, and low productivity (CIDB, 2020). South Africa, as one of the country's key economic and construction hubs, provides a pertinent regional case study to explore whether and how robotics could contribute towards addressing these challenges. The research is therefore driven by the need to bridge the gap between global best practices and local realities, offering insight into the readiness of local construction firms, policy constraints, skill levels, and infrastructural limitations.

The study is situated in the broader context of South Africa's push toward modernising its construction sector amid declining productivity and global competitiveness. The government's National Development Plan (NDP) and the Construction Industry Development Board (CIDB) have underscored the importance of technological advancement in improving infrastructure delivery (CIDB, 2020). South Africa, with its urban expansion and ongoing mega-projects in transport and housing, provides a rich environment to examine whether robotics is being used effectively to meet strategic construction goals. Yet, industry stakeholders often cite barriers such as capital investment limitations, cultural resistance to change, and insufficient training as hindrances to adopting advanced technology (Aigbavboa, et al., 2020).

The COVID-19 pandemic further emphasized the need for contactless and automated solutions in construction, prompting a re-evaluation of manual processes and worker density on sites (Gbadamosi et al., 2021; Aghimien et al., 2022). However, post-pandemic recovery plans in South Africa have not clearly outlined strategies to scale robotic technologies, revealing a potential disconnect between policy and practice. This study will investigate how these global and national drivers translate into real actions on the ground in South Africa's construction environment.

The study is worth conducting for several reasons. Firstly, it contributes to the limited body of academic literature on construction robotics in the African context, where labour-intensive methods still dominate. Secondly, it informs policymakers and industry stakeholders on how to align construction sector development with the Fourth Industrial Revolution (4IR) goals. Lastly, understanding the level of integration of robotics may also help construction firms prepare for inevitable digital transformations, potentially leading to cost reductions, safer worksites, and time efficiencies (Balaguer and Abderrahim, 2008). Although several international studies have examined robotics adoption in construction, limited research has focused specifically on the South African construction industry, particularly from an operational, technological, and cost-related perspective. This study addresses this gap by synthesising evidence on the barriers, cost implications, and implementation strategies influencing robotics utilisation within South Africa. The study therefore contributes context-specific insights that support policy development and industry transition towards Construction 4.0.

2. Literature Review

The adoption of robotics in construction has accelerated globally due to increasing demands for productivity, safety, and efficiency within the Construction 4.0 agenda. In developed economies such as Japan, Germany, and the United States, robotics has been successfully deployed for activities including bricklaying, demolition, autonomous site monitoring, and additive manufacturing (Bock, 2015; Zhou et al., 2013). These technologies have demonstrated the potential to reduce workplace accidents, improve construction precision, and minimise project delays. However, the extent of robotics integration varies significantly between developed and developing economies due to differences in technological readiness, infrastructure, and investment capacity (Oesterreich and Teuteberg, 2016).

In South Africa, robotics adoption remains relatively limited despite growing discourse surrounding digital transformation in the construction industry. Existing studies indicate that the sector continues to rely heavily on labour-intensive practices because of cost sensitivities, fragmented project delivery systems, and limited technological maturity (Mpofu and Kajimo-Shakantu, 2020). While global literature frequently presents robotics as a pathway to productivity improvement, such assumptions are not easily transferable to the South African context where firms, particularly SMEs, operate under constrained financial conditions. This highlights an important gap between international best practices and local industry realities.

Economic and financial barriers are consistently identified as the most significant constraints to robotics utilisation in construction. The procurement, operation, and maintenance of robotic systems require substantial capital investment, which many South African contractors are unable to sustain (Smallwood and Allen, 2019). Unlike large firms in developed economies that benefit from economies of scale and repetitive project workflows, South African contractors often undertake short-term and fragmented projects, making the return on investment uncertain. Oke et al. (2020) further argue that lifecycle costs, including software upgrades, maintenance, and imported spare parts, significantly increase the total cost of ownership. Consequently, robotics adoption remains concentrated in pilot projects rather than mainstream implementation.

Beyond financial barriers, the shortage of skilled human capital limits the effective deployment of robotics technologies. Studies have shown that the South African construction workforce lacks specialised competencies in automation, coding, systems integration, and digital project management (Aghimien et al., 2022). This skills deficit is exacerbated by weak collaboration between universities, technical institutions, and industry stakeholders, resulting in limited exposure to practical robotics applications. Although some scholars advocate increased investment in training and professional development, there is limited evidence demonstrating how existing educational frameworks can adequately support large-scale robotics integration within construction environments.

Technological and infrastructural limitations also undermine robotics adoption in South Africa. Robotics systems depend heavily on stable digital infrastructure, reliable electricity supply, and integrated data environments such as Building Information Modelling (BIM) platforms. However, the inconsistent adoption of BIM and persistent load-shedding challenges reduce operational reliability and increase downtime risks (Aigbavboa et al., 2016; Akinradewo, 2020). While studies acknowledge these infrastructural constraints, limited research critically evaluates how energy instability specifically affects the long-term economic sustainability of robotics in construction projects.

Regulatory and socio-technical factors further complicate robotics implementation. Existing occupational health and safety frameworks in South Africa provide limited guidance on the operation and regulation of collaborative robotics systems, forcing firms to rely on international standards such as ISO 10218 (ISO, 2016). This regulatory uncertainty contributes to cautious adoption by contractors and insurers. Furthermore, labour unions and workers often perceive robotics as a threat to employment opportunities within an already labour-intensive industry (Haupt and Smallwood; 2018). Such resistance illustrates that robotics adoption is not solely a technological issue but also a socio-economic and organisational challenge requiring effective change management strategies.

Although prior studies have examined isolated aspects of robotics adoption, much of the literature remains descriptive and fragmented, with limited synthesis of operational, technological, financial, and socio-technical dimensions within the South African construction context. Existing research largely focuses on developed economies, leaving insufficient context-specific evidence for emerging African markets. This study addresses this gap by critically synthesising literature on the challenges, cost implications, and strategic interventions influencing robotics utilisation in South African construction projects. By integrating these dimensions, the study contributes a more holistic understanding of the readiness of the South African construction industry for robotics-driven transformation under Construction 4.0.

3. Research Methodology

This study adopted a qualitative research approach anchored in a Systematic Literature Review (SLR). The qualitative approach was considered appropriate because the study sought to explore the contextual realities, perceptions, and operational challenges associated with robotics integration in the South African construction industry. Qualitative research enables the interpretation of socio-technical issues that cannot be fully explained through numerical analysis alone (Denzin and Lincoln, 2017). Since robotics adoption involves organisational readiness, financial constraints, technological capacity, and regulatory issues, the qualitative approach provided a holistic understanding of the phenomenon.

The study employed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework to ensure transparency, rigour, and replicability throughout the review process. The PRISMA process consisted of four stages: identification, screening, eligibility, and inclusion. During the identification stage, literature was sourced from reputable databases including ScienceDirect, Taylor & Francis, Emerald Insight, Google Scholar, and institutional publications. Search keywords included “construction robotics,” “automation in construction,” “Construction 4.0,” “robotics adoption,” “digital construction,” and “South African construction industry.” The inclusion criteria comprised peer-reviewed journal articles, conference papers, policy documents, and industry reports published in English between 2015 and 2025 that focused on robotics adoption, operational challenges, cost implications, or implementation strategies in construction. Studies

unrelated to construction robotics, non-English publications, duplicate articles, opinion pieces without empirical or conceptual relevance, and studies outside the selected timeframe were excluded.

The PRISMA screening process resulted in 70 initially identified records, of which 5 duplicates and irrelevant articles were removed during title and abstract screening (Figure 1). Thereafter, 59 articles were assessed for eligibility through full-text review, while 2 studies were excluded for insufficient relevance and methodological limitations. Ultimately, 55 publications were retained for the final review and thematic analysis. Data extracted from the selected studies were analysed using thematic analysis following the procedures proposed by Braun and Clarke (2006). The analysis involved repeated reading of articles, coding of recurring concepts, grouping related codes into themes, and synthesising findings into major thematic categories aligned with the study objectives. The main themes identified included operational and technological challenges, cost-related impacts, and strategies for improving robotics utilisation.

To ensure reliability and validity, the study adopted several measures. First, only credible and peer-reviewed sources from established databases were included to improve data reliability. Second, the use of explicit inclusion and exclusion criteria minimised selection bias and enhanced consistency in the review process. Third, data triangulation was achieved by comparing findings across academic publications, industry reports, and policy documents (CIDB, 2020; World Bank, 2022). Lastly, maintaining a transparent PRISMA procedure and systematic coding process enhanced the dependability and replicability of the findings (Tranfield et al., 2003).

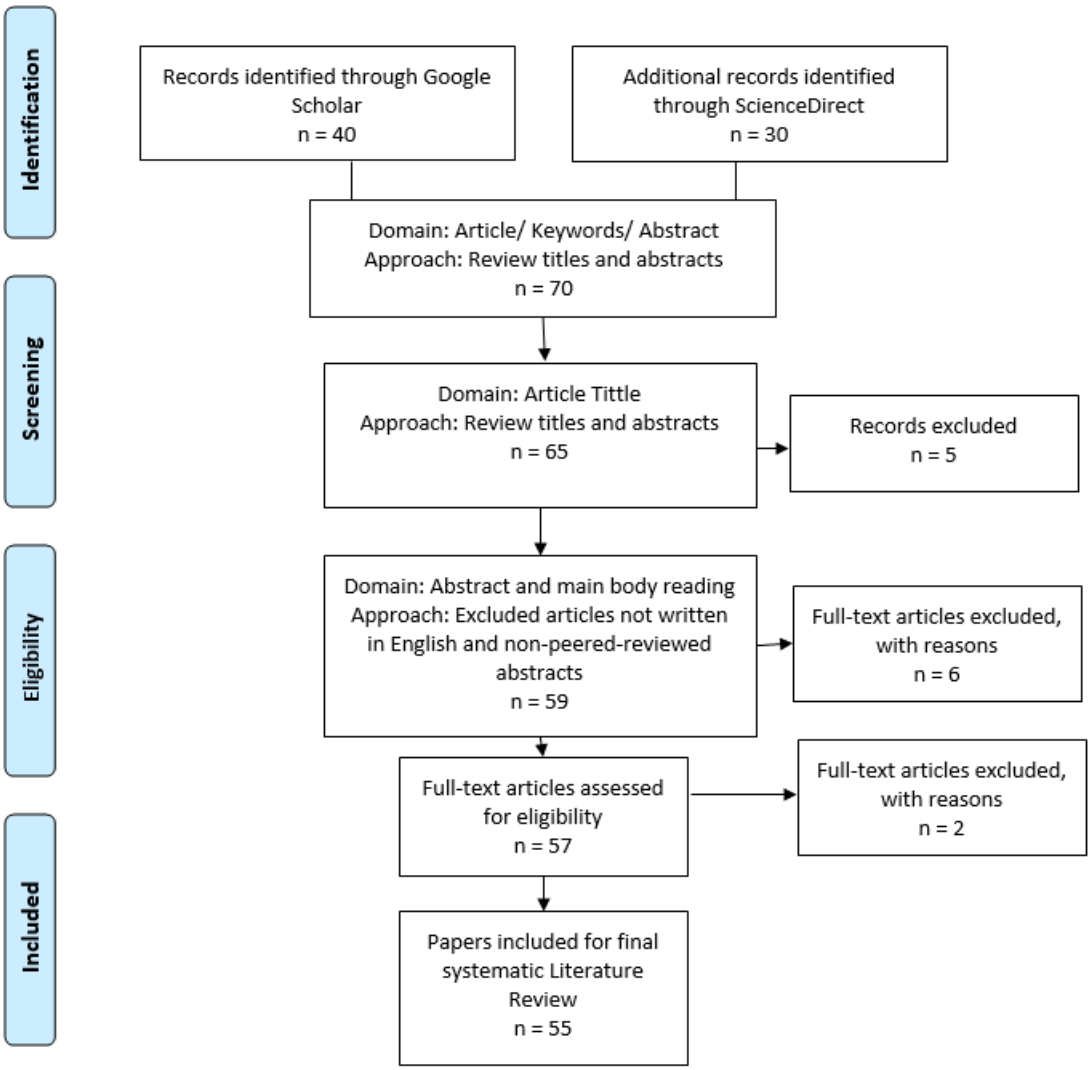

Figure 1: Research PRISMA Flow diagram

4. Results

Key Operational and Technological Challenges Affecting the Utilisation of Robotics in Construction Projects in South Africa

The results represented in Figure 2 are based on the key operational and technological challenges with the highest frequency rates affecting the utilisation of robotics in South African construction projects. medium-sized enterprises (SMEs) that dominate the South African construction market. This challenge is compounded by limited access to funding, a lack of government incentives, and uncertainty regarding return on investment. Similarly, skills shortages and weak organisational readiness further constrain adoption, as limited technical expertise, insufficient training, and minimal collaboration between academia and industry hinder effective implementation and long-term sustainability of robotics in construction

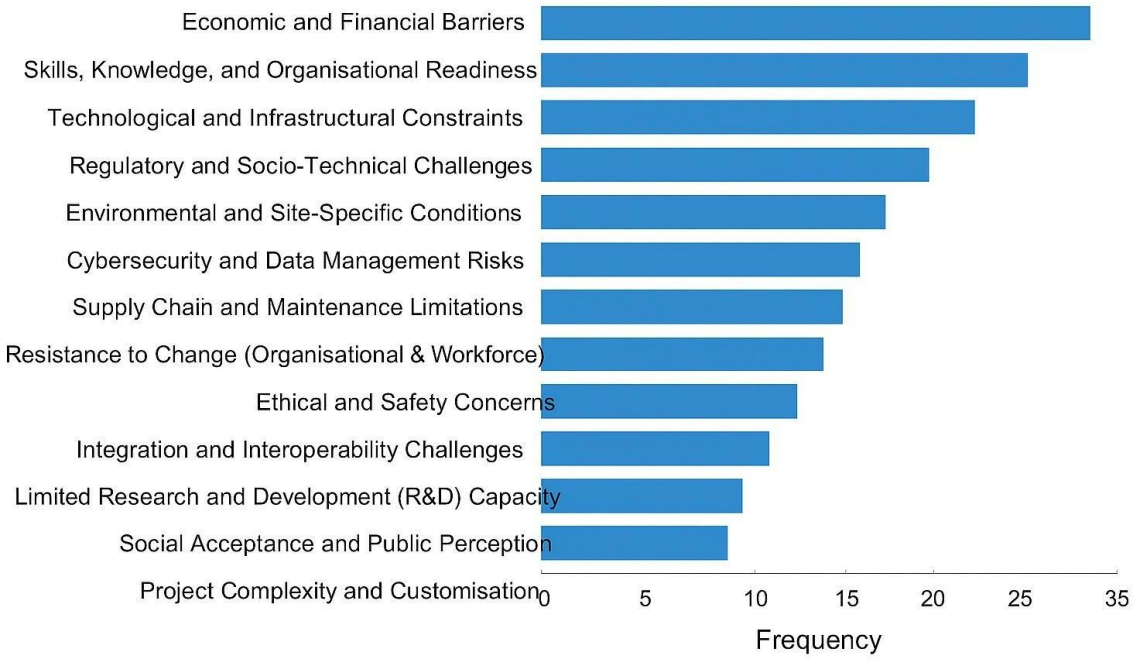

Figure 2: Key Operational and Technological Challenges Affecting the Utilisation of Robotics in Construction Projects in South Africa

According to the analysis of 55 publications, challenges such as economic and financial barriers (30/55 = 54.5%), skills, knowledge, and organisational readiness (27/55 = 49.1%), technological and infrastructural constraints (23/55 = 41.8%), and regulatory and socio-technical challenges (21/55 = 38.1%) emerged as the most frequently cited barriers. These are followed by environmental and site-specific conditions (19/55 = 34.5%), cybersecurity and data management risks (18/55 = 32.7%), supply chain and maintenance limitations (15/55 = 27.3%), resistance to change (organisational & workforce) (14/55 = 24.45%), ethical and safety concerns (13/55 = 23.6%), integration and interoperability challenges (12/55 = 21.8%), limited research and development (R&D) capacity (9/55 = 16.4%), and social acceptance and public Perception (7/55 = 17.7%).

From the analysis, economic and financial barriers remain the most dominant challenge, largely due to the high procurement and maintenance costs of robotic systems, which discourage adoption among small and (Akinradewo et al., 2020; Aghimien et al., 2022).

Cost-Related Impacts Resulting from Challenges in the Implementation and Maintenance of Robotic Technologies in the South Africa Construction Industry

The results represented in Figure 3 are based on cost-related impacts with high frequency rates identified across the reviewed publications. According to the analysis, major cost challenges include upfront capital investment (28/55 = 50.9%), maintenance and lifecycle costs (26/55 = 47.3%), infrastructure and integration costs (24/55 = 43.6%), social and regulatory compliance costs (19/55 = 34.5%), high initial investment and financing constraints (18/55 = 32.7%), maintenance costs and long-term economic sustainability (17/55 = 30.9%), financing and capital structure impacts (15/55 = 27.3%), maintenance, spare parts, and supply-chain cost impacts (14/55 = 30.9%), downtime, reliability, and contingency cost impacts (13/55 = 23.6%), training, upskilling, and human capital cost impacts (12/55 = 21.8%), integration,

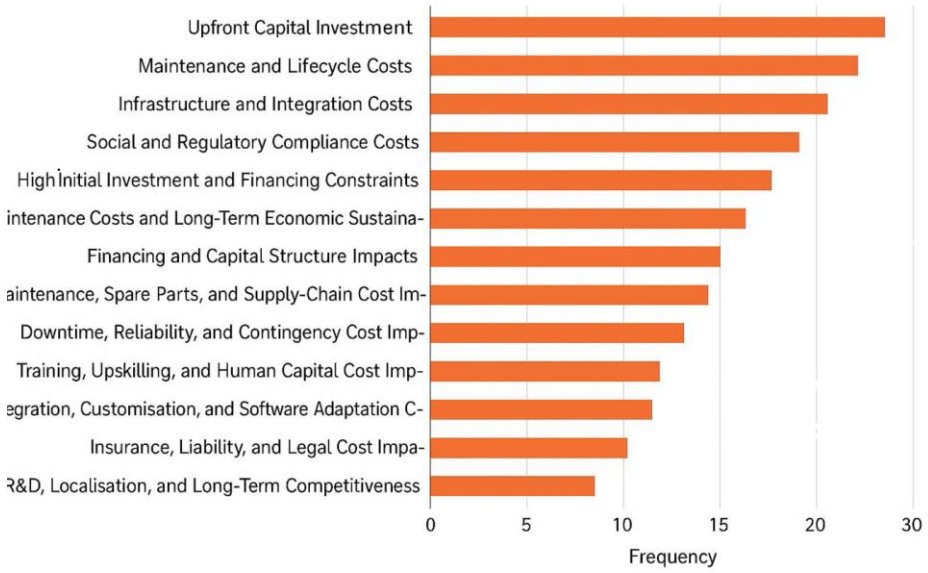

Figure 3: Cost-Related Impacts Resulting from Challenges in the Implementation and Maintenance of Robotic Technologies

customisation, and software adaptation cost impacts (11/55 = 20.0%), insurance, liability, and legal cost impacts (10/55 = 18.2%), and R&D, localisation, and long-term competitiveness cost impacts (9/55 = 16.4%).

From the result analysis, upfront capital investment emerges as the most significant cost-related impact influencing robotics adoption in South African construction. The high initial expenditure required to procure and deploy robotic technologies limits accessibility for small and medium-sized enterprises (SMEs) and reduces the financial feasibility of large-scale implementation. This, coupled with maintenance and lifecycle costs, underscores the financial strain associated with the integration and sustainability of robotics within the local construction industry (Mpofu and Kajimo-Shakantu, 2020).

Strategies that can be Employed to Overcome the Major Challenges in the Adoption and Effective Use of Robotics in Construction Projects within South Africa

The results represented in Figure 4 are based on the strategies with the highest frequency rate identified

Figure 4: Strategies to Overcome the Major Challenges in the Adoption and Effective Use of Robotics in Construction Projects

across 55 reviewed publications. According to figure 3, the most frequently cited remedies include financial support and incentives (30/55 = 54.5%), skills development and human capacity building (28/55 = 50.9%), technological and infrastructural readiness (27/55 = 49%), regulatory and socio-technical measures (25/55 = 45.5%), financial innovation and alternative funding mechanisms (24/55 = 43.6%), localisation and indigenous innovation in robotics (22/55 = 40%), awareness creation and change management strategies (21/55 = 38.2%), financing innovations and shared asset models (20/55 = 36.4%), localisation, supplier development and maintenance ecosystems (19/55 = 34.5%), curriculum reform, TVET and continuous professional development (18/55 = 32.7%), standards, certification and regulatory sandboxes (17/55 = 30.9%), procurement reform and value-based contracting (15/55 = 27.3%), and energy resilience and power supply interventions (14/55 = 25.45%).

From the result analysis, financial support and incentives emerged as the most frequently emphasised remedy, underscoring the significant role that fiscal measures and government-backed funding play in enabling robotics adoption within the South African construction industry. This finding aligns with international evidence suggesting that financial mechanisms such as tax incentives, subsidies, and leasing models substantially lower entry barriers and promote wider adoption among small and medium-sized enterprises (Mpofu and Kajimo-Shakantu, 2020; Oke et al., 2021)

5. Conclusion and Recommendations

This study assessed the integration and utilisation of robotics within the South African construction industry, with emphasis on the operational, technological, and cost-related challenges limiting widespread adoption. The findings demonstrate that although robotics has the potential to significantly improve productivity, safety, precision, and project efficiency, its utilisation in South Africa remains limited, fragmented, and largely experimental. Economic and financial barriers emerged as the most dominant challenge, particularly high procurement, maintenance, and lifecycle costs, which disproportionately affect small and medium-sized enterprises (SMEs). These findings support the studies of Mpofu and Kajimo-Shakantu (2020) and Oke et al. (2021), which identified cost and financial uncertainty as major impediments to technological innovation in developing construction economies.

The study further revealed that weak organisational readiness, inadequate technical expertise, unstable energy supply, and limited digital infrastructure continue to hinder effective robotics deployment. These findings reinforce the arguments of Aigbavboa et al. (2020) and Aghimien et al (2022), who emphasised that digital transformation in construction is not solely dependent on technology acquisition, but also on institutional capacity, workforce competence, and supporting infrastructure. The persistence of regulatory uncertainty and socio-technical resistance also suggests that robotics adoption in South Africa is shaped as much by social and policy conditions as by technological capability. This demonstrates that the transition towards Construction 4.0 within developing economies is significantly more complex than the experiences reported in technologically advanced countries.

Critically, the study contributes to knowledge by providing context-specific evidence on robotics integration within the South African construction industry, an area that remains underexplored in existing literature. Unlike previous studies that primarily focus on developed economies, this study synthesises operational, financial, technological, and socio-technical dimensions of robotics adoption within an African construction context. The study therefore extends Construction 4.0 discourse beyond technologically mature environments and highlights the importance of contextual realities such as energy instability, limited digital maturity, and labour-market sensitivities in shaping robotics adoption outcomes.

The study also contributes methodologically by demonstrating the value of systematic literature review and thematic synthesis in consolidating fragmented evidence relating to construction robotics in emerging economies. The findings provide a foundation for policymakers, contractors, and professional bodies to formulate targeted interventions such as financial incentives, localised innovation strategies, skills development programmes, and regulatory reforms that can accelerate sustainable robotics adoption in South Africa. Beyond its practical relevance, this study contributes theoretically to the growing scholarship on Construction 4.0 and technology adoption in developing economies. The findings reinforce existing socio-technical and innovation diffusion theories by demonstrating that robotics adoption in construction is not determined solely by technological availability, but also by the interaction between economic capacity, organisational readiness, institutional support, and workforce acceptance. While previous studies on robotics adoption have largely focused on technologically advanced economies, this study extends the discourse by providing context-specific evidence from South Africa, where infrastructural instability, labour market sensitivities, and financial constraints significantly shape technology uptake.

Despite these contributions, the study is limited by its reliance on secondary data and the absence of empirical project-level validation. Future studies should therefore adopt mixed-method or quantitative approaches to

evaluate the practical performance, cost-benefit implications, and long-term return on investment of robotics across different categories of construction projects in South Africa

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Drivers and Barriers to the Adoption of Robotics and 3D Printing in Construction in the Global South: A Systematic Review

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Abstract

This study used a systematic literature review guided by the PRISMA approach to identify and critically analyse the main drivers and barriers affecting the adoption of robotics and three-dimensional (3D) printing in construction across the Global South. Peer-reviewed articles, book chapters, and books were examined from the Scopus and Web of Science databases covering 2020 to 2026. The review framework facilitated the systematic identification of enabling factors, such as productivity improvements, design flexibility, and sustainability goals, as well as major obstacles, including high capital costs, limited technical skills, infrastructural gaps, and socio-cultural resistance. The results show that while the technological potential of robotics and 3D printing (additive manufacturing) is widely recognized, adoption is mainly hindered by structural and institutional issues rather than technical limitations. By highlighting specific context-related factors, this review advances construction innovation research and offers practical insights for policymakers, industry leaders, and development partners working in the construction sector in the Global South.

Keywords: Automation, Construction Technology, Global South, Robotics, 3D Printing.

1. Introduction

The construction industry remains among the most labour-intensive and technologically conservative sectors worldwide, characterized by fragmented processes, limited standardization, and persistent inefficiencies that constrain productivity, safety, and environmental performance (Banihashemi et al., 2025; Dindorf & Wos, 2024). These structural limitations have intensified calls for transformative innovations capable of redefining project delivery and operational efficiency. Within this context, robotics and three-dimensional (3D) printing have emerged as core components of the Construction 4.0 paradigm, integrating automation, digitization, and additive manufacturing to enhance precision, reduce material waste, and improve occupational safety (Casini, 2021; Mishra, 2025). Empirical evidence indicates that these technologies can streamline workflows, accelerate project timelines, and enable complex architectural forms that are difficult to achieve through conventional methods (Banihashemi et al., 2025).

Despite their demonstrated potential, adoption patterns remain geographically uneven. Advanced economies in East Asia, Europe, and North America have achieved comparatively higher levels of integration, supported by robust research and development ecosystems, industrial automation capacity, and enabling policy frameworks (Lopes de Aquino Brasil & Carmo Pena Martinez, 2025). In contrast, uptake across the Global South has been slower and more fragmented, constrained by high capital costs, skills deficits, regulatory uncertainty, and institutional limitations (Akinradewo et al., 2023a; Okangba et al., 2025). Yet, rapid urbanization, housing deficits, and infrastructure demands in these regions simultaneously create strong incentives for technological leapfrogging (Akinradewo et al., 2023b).

Notwithstanding the growing scholarly interest in construction automation, existing research remains disproportionately centred on Global North contexts, limiting insight into region-specific determinants shaping adoption trajectories in developing economies. To address this gap, this study undertakes a systematic review to synthesize evidence on the drivers and barriers influencing the adoption of robotics and 3D printing in construction across the Global South. By critically mapping technological, organizational, and environmental determinants, and contrasting adoption dynamics across global contexts, the study advances context-sensitive policy and industry strategies to support sustainable digital transformation in construction.

2. Conceptual and Theoretical Framework

Given the fragmented and socio-technical nature of construction systems, understanding automation adoption requires an integrative perspective that extends beyond individual-level explanations. At the foundational level, Rogers' Diffusion of Innovation (DOI) theory explains how innovation attributes, such as relative advantage, compatibility, complexity, trialability, and observability influence adoption

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decisions and differentiate adopter categories across social systems (Yu, 2022; Yadegari et al., 2024). Complementing DOI, behavioural models such as the Technology Acceptance Model (TAM) and the Unified Theory of Acceptance and Use of Technology (UTAUT) highlight the importance of perceived usefulness, ease of use, performance expectancy, and behavioural intention in shaping technology acceptance among organisational actors (Okangba et al., 2025).

While diffusion and behavioural theories provide important insights into technology acceptance, the institutional complexity and project-based characteristics of the construction sector necessitate a broader organisational perspective. Accordingly, the Technology–Organization–Environment (TOE) framework offers a robust basis for understanding adoption as an outcome of interactions among technological, organisational, and environmental contexts (Prakash, 2025). This framework is particularly relevant in heterogeneous and resource-constrained construction environments where technological investments are strongly conditioned by institutional and infrastructural realities.

Beyond technological and organisational considerations, the integration of robotics and additive manufacturing technologies constitutes a broader socio-technical transformation of construction systems. Accordingly, this study is further informed by socio-technical theory, which emphasises the reciprocal and co-evolutionary relationship between technological systems and social arrangements (Stephen, 2023). Empirical evidence from digital transformation initiatives in construction demonstrates that organisational culture, communication networks, labour relations, and workforce dynamics significantly mediate the effectiveness and sustainability of technological implementation (Zomer et al., 2021). Consequently, the adoption of robotics and 3D printing should be understood as a process of socio-technical reconfiguration rather than merely technological substitution.

By integrating the Diffusion of Innovation theory, the Technology–Organization–Environment framework, and socio-technical theory, this study advances an interdisciplinary and multi-level conceptual framework for examining the adoption of robotics and 3D printing technologies in the construction sector of the Global South. The framework recognises that technology diffusion emerges from the interaction among innovation attributes, organisational preparedness, institutional environments, and socio-cultural dynamics. This theoretical synthesis enables a holistic understanding of the drivers and barriers influencing construction automation in institutionally complex and economically constrained contexts.

3. Research Methodology

This study adopted a systematic literature review (SLR) design guided by the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework (Page et al., 2021) to ensure methodological transparency, rigour, and replicability. A structured search was conducted in the Scopus and Web of Science databases using Boolean operators and wildcard combinations of keywords related to robotics, 3D printing (additive manufacturing), construction automation, digital construction, and the Global South, engaging the theoretical frameworks of diffusion of innovations, technology acceptance model (TAM) and the unified theory of acceptance and use of technology (UTAUT), technology–organization–environment (TOE) framework, and socio-technical theory. The review covered publications from 2020 to 2026 to capture recent technological and adoption trends within the construction industry.

Inclusion criteria comprised peer-reviewed journal articles, conference papers, books, and book chapters published in English that empirically examined the adoption of robotics and/or 3D printing in the construction sector. Conceptual studies without empirical grounding and studies addressing digital technologies without explicit focus on robotics or additive manufacturing were excluded. The initial search yielded 752 records. After conducting relevance screening of the records, 193 records were assessed for eligibility. Thereafter, duplicates records were removed together with the low relevance and inaccessible records using "The Evidence Review Accelerator (TERA)" tool, which resulted in the final included records of 27 publications (21 journal articles, 4 book chapters, and 2 books). The study's systematic review flow is represented in Figure 1 with the embedded PRISMA approach flow.

Data were extracted using a predefined coding framework capturing conceptual, contextual, and adoption-related dimensions. A thematic analysis was subsequently conducted to identify recurring patterns, drivers and barriers of robotics and 3D printing in construction, interrelationships, and dominant narratives. Methodological quality was appraised using the Critical Appraisal Skills Programme (CASP) Qualitative Checklist, with appraisal outcomes informing study inclusion and evidential weighting to enhance the reliability and integrity of the synthesis.

4. Findings

4.1. Overview of Robotics and 3D Printing in Construction

The landscape of robotics and 3D printing within the construction industry represents a paradigm shift from traditional manual processes toward automated, digitally driven fabrication. Construction robotics

Figure 1: The Study's Systematic Review Flow Embedding PRISMA Flow (Source: Authors)

refers to the integration of automated machines and robotic systems to perform site-based and off-site tasks that historically relied on human labour to improve precision, safety, productivity, and quality in construction workflows. These systems encompass autonomous and semi-autonomous manipulators, mobile robotic platforms, and collaborative robots (cobots) capable of performing construction tasks such as bricklaying, material handling, structural assembly, inspection, and demolition (Liu et al., 2024)

Similar to robotics, 3D printing, also known as additive manufacturing (AM), is defined as the layer-by-layer fabrication of physical components from three-dimensional digital models. In the construction context, this includes concrete printing, gantry-based systems, and robotic arm-based extrusion technologies that deposit cementitious mixtures, polymers, or composite materials to build structural elements or entire buildings (Lopes de Aquino Brasil & Carmo Pena Martinez, 2025). Techniques such as robocasting and contour crafting illustrate the range of methodologies where material is extruded or bound with precision, offering high design flexibility, reduced waste, and rapid construction compared to conventional cast-in-place techniques (Vanaei & Elahinia, 2024).

In recent years, global trends and innovations have showcased the maturation of these technologies. Robotics research in construction continues to grow with expanding hardware capabilities, AI-enhanced control systems, and multi-robot and mobile platforms, enabling complex geometries and automated quality monitoring in real time (Li et al., 2025). Likewise, 3D printing has transitioned from prototyping to full-scale building projects, with concrete printers capable of producing walls, structural elements, and bespoke architectural forms with improved sustainability profiles and reduced labour demands (Agegn et al., 2026).

Although the majority of research and industrial deployment has been concentrated in North America, Europe, and parts of Asia, there are emerging applications and pilot initiatives in the Global South. For example, Latin America has witnessed the construction of regionally significant 3D-printed concrete structures, such as the first 3D-printed home in Chile built in under 30 hours using industrial robotic printers, signifying a shift toward rapid digital construction methods to address housing needs in diverse climates and seismic zones (Rojas et al., 2025). Similarly, non-profit programmes in Mexico and Haiti have used 3D printing to deliver affordable housing communities, demonstrating the potential social impact of additive technologies in developing contexts.

Research in Africa also highlights interest in leveraging 3D printing as a mechanism for addressing housing shortages and sustainability challenges, while acknowledging economic and regulatory barriers that currently limit widespread adoption in countries such as South Africa (Moghayedi et al., 2024).

These trends therefore illustrate that robotics and 3D printing in construction are not only expanding technologically but are increasingly being tested and adapted within diverse regional contexts. Nonetheless, the diffusion of these innovations into the Global South faces unique constraints and opportunities, underscoring the importance of contextualised research on drivers, barriers, and strategies for adoption in emerging economies.

4.2. Robotics and 3D Printing Adoption Drivers in Construction

The adoption of robotics and 3D printing in construction across the Global South is propelled by interrelated technological, organizational, and environmental drivers that are collectively shaping firm-level and project-level decision-making. These drivers operate as enablers, highlighting the value propositions of advanced construction technologies in contexts marked by resource constraints, rapid urbanization, and evolving policy landscapes. Rather than functioning in isolation, they operate synergistically to position advanced construction technologies as instruments of productivity enhancement, quality improvement, and systemic modernization.

Technological drivers centre on demonstrable gains in efficiency, precision, and safety. Robotic automation and concrete 3D printing streamline repetitive and labour-intensive tasks, enable continuous operations, and significantly compress project timelines (Olatunde et al., 2023; Okangba et al., 2025). In concrete 3D printing, layer-by-layer fabrication enhances dimensional accuracy and structural integrity, reducing variability and human error while meeting rising performance standards in mass housing and urban infrastructure (Xu et al., 2022; Su et al., 2024). Additionally, robotic systems mitigate occupational risks by undertaking hazardous tasks, thereby reducing worker exposure to high-risk environments and addressing persistent safety challenges in developing construction sectors (Wang et al., 2025; Li et al., 2025).

Organizational drivers further reinforce adoption through clear economic and strategic benefits. Firms increasingly recognize long-term cost efficiencies derived from reduced labour dependency, minimized material waste, and shorter delivery cycles, thereby improving return on investment and financial sustainability (Banihashemi et al., 2025; Akinradewo et al., 2023b). Besides cost considerations, early adopters gain competitive differentiation through enhanced production flexibility, accelerated execution, and the capacity to deliver complex and customized designs (Olatunde et al., 2023). The integration of these technologies also stimulates workforce upskilling, strengthening innovation capacity and long-term organizational resilience.

Environmental and policy drivers provide critical enabling conditions. Regulatory incentives, innovation grants, and digital transformation agendas aligned with Construction 4.0 reduce uncertainty and legitimize technological experimentation (Okangba et al., 2025). Concurrently, sustainability imperatives and escalating urban demand intensify pressures for resource-efficient and low-waste construction practices, for which robotics and 3D printing offer viable solutions (Su et al., 2024; Akinradewo et al., 2023b). Overall, these drivers explain the growing traction of automation and additive manufacturing as transformative enablers of construction modernization in the Global South.

4.3. Barriers to the Adoption of Robotics and 3D Printing in Construction

Despite the transformative potential of robotics and 3D printing, their adoption across construction sectors in the Global South remains constrained by interrelated technological, organizational, and institutional barriers. Adoption challenges extend beyond technical feasibility to encompass financial capacity, skills readiness, regulatory clarity, and socio-cultural acceptance. These layered constraints limit the transition from pilot experimentation to scalable industrial deployment, underscoring the need for context-sensitive policy and industry responses.

Technological barriers significantly constrain the adoption of robotics and 3D printing in construction, particularly in developing economies. High upfront capital costs associated with acquisition, installation, calibration, and system integration pose significant obstacles, especially for small and medium-sized enterprises that dominate construction markets in developing economies (Akinradewo et al., 2023a). Limited access to affordable financing further restricts firms' risk-bearing capacity. In addition, the absence of standardization and interoperability across proprietary hardware and software platforms complicates integration with existing digital infrastructures such as Building Information Modelling systems (Xu et al., 2022; Liu et al., 2024). Concerns regarding system reliability in harsh site conditions, unstable power supply, and limited local maintenance expertise further heighten perceived implementation risk (de Soto & Skibniewski, 2020).

Organizational barriers also impede adoption. Resistance to change often linked to fears of job displacement and skills obsolescence reduces workforce acceptance of automation technologies (Rojas et al., 2025). The scarcity of structured training

and capacity-building initiatives reinforces technical skill gaps, limiting firms' preparedness for digital transformation. Moreover, inadequate managerial awareness of the operational, financial, and strategic implications of robotics and additive manufacturing constrains informed decision-making (Olatunde et al., 2023; Agegn et al., 2026). These challenges are exacerbated by the fragmented and informal structure of construction industries in many developing economies.

The environmental barriers, comprising institutional and socio-cultural factors further contribute to the adoption limitation. For example, weak or ambiguous regulatory frameworks, coupled with the absence of clear standards governing safety, certification, and liability in automated construction, generate uncertainty for early adopters (Dindorf & Wos, 2024). Furthermore, cultural preferences for traditional construction practices and scepticism toward automation reduce stakeholder buy-in and slow implementation (Akinradewo et al., 2023a). Conclusively, these barriers signify that adoption in the Global South constitutes a complex socio-technical transition requiring coordinated policy reform, standardization, financial instruments, and sustained investment in human capital development.

4.4. Comparative Analysis: Global North vs. Global South

The adoption of robotics and 3D printing in construction exhibits marked disparities between the Global North and the Global South, driven by differences in economic capacity, institutional maturity, technological infrastructure, and industry organization. In the Global North, adoption has advanced from pilot experimentation to scalable commercial deployment, supported by mature R&D ecosystems, regulatory clarity, and high levels of digital integration across the construction value chain (Lopes de Aquino Brasil & Carmo Pena Martinez, 2025; Banihashemi et al., 2025). By contrast, adoption in the Global South remains predominantly nascent and project-based, frequently confined to demonstration initiatives or donor-supported schemes, with limited evidence of sustained industrial-scale integration (Okangba et al., 2025).

In advanced economies, robotics and additive manufacturing are increasingly embedded within Construction 4.0 strategies, leveraging BIM, digital twins, and automated fabrication to address labour shortages, demographic shifts, and sustainability imperatives (Banihashemi et al., 2025). More so, adoption in the Global North is largely firm-driven and market-oriented, facilitated by private investment, standardized processes, and interoperable digital systems. On the contrary, in the Global South, integration is shaped by cost sensitivity, infrastructural deficits, fragmented supply chains, and the prevalence of informal construction practices (Agegn et al., 2026). In the Global South, technology adoption is often problem-driven, motivated by urgent housing or infrastructure needs, rather than embedded within long-term automation roadmaps.

These structural asymmetries underscore the limits of direct policy transfer. While lessons from the Global North highlight the importance of regulatory coherence, skills development, and phased implementation pathways (Mishra, 2025), contextual adaptation remains critical. In labour-abundant settings, automation may be perceived as a threat to employment, requiring socially inclusive transition strategies centred on workforce upgrading and job transformation (Olatunde et al., 2023). Accordingly, effective adoption in the Global South requires context-sensitive policy design, hybrid business models, and socio-technical alignment attuned to local economic and institutional realities rather than replication of Global North models.

5. Discussion

5.1. Synthesis of Key Findings

The review indicates that the adoption of robotics and 3D printing in the construction industries of the Global South is driven by a tension between substantial technological potential and deeply embedded contextual limitations. Reported benefits, particularly improvements in efficiency, productivity, occupational safety, and environmental sustainability, constitute the principal motivations for adoption and align with broader Construction 4.0 evidence from developed and developing contexts (Okangba et al., 2025). These benefits, however, do not translate automatically into widespread implementation because adoption is mediated by the institutional, financial, and human-capital conditions within which construction firms operate.

High capital requirements, shortages of specialised skills, fragmented industry structures, and underdeveloped regulatory frameworks collectively restrict firms' capacity to integrate, sustain, and scale these technologies. Consequently, the adoption trajectory in the Global South differs markedly from that of the Global North, where stronger organisational readiness and greater policy alignment facilitate diffusion across the construction sector. In the Global South, implementation remains predominantly incremental, experimental, and concentrated in isolated pilot projects, with substantial disparities across geographical regions and firm sizes (Akinradewo et al., 2023a).

5.2. Interrelationships Between Drivers and Barriers

The review highlights that drivers and barriers are interdependent rather than isolated forces. For example,

while robotics and 3D printing can generate long-term cost savings and productivity gains, high upfront investments and uncertain ROI constrain organizational commitment, particularly among small and medium-sized enterprises which are prevalent in the Global South construction sector (Rojas et al., 2025). Similarly, potential gains in safety and quality are undermined by limited technical capacity, lack of maintenance expertise, and inadequate digital infrastructure (Agegn et al., 2026). These dynamics align with the Technology–Organization–Environment (TOE) and socio-technical frameworks, emphasizing that technological advantages alone are insufficient without supportive organizational capabilities and enabling institutional conditions (Yadegari et al., 2024; Prakash, 2025).

5.3. Implications for Policy and Practice

The findings from the study signify that policy interventions must be context-sensitive to address the uncertainties in automated construction methods while motivating innovation adoption. Governments in the Global South can play a catalytic role through targeted subsidies, public procurement strategies, and workforce development programmes that reduce entry barriers and mitigate investment risk (Mishra, 2025). Regulatory frameworks should also facilitate incremental experimentation and the integration of automated technologies into existing construction practices while ensuring safety and quality compliance (Won et al., 2022).

For practitioners, phased or hybrid adoption strategies, such as off-site 3D printing, semi-automated robotics, and pilot-scale projects, will be more viable than immediate full automation. Workforce development should focus on skills transformation rather than displacement, fostering human–machine collaboration and enhancing long-term industry resilience (Oke et al., 2025). By aligning technological capabilities with organizational readiness and policy support, construction firms in the Global South can gradually scale adoption while mitigating financial, technical, and operational risks.

5.4. Recommendation

The evidence synthesized in this systematic review indicates that the effective adoption of robotics and 3D printing in construction across the Global South requires coordinated, context-sensitive action across strategic, policy, industry, academic, and research domains. Rather than pursuing immediate full-scale automation, construction stakeholders should adopt phased and hybrid implementation pathways that align technological ambition with organisational readiness and financial capacity (Bou Hatoum & Nassereddine, 2025). Off-site additive manufacturing, semi-automated robotic systems, and pilot-scale demonstration projects can reduce implementation risks, strengthen institutional expertise, and generate credible evidence of technological and economic value. These measures should be supported by sustained capacity-building in technical competence, digital literacy, and change management to address skills deficits and workforce resistance while promoting productive human–machine collaboration rather than technological displacement.

Governments should complement these organisational strategies by establishing clear regulatory frameworks covering the safety, quality assurance, certification, and liability requirements of automated and additive construction methods. Targeted policy instruments, including tax incentives, innovation grants, preferential public procurement, and support for local manufacturing, can lower entry barriers, stimulate investment, and strengthen market confidence. Equally important is the development of robust industry–academia–government partnerships capable of supporting the co-design of locally appropriate technologies, applied demonstration projects, and industry-responsive training programmes. Such collaboration would accelerate knowledge transfer, strengthen domestic technological capabilities, and foster sustainable innovation ecosystems adapted to the socioeconomic, infrastructural, and institutional realities of the Global South.

6. Conclusion and Further Research

This systematic review shows that the adoption of robotics and 3D printing in the Global South construction industry is shaped by interconnected technological, financial, institutional, regulatory, and labour-market conditions. Although these technologies can improve productivity, precision, safety, material efficiency, and sustainability, their diffusion remains limited by high investment costs, skills shortages, weak digital infrastructure, fragmented industry structures, and uncertain regulatory frameworks. The review contributes to knowledge by extending Construction 4.0 and innovation-adoption scholarship to underexamined Global South contexts and demonstrating that adoption is not simply a matter of technology transfer, but a socio-technical process dependent on local capability, institutional readiness, financing, regulation, and workforce adaptation.

The findings have concrete implications for policy and practice. Governments should introduce innovation grants, tax incentives, import-duty relief, regulatory sandboxes, and public procurement provisions that support tested and locally appropriate construction technologies. Standards bodies, building authorities, and professional councils should establish clear requirements for structural integrity, safety, equipment certification, liability, and quality assurance. Contractors, technology providers, materials suppliers, financial institutions, insurers, universities, technical colleges, and trade unions should collaborate through shared fabrication centres, demonstration projects,

workforce reskilling, equipment-leasing schemes, and locally adapted technology development. Institutional reforms should also integrate robotics, additive manufacturing, digital design, maintenance, and technology governance into construction-related education and professional training.

Future research should move beyond exploratory studies towards longitudinal, cross-country, and project-level investigations of costs, productivity, safety, environmental performance, and scalability. Greater attention should be given to employment effects, informal labour, small and medium-sized contractors, gender inclusion, local materials, maintenance capacity, and unequal access to training and finance. Comparative studies should also assess alternative adoption models, including equipment-as-a-service, shared fabrication hubs, public-private partnerships, and university-industry innovation centres. Such research is necessary to determine how robotics and 3D printing can be institutionalised in ways that support inclusive industrial development, employment resilience, infrastructure delivery, and sustainable urban transformation.

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Robotic Technologies for Hazardous Construction Tasks: Implications for Occupational Health and Safety

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Abstract

This study examines the potential roles of robotic technologies in executing hazardous construction tasks and advancing occupational health and safety (OHS). Drawing on a comprehensive analysis of accident trends, risk profiles, and limitations of conventional safety management using structured literature review methodology, the study synthesizes current applications of robotics in work at height, demolition, excavation, confined spaces, and emergency response. It evaluates the integration of robotics with digital construction systems (BIM, IoT, and AI) and analyses levels of automation and human–robot interaction. The findings highlight significant potential for risk reduction, ergonomic improvement, and accident prevention, while also identifying emergent safety, psychological, and regulatory challenges associated with collaborative robotics. By examining drivers, barriers, and global adoption patterns, the study advances a socio-technical perspective on safe automation and proposes policy, industry, and research pathways to support responsible and sustainable deployment of robotics in hazardous construction environments.

Keywords: Construction Robotics, Occupational Health and Safety, Hazardous Work, Automation, Human–Robot Interaction.

1. Introduction

The construction industry remains one of the world's most hazardous sectors, it consistently reports high rates of occupational injuries, illnesses, and fatalities due to its inherently complex, dynamic, and physically demanding work environments (Liang & Cheng, 2023). The traditional "Focus Four" hazards: falls, struck-by incidents, caught-in/between accidents, and electrocutions continue to dominate injury statistics, thereby imposing significant emotional, medical, and economic burdens on workers and their families (Harris et al., 2023). Beyond acute accidents, prolonged exposure to noise, dust, repetitive movements, heavy lifting, and ergonomic strain contributes to chronic health conditions among craft workers. Occupational health and safety (OHS) therefore remain a persistent concern for researchers, policymakers, employers, and industry practitioners. Although safety regulations, protective equipment, and risk-control procedures have advanced, serious injuries remain prevalent, strengthening the case for technological interventions capable of reducing workers' exposure to hazards at their source and throughout the project lifecycle (Earnest et al., 2026).

Within this context, robotic technologies and automation are emerging as transformative tools for addressing hazardous construction tasks that have historically placed human workers at unacceptable risk. Robotics spans a spectrum from autonomous inspection robots and unmanned aerial vehicles (UAVs) to collaborative robots ("cobots") and wearable assistive systems such as exoskeletons, each designed to replace or augment human participation in dangerous work processes. Recent empirical and conceptual studies highlight how mobile robots can autonomously navigate complex jobsite environments to perform safety inspections, while exoskeletons and cobots can reduce physical strain and musculoskeletal disorders, which are key contributors to chronic disability (Urrea & Kern, 2025). However, introducing robotic systems into unstructured and continuously changing construction environments may also generate proximity hazards, human–robot interaction risks, operational uncertainty, and concerns about algorithmic reliability (Niehaus et al., 2025). Robotics must therefore be examined not merely as a technical solution, but as an intervention that can simultaneously mitigate existing hazards and create new categories of occupational risk.

Socio-Technical Systems Theory provides the principal theoretical lens for examining this duality. The theory conceptualises workplace performance and safety as outcomes of interactions between social and technical subsystems rather than as products of technology alone. From this perspective, the deployment of robotics represents more than the substitution of machinery for human labour. It reconfigures the interdependent relationships among workers, robotic technologies, organisational procedures, task structures, managerial

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practices, and safety cultures (Ang, Sankaran & Liu, 2025). This theoretical framing is especially important because existing studies have predominantly emphasised the technical capabilities, operational efficiency, and productivity benefits of robotics, while paying comparatively limited attention to how robotic adoption transforms risk exposure and human–work system relationships (Lin et al., 2025; Bahadori-Jahromi et al., 2025). Although robotic systems may reduce direct exposure to demolition, excavation, inspection, material handling, and work-at-height hazards, they may also create operational complexity, coordination failures, system dependencies, communication difficulties, and unintended vulnerabilities. The central issue is therefore not simply whether robotics improves construction safety, but under what organisational, technological, and behavioural conditions such improvements are achieved.

High Reliability Theory complements this central lens by directing attention to the organisational capabilities required to manage technologically complex operations in hazardous environments. From this perspective, superior safety performance depends not only on sophisticated robotic systems, but also on organisational resilience, continuous learning, operational redundancy, sensitivity to emerging hazards, and proactive risk management (Lin et al., 2025). The theory therefore provides a basis for assessing whether robotic integration strengthens the reliability of construction operations or produces emergent risks that undermine established safety controls. Human Factors Theory further extends the analysis by foregrounding the cognitive, ergonomic, and psychosocial dimensions of human–robot collaboration. Although robotics can reduce physical strain, fatigue, and workers' exposure to hazardous environments, it may also affect operator workload, situational awareness, trust in automation, decision-making, and human–machine coordination (Giallanza et al., 2024). Together, these perspectives demonstrate that effective robotic integration requires attention to technical reliability, organisational preparedness, and the physical and cognitive capacities of workers.

Accordingly, important questions remain regarding how robotic systems redistribute occupational risks, how human–robot collaboration affects workers' ergonomic and psychosocial wellbeing, and how system design, regulation, training, and safety-management practices should evolve to ensure that technological innovation strengthens rather than compromises worker safety. Addressing these questions requires an interdisciplinary synthesis of robotics, construction management, safety science, organisational studies, and human factors research. Anchored principally in Socio-Technical Systems Theory and supported by High Reliability Theory and Human Factors Theory, this review examines robotics as both a hazard-mitigation mechanism and a possible source of emerging risk. This theoretically integrated approach provides a basis for explaining why similar robotic technologies may produce different OHS outcomes across construction contexts and advances a more holistic understanding of worker safety and wellbeing within Construction 4.0.

2. Research Methodology

This study adopts a structured literature review design to examine the role of robotic technologies in mitigating hazardous construction tasks and advancing occupational health and safety (OHS) outcomes. The exploratory approach is appropriate given the interdisciplinary and evolving nature of robotics integration within construction environments, where empirical evidence remains fragmented across engineering, construction management, ergonomics, and safety science domains. The review aimed to map existing knowledge, identify dominant research themes, and uncover gaps related to robotic deployment in high-risk operations such as demolition, excavation, confined-space work, height-related tasks, and exposure to toxic or extreme conditions.

A structured search strategy was implemented across major academic databases, including Scopus and Web of Science with targeted searches in leading construction automation and safety journals. Keywords and Boolean combinations include terms such as "construction robotics," "hazardous tasks," "occupational health and safety," "automation in construction," "robot-assisted demolition," and "remote operation systems." Peer-reviewed journal articles, conference proceedings, and authoritative industry reports published in English within the last seven (7) years were considered to capture recent technological advancements.

Studies were screened based on predefined inclusion criteria focusing on relevance to hazardous task substitution, risk reduction, worker exposure mitigation, and documented safety outcomes. The initial search process identified 538 records. Following relevance screening, 104 studies were subjected to eligibility assessment. Duplicate records, studies with limited relevance, and inaccessible publications were subsequently eliminated using The Evidence Review Accelerator (TERA) tool, resulting in a refined dataset comprising studies that met the predefined inclusion criteria and ensured the rigour and reliability of the review process. A total number of 41 publications were analysed and included in the study, comprising 36 journal articles, 2 conference proceedings, and 3 book chapters.

The selected literature was subjected to thematic synthesis and qualitative content analysis to identify patterns in technological application, safety

performance, implementation drivers and barriers, and regulatory implications. Findings were categorized into occupational health and safety challenges in construction; robotic applications for hazardous construction tasks; implications for occupational health and safety; drivers and barriers to adoption of safety-oriented construction robotic; and comparative perspectives and global experiences. This analytical process enabled the development of recommendations for the adoption of robotic technologies for hazardous construction tasks for policy, industry, and practice in form of regulatory frameworks for safe deployment of construction robots, industry guidelines and best practices, and workforce training and safety culture transformation. Methodological rigour was systematically evaluated using the Critical Appraisal Skills Programme (CASP) Qualitative Checklist. The appraisal results informed both study inclusion decisions and the evidential weighting applied during synthesis, thereby enhancing the credibility, methodological robustness, and interpretive integrity of the review findings.

3. Findings

3.1. Occupational Health and Safety Challenges in Construction

The construction industry remains one of the most hazardous sectors globally due to the dynamic, complexity, and task-intensive nature of its operations. Its core activities, including work at heights, excavation, heavy equipment operation, demolition, and hazardous material handling expose workers to elevated risks of falls, struck-by incidents, electrocutions, ergonomic strain, and chemical hazards. These exposures are often simultaneous and compounding; for instance, lifting heavy materials at elevation increases both musculoskeletal and fall risks. Although task-based exposure characterization is widely adopted to inform preventive controls, the intermittent and heterogeneous configuration of construction work complicates conventional hazard profiling and limits the effectiveness of traditional exposure assessment tools (Olimat et al., 2025).

Longitudinal safety research continues to report disproportionately high injury and fatality rates in construction compared with other industrial sectors. Falls, caught-in/between incidents, and struck-by events consistently dominate accident statistics, reflecting the inherently physical and high-risk character of construction tasks (Adebowale & Agumba, 2024). Despite progressive regulatory developments since the 1970s, accident prevalence remains significant, underscoring structural vulnerabilities in safety governance (Olimat et al., 2025). Empirical studies further identify inadequate safety training, insufficient personal protective equipment (PPE), and entrenched risk-taking cultures as predictors of elevated accident rates within firms (Hassan et al., 2025).

While regulatory compliance, hazard identification, and risk assessment frameworks have yielded incremental improvements, they remain constrained by static evaluation models that inadequately address rapidly evolving site conditions, transient labour structures, and multi-contractor complexity. Implementation barriers, including limited safety resources, weak managerial commitment, fragmented communication, high labour turnover, and constrained worker participation continue to undermine proactive risk control (Rantsatsi, 2025). Increasing production pressures and compressed project timelines further exacerbate these weaknesses. Consequently, emerging scholarship advocates a transition toward transformative safety paradigms integrating robotics, automation, real-time data analytics, and dynamic risk modelling, alongside strengthened safety culture and participatory governance mechanisms to achieve sustainable reductions in occupational injuries and fatalities (Olimat et al., 2025).

3.2. Robotic Applications for Hazardous Construction Tasks

Robotic technologies are increasingly deployed to mitigate high-risk work at height, a leading cause of fatalities in construction. Tasks such as façade inspection, exterior finishing, and maintenance traditionally require workers on scaffolds or elevated platforms. Unmanned aerial vehicles (UAVs), wall-climbing robots, and aerial manipulators are enabling visual inspection, structural mapping, and light maintenance without human exposure to fall hazards. The advanced sensing technologies and deep-learning detection systems are also allowing real-time monitoring of fall risks, enhancing hazard identification and situational awareness (Urrea & Kern, 2025; Sahoo et al., 2025). While autonomous navigation, adhesion mechanics, and aerial manipulation are further supporting precision operations like drilling and anchor setting, thereby substantially reducing fall-risk exposure.

In demolition, excavation, and material handling, robotics reduces human exposure to structural collapse, debris, and hazardous materials. Remote-controlled demolition machines with hydraulic breakers, saws, or shears allow operators to perform tasks safely from a distance, lowering traumatic injury risks (Liu et al., 2024). Also, the autonomous heavy equipment platforms enable remote or automated execution of repetitive excavation and earthmoving tasks, minimizing operator exposure to unstable ground and mobile equipment hazards (Liu & Kim, 2025). Additionally, automated guided vehicles (AGVs) and robotic lifting systems are being used to transport heavy materials across uneven or congested sites, improving ergonomics and protecting workers from

musculoskeletal and struck-by injuries (Liu et al., 2024).

Furthermore, robotics is also being used in confined spaces and toxic environments where human entry is highly hazardous. Specialized tethered crawlers, vine-like robots, and ATEX-certified inspection systems can navigate narrow or contaminated spaces, perform inspections, and collect sensor data without human presence which reduces the risks of asphyxiation, poisoning, or entrapment (Qu, 2026). These systems provide rich situational awareness while ensuring compliance with occupational health standards, enabling safer operations in environments traditionally prohibitive for personnel.

Finally, robotic inspection, monitoring, and emergency response systems also enhance both routine and crisis safety management. UAVs and autonomous mobile robots equipped with LiDAR and cameras can conduct frequent, high-resolution inspections and safety audits, improving defect detection and quality assurance while reducing exposure to hazardous conditions (Halder & Afsari, 2023). In emergencies, teleoperated reconnaissance robots can detect hazards such as gas leaks or fire hotspots, and assess post-collapse conditions without risking additional personnel, thereby enhancing situational awareness and enabling timely, life-saving interventions (Naik et al., 2025).

3.3. Drivers and Barriers to Adoption of Safety-Oriented Construction Robotics

The adoption of safety-oriented construction robotics is primarily propelled by rapid technological advancements and demonstrable performance gains in precision, productivity, and occupational safety. Autonomous inspection drones, collaborative robots (cobots), and robotic systems for hazardous material handling reduce human exposure to high-risk environments while improving task consistency and operational efficiency. Emerging capabilities in autonomous navigation, human–robot collaboration, and sustainability-oriented automation further enhance their applicability in repetitive and dangerous construction activities (Xu et al., 2025). Evidence from systematic reviews indicates that integration with digital platforms such as Building Information Modelling strengthens the productivity–safety nexus, reinforcing the economic and operational rationale for deployment amid labour shortages and demographic transitions (Lin et al., 2025).

Notwithstanding these technological drivers, organizational and workforce barriers significantly constrain widespread uptake. Industry fragmentation, tight margins, and entrenched work practices discourage capital-intensive investments in robotics, particularly among small and medium-sized enterprises (Akinradewo et al., 2024). Persistent skills gaps, limited access to specialized training, and low awareness of robotic capabilities undermine readiness for implementation and contribute to workforce resistance (Obi et al., 2025). Sociotechnical analyses further demonstrate that leadership vision, change management strategies, and proactive workforce development are decisive mediating factors; firms with innovation-oriented cultures are more likely to realize safety and productivity gains, whereas conservative organizational climates inhibit adoption (Ang et al., 2024).

Externally, regulatory, ethical, and liability uncertainties introduce additional complexity into adoption decisions. The deployment of robots in dynamic, human-shared construction environments generates novel safety risks that existing occupational health and safety frameworks only partially address, particularly in relation to autonomous decision-making and emergent hazards (Earnest et al., 2026). Ambiguities in standards, certification pathways, insurance coverage, and incident liability contribute to cautious implementation strategies, especially where collaborative robots operate in close proximity to workers (Vecellio Segate & Daly, 2024). Ethical concerns regarding workforce displacement, equitable access to robotic technologies, and trust in autonomous systems further shape stakeholder perceptions, underscoring the need to balance technological innovation with social responsibility and worker well-being (Callari et al., 2024).

3.4. Comparative Perspectives and Global Experiences

In developed construction markets, robotics adoption has accelerated over the past decade in regions such as the United States, Europe, Japan, South Korea, and China, driven by labour shortages, productivity pressures, and heightened safety expectations. Research aligned with Construction 4.0 paradigms highlights autonomous navigation, sensor fusion, and human–robot collaboration as core innovations (Xu et al., 2025). Applications including autonomous earthmoving, prefabrication systems, inspection drones, semi-autonomous manipulators, and exoskeletons have demonstrably reduced worker exposure to repetitive and hazardous tasks (Earnest et al., 2026; Hilmi et al., 2024). Despite these advances, adoption remains uneven, particularly among small- and medium-sized firms, due to high capital costs, perceived technical risks, and regulatory complexity (Ting & Kong, 2025).

However, the emerging and developing economies face structural barriers such as limited capital, digital infrastructure constraints, and lower workforce technological readiness, which slow robotics integration compared to advanced markets (Ibrahim et al., 2026). Nevertheless, even incremental adoption can provide significant occupational health benefits, particularly for high-risk tasks like demolition,

confined-space inspection, and structural monitoring. Case studies indicate that aligning robotics deployment with smart city initiatives and modular prefabrication strategies can overcome resource limitations, offering safer, more efficient solutions while supporting local labour market constraints (Alazmi et al., 2025). More importantly, strategic investments in vocational training, education, and public–private partnerships are critical to developing sustainable digital competencies for robotics adoption.

The global impacts on occupational safety standards are profound. While robotics reduces exposure to traditional construction hazards, it also introduces novel risk profiles that require careful management (Earnest et al., 2026). International standards, including International Standard Organization (ISO) frameworks, are beginning to address industrial robotics safety, but construction-specific guidance lags due to project variability. Bridging this gap will require globally harmonized occupational safety guidelines integrating hazard analysis, prevention-through-design principles, and human-centred risk assessment. Finally, collaboration among regulators, industry stakeholders, and researchers will be essential to ensure that robotics enhances worker safety without introducing unintended vulnerabilities.

3.5. Implications for Occupational Health and Safety

The integration of robotic technologies into hazardous construction tasks presents substantial implications for occupational health and safety (OHS), particularly in relation to risk reduction and accident prevention. Autonomous mobile robots, robotic demolition systems, and inspection drones increasingly assume high-risk operations associated with falls, struck-by incidents, confined spaces, and toxic exposures, thereby limiting direct human exposure to hazardous environments. Industry evidence indicates that robotic deployment can reduce repetitive hazardous work by up to 72% and eliminate certain high-risk exposure scenarios altogether (Emani, 2026). In addition, AI-enabled robotic systems equipped with advanced perception and adaptive motion planning dynamically respond to changing site conditions, mitigating collision risks and unsafe configurations (Shah & Mishra, 2024). These capabilities reinforce prevention-through-design principles and strengthen the hierarchy-of-controls framework central to contemporary OHS practice.

In addition to accident mitigation, robotics contributes to improved ergonomic outcomes by addressing the high prevalence of musculoskeletal disorders (MSDs) in construction. Wearable exoskeletons and collaborative robotic platforms redistribute biomechanical loads, reduce repetitive strain, and promote safer working postures, thereby decreasing cumulative fatigue and physical stress (Niehaus et al., 2025). Such applications align with ergonomic role-allocation models, wherein robots assume physically demanding tasks while workers engage in supervisory or lower-risk functions (Merlo et al., 2024). However, ergonomic benefits depend on appropriate system calibration, anthropometric alignment, and task compatibility; poorly configured systems may introduce new forms of discomfort or strain. Effective integration therefore necessitates rigorous ergonomic assessment and adaptive design strategies to ensure sustained reductions in MSD incidence.

Notwithstanding these physical safety gains, robotic integration introduces psychological, cognitive, and systemic risks that require careful governance. Human–robot collaboration (HRC) environments can heighten mental workload, vigilance demands, and stress levels, with empirical studies reporting increased emotional strain during cobot-assisted construction tasks (Wang, 2025). Broader safety reviews also identify cognitive distraction, trust miscalibration, and reduced situational awareness as emerging psychosocial risk factors in HRC settings (Lin et al., 2025).

Furthermore, mechanical malfunctions, software failures, cybersecurity vulnerabilities, and the absence of construction-specific collaborative safety standards present additional hazards (Earnest et al., 2026; Liu et al., 2025; Urrea & Kern, 2025). These evolving risk landscapes underscore the necessity for systemic, human-centred OHS frameworks that incorporate tailored risk assessment, regulatory development, and standardisation to ensure that robotic adoption enhances, rather than compromises worker health and safety outcomes. Table 1 presents a concise synthesis of the relationships among major construction hazards, corresponding robotic applications, and their implications for occupational health and safety.

4. Discussion

Robotics adoption in developed construction markets, including the United States, Europe, Japan, South Korea, and China has accelerated over the past decade, propelled by labour shortages, productivity imperatives, and stringent safety expectations. Recent bibliometric evidence indicates a marked expansion in robotics research aligned with Construction 4.0 paradigms, emphasizing autonomous navigation, sensor integration, and human–robot collaboration (Xu et al., 2025). The review shows that autonomous earthmoving systems, inspection drones, prefabrication robots, and exoskeleton technologies can reduce worker exposure to hazardous and repetitive tasks, particularly in trenching, grading, and heavy lifting operations (Hilmi et al., 2024; Earnest et al., 2026). Nevertheless, adoption remains uneven, as high capital costs, technical uncertainty, and regulatory complexity continue to constrain small and medium-sized

Table 1: Summary mapping of construction hazards, robotic applications, and OHS implications

Major Construction Hazard	Robotic Applications	Key OHS Implications	Supporting Literature
Falls and work at height	UAVs, wall-climbing robots, and aerial manipulators	Reduce worker exposure to scaffolds, roofs, and elevated structures; require reliable navigation and fail-safe controls	Urrea and Kern (2025); Sahoo et al. (2025)
Demolition, excavation, and mobile-equipment hazards	Remote-controlled demolition robots and autonomous heavy equipment	Limit exposure to structural collapse, debris, unstable ground, and equipment collisions; introduce risks from system or sensor failure	Liu et al. (2024); Liu and Kim (2025)
Heavy lifting and repetitive work	AGVs, robotic lifting systems, cobots, and exoskeletons	Reduce musculoskeletal strain, fatigue, and struck-by risks; poor calibration may create new ergonomic hazards	Niehaus et al. (2025); Merlo et al. (2024)
Confined, toxic, and contaminated environments	Tethered crawlers, vine robots, ATEX-certified systems, and sensor-equipped robots	Minimise exposure to asphyxiation, poisoning, entrapment, and hazardous substances; depend on accurate sensing and communication	Qu (2026); Naik et al. (2025)
Inspection, monitoring, and emergency response	UAVs, LiDAR-equipped mobile robots, and teleoperated reconnaissance systems	Improve hazard detection, situational awareness, and emergency assessment; require human oversight, cybersecurity, and clear accountability	Halder and Afsari (2023); Earnest et al. (2026)

enterprises (Ting & Kong, 2025). In developing and emerging economies, robotics integration is moderated by structural constraints such as limited capital access, inadequate digital infrastructure, and workforce skill gaps (Ibrahim et al., 2026). Despite these barriers, robotics presents substantial occupational health benefits in high-risk activities including demolition, confined-space inspection, and structural monitoring. Evidence from policy-aligned Construction 4.0 initiatives demonstrates that integration can be catalysed when robotics deployment is embedded within broader smart city and infrastructure modernization strategies (Alazmi et al., 2025). Additionally, modular automation and off-site prefabrication offer context-sensitive entry points, particularly where controlled production environments mitigate site-level uncertainties.

Globally, the expansion of construction robotics carries significant implications for occupational safety governance. While automation reduces exposure to traditional hazards, it simultaneously introduces new risk profiles requiring adaptive regulatory responses (Earnest et al., 2026). Although, organizations such as the International Standard Organization (ISO) have advanced robotics safety standards in industrial domains, construction-specific frameworks remain underdeveloped due to the sector's variability and project-based complexity. There is therefore a pressing need for harmonized international guidelines that integrate prevention-through-design principles, job hazard analysis, and human-centred risk assessment to ensure that robotics adoption enhances, rather than compromises, worker safety across diverse economic contexts.

5. Recommendation for Policy, Industry, and Practice

The safe integration of robotic technologies into hazardous construction tasks requires an adaptive and forward-looking regulatory architecture. Policymakers should embed robotics within existing occupational health and safety legislation while addressing emergent risks associated with human–robot interaction, algorithmic governance, cybersecurity, and liability allocation. Harmonized international standards, performance-based regulatory instruments, and safety-by-design procurement frameworks are essential to ensure certification integrity, risk assessment rigour, and data governance compliance. Regulatory coherence, coupled with incentive-driven public procurement, can accelerate responsible diffusion while safeguarding worker welfare.

At the industry and organizational levels, regulatory principles must be operationalized through standardized safety protocols, continuous risk monitoring, and clearly defined accountability structures across technology providers, contractors, and site managers. Firms should implement pre-deployment validation, digital twin simulations, and real-time safety analytics to mitigate high-risk exposures, while industry consortia should facilitate benchmarking and knowledge sharing. Concurrently, workforce transformation is imperative: training programmes must extend beyond technical operation to

encompass systems literacy, ethical awareness, and human–machine collaboration competencies. By aligning regulatory innovation, industrial governance, and safety culture transformation, stakeholders can ensure that robotics functions as a protective augmentation mechanism that substantively advances occupational health and safety outcomes within the construction sector.

6. Conclusion

This study critically examined the role of robotic technologies in mitigating hazardous construction tasks and enhancing occupational health and safety (OHS) outcomes. The findings indicate that robotics, particularly in high-risk operations such as demolition, confined-space inspection, heavy lifting, and exposure-intensive activities substantially reduces direct worker exposure to physical, chemical, and ergonomic hazards. Evidence across applications demonstrates measurable improvements in injury prevention, exposure control, task precision, and operational reliability. Nonetheless, persistent barriers remain, including high capital costs, integration complexities, workforce skill deficits, and regulatory uncertainty. Overall, the results reposition robotics not merely as a productivity instrument but as a transformative safety intervention capable of fundamentally redistributing risk within construction systems.

Future research should prioritize longitudinal, multisite investigations to quantify long-term occupational health impacts across diverse construction contexts, while refining risk assessment frameworks that address emergent hazards within human–robot ecosystems. By situating robotics within a prevention-through-design paradigm, this study advances OHS scholarship through an integrated lens that links technological adoption, workforce transformation, regulatory evolution, and organizational safety culture. It highlights the imperative for proactive policy development, targeted capacity building, and ethically grounded human–robot collaboration models to ensure that technological innovation strengthens, rather than compromises the foundational objectives of worker protection and sustainable construction practice.

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Student Attendance and Academic Performance in a GenAI-Enabled Quantity Surveying Learning Environment

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Abstract

The increasing availability of Generative Artificial Intelligence (GenAI) tools is reshaping teaching, learning, and assessment practices in higher education. While GenAI offers opportunities to support independent learning and accessibility, concerns remain regarding student engagement, attendance, assessment authenticity, and competency development within applied disciplines. These concerns are particularly relevant in Quantity Surveying (QS) education, where measurement modules require students to develop technical competence, analytical reasoning, and professional judgement through guided practical activities.

This study investigates the relationship between student attendance and academic performance within a Level 4 QS Measurements module delivered at a UK higher education institution. A quantitative research approach was adopted using secondary data analysis of anonymised attendance records and assessment outcomes from 60 undergraduate students. Descriptive statistical analysis was conducted to examine patterns between attendance, coursework performance, and overall module achievement.

Findings suggest that students attending seven to ten sessions generally achieved higher average grades and pass rates than students attending fewer sessions. The analysis also identified variation between CW01 and CW02 performance, suggesting that different assessment components may evidence different aspects of students' technical understanding within technology-enabled learning environments.

This study contributes empirical evidence to the limited literature on attendance-performance relationships in QS education. The findings suggest that attendance remains an important component of academic performance in Quantity Surveying measurement education and highlight the need for authentic assessment approaches that support technical competency development in AI-enabled learning environments.

Keywords: Student Attendance; Academic Performance; Generative Artificial Intelligence (GenAI); Quantity Surveying Education; Measurement Education.

1 Introduction

The rapid advancement of Generative Artificial Intelligence (GenAI) technologies is transforming teaching, learning, and assessment practices across higher education (HE) (Timotheou *et al*, 2023). Tools such as ChatGPT are increasingly used by students to support academic writing, problem-solving, information retrieval, and assessment preparation (Jose *et al*., 2024). Recent studies suggest that GenAI is reshaping pedagogical practices and prompting universities to reconsider approaches to teaching, learning, and assessment design (Kasneci *et al*., 2023; Clegg & Sarkar, 2024).

Within built environment education, the adoption of GenAI presents both opportunities and challenges (Adebayo *et al*., 2025). The increasing digitalisation of the construction industry is transforming professional practice and competency expectations, requiring HE institutions to prepare graduates for technology-enabled working environments (Sawhney & Knight, 2023). Built environment education combines theoretical knowledge, technical competence, and professional skills development across a range of disciplines, including Quantity Surveying, Construction Management, Architecture, and Real Estate (Cotgrave & Alkhaddar, 2006; Sawhney & Knight, 2023). Consequently, universities must ensure that technological innovation enhances rather than replaces the development of these core competencies.

Student attendance has long been recognised as an important contributor to academic success within HE. Attendance facilitates engagement, interaction, guided learning, and timely feedback, all of which contribute to improved learning outcomes (Sanchez & Aleman, 2011). In technical disciplines such as Quantity Surveying, attendance may be particularly important because learning activities frequently involve practical demonstrations, drawing interpretation, quantity take-offs, and the application of New Rules of Measurement (NRM) principles (RICS, 2021; Qadir, 2023). These activities often require direct interaction with tutors and

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iterative problem-solving processes that can be difficult to replicate through independent study alone.

The growing availability of GenAI tools has raised questions regarding how technology-enabled learning environments may influence student engagement and learning behaviours (Rasul *et al*., 2024). While AI-supported tools can enhance accessibility and independent learning opportunities, concerns remain regarding reduced classroom engagement, over-reliance on technology, and the maintenance of authentic competency development within professional disciplines (Cotton *et al*., 2024; Adebayo *et al*., 2025). However, empirical evidence examining attendance and academic performance within Quantity Surveying education remains limited, particularly in the context of increasingly AI-enabled learning environments.

Therefore, this study investigates the relationship between student attendance and academic performance within a Level 4 Quantity Surveying Measurements module delivered at a UK HE institution. By examining attendance patterns and assessment outcomes, the study seeks to contribute to the understanding of student engagement within contemporary technology-enabled learning environments and to inform the design of authentic teaching and assessment practices within Quantity Surveying education.

2 Literature Review

2.1 GenAI and Student Learning Behaviour

Artificial Intelligence (AI) refers to computer systems capable of performing tasks that typically require human intelligence, including learning, reasoning, and problem-solving (Russell & Norvig, 2021). Generative Artificial Intelligence (GenAI), a subset of AI, can generate human-like outputs such as text, images, and code through large-scale machine learning models (Kasneci *et al*., 2023). The emergence of Large Language Models (LLMs), has significantly influenced HE by providing students with accessible tools for information retrieval, content generation, and learning support. Since the public release of ChatGPT in 2022, the adoption of GenAI within HE has increased rapidly (Kasneci *et al*., 2023). Students increasingly use these tools for academic writing, idea generation, information retrieval, problem-solving, and assessment preparation (Baidoo-Anu *et al*., 2024; Jose *et al*., 2024). Research suggests that GenAI can improve learning accessibility, enhance productivity, support personalised learning experiences, and increase student motivation through timely and tailored academic assistance (Jose *et al*., 2024; Timotheou *et al*., 2023).

Despite these benefits, concerns remain regarding academic integrity, over-reliance on AI-generated outputs, reduced critical thinking, and diminished independent learning (Kasneci *et al*., 2023; Qadir, 2023; Cotton *et al*., 2024). Within built environment education, academics have expressed concerns regarding plagiarism, assessment authenticity, and increasing student dependence on AI-generated content (Adebayo *et al*., 2025). Consequently, HE institutions are increasingly reconsidering assessment design strategies to support responsibleAI integration while maintaining authentic learning and competency development (Clegg & Sarkar, 2024; Rasul *et al*., 2024).

2.2 Attendance, Engagement and Academic Performance

Student attendance has long been associated with academic achievement within HE (Fang *et al*., 2024). Previous studies have demonstrated positive relationships between attendance, engagement, participation, and assessment performance, suggesting that regular attendance contributes to improved learning outcomes and academic success (Sanchez & Aleman, 2011; Bennett & Yalams, 2013). Attendance enables students to engage directly with teaching activities, interact with peers and tutors, and receive timely feedback that supports deeper learning and knowledge retention. The relationship between attendance and performance is closely linked to active learning principles. Beyond physical presence, meaningful engagement involves active participation, interaction with learning materials, and commitment to the learning process (Sanchez & Aleman, 2011; Fang *et al*., 2024). Students who engage more actively with educational activities generally achieve stronger academic outcomes than those who participate minimally (Fang *et al*., 2024).

The importance of attendance may be particularly significant within technical and professionally oriented disciplines. Subjects such as engineering, construction management, and Quantity Surveying require students to develop practical skills, analytical reasoning, and professional judgement through guided learning activities and iterative feedback processes (Bennett & Yalams, 2013). Therefore, attendance remains an important predictor of academic achievement despite increasing digital learning opportunities.

2.3 Attendance and Learning in AI-Enabled Environments

The growing availability of GenAI tools has created new opportunities for students to access academic support beyond traditional classroom settings. AI-powered systems can provide explanations, generate content, summarise information, and assist with problem-solving activities, allowing students to engage with learning materials independently and at any time (Kasneci *et al*., 2023; Baidoo-Anu *et al*., 2024). While these developments enhance accessibility and flexibility, they have also raised questions regarding student engagement and participation. Researchers have highlighted concerns that AI-supported learning may reduce interaction with teaching activities and alter

traditional learning behaviours (Cotton *et al*., 2024; Rasul *et al*., 2024). Consequently, students may perceive less reliance on scheduled teaching sessions when alternative forms of academic support are readily available.

However, limited empirical evidence examines whether attendance continues to matter for academic performance in AI-enabled learning environments, as most studies focus on GenAI opportunities and risks rather than attendance and achievement (Kasneci *et al*., 2023; Timotheou *et al*., 2023).

2.4 Quantity Surveying Measurement Education

Quantity Surveying (QS) measurement education is fundamental to the development of professional competency within built environment programmes. Measurement modules require students to interpret construction drawings, apply New Rules of Measurement (NRM) standards, undertake quantity take-offs, and prepare accurate quantities for cost estimating and Bills of Quantities production (RICS, 2021). These activities require technical knowledge, numerical accuracy, analytical reasoning, and professional judgement (Qadir, 2023; Adebayo *et al*., 2025). Unlike many theory-based subjects, QS measurement education relies heavily on practical and experiential learning approaches. Students develop competency through guided practice, classroom demonstrations, workshop activities, and continuous tutor feedback. The preparation of accurate quantity take-offs requires students to interpret design information, identify measurement requirements, and make informed professional decisions that extend beyond automated content generation (Qadir, 2023; Adebayo *et al*., 2025).

While GenAI may support independent learning and information access, it cannot fully replicate the practical engagement, contextual understanding, and professional judgement required within Quantity Surveying practice. Consequently, attendance and active participation remain important components of competency development within QS measurement education (AI4QS, 2026).

2.5 Research Gap

Existing research has examined relationships between student attendance, engagement, and academic performance (Bennett & Yalams, 2013; Sanchez & Aleman, 2011; Fang *et al*., 2024). However, most studies such as Bennett & Yalams (2013) and Fang *et al*. (2024) have been conducted within general HE contexts, with limited attention given to technical disciplines such as Quantity Surveying. Furthermore, little empirical evidence exists regarding whether attendance remains an important predictor of academic success within Quantity Surveying measurement education in increasingly AI-enabled learning environments. To address this gap, this study examines attendance patterns and academic performance in a Level 4 Quantity Surveying Measurement module at a UK HE institution, within a learning environment where students have increasing access to GenAI tools that may support learning and assessment preparation. The study provides foundational evidence on whether attendance remains an important feature of academic performance in QS measurement education within a GenAI-enabled context.

3. Research Methodology

A single-case study design has been employed in this study, where a Level 4 Quantity Surveying Measurements module delivered within a full-time undergraduate QS programme at a UK HE institution has been selected as the case. This design is justified by the fact that case studies can incorporate, or even be solely dependent upon, quantitative evidence (Yin, 2009). The relationship between student attendance and academic performance where GenAI tools are readily available has been examined by conducting descriptive statistical analysis. The study does not measure the direct influence of GenAI but investigates attendance-performance relationships within a contemporary AI-enabled learning context.

The module comprised two coursework assessments: CW01 (25%), an individual presentation assessing understanding of measurement principles and communication skills, and CW02 (75%), a cost-estimating exercise requiring students to prepare quantities from construction drawings. CW02 assessed technical competency, quantity take-off skills, numerical accuracy, and professional judgement. The initial dataset contained 84 student records, including attendance data, coursework marks, final grades, and progression outcomes. Twenty-four records were excluded due to DNS (Did Not Submit) and DNP (Did Not Participate) outcomes, resulting in a final sample of 60 students. Attendance was measured across ten scheduled teaching sessions. Assessment performance was evaluated using CW01 and, CW02 marks, and final weighted module grades. Descriptive statistical analysis was used to examine attendance distributions, average performance, pass rates, and variations between assessment components.

Institutional ethical approval was granted for the use of this secondary data, and all records were processed in accordance with GDPR and university data protection policies. Student data were anonymised prior to analysis. The findings are limited to a single institution and module context. In addition, the study relies on descriptive statistics and does not directly measure student use of GenAI technologies. Therefore, the findings should be interpreted within these limitations.

4. Findings and Discussion

4.1 Overall Attendance and Assessment Performance Profile

The analysis of 60 valid student records demonstrated notable variation in both attendance and assessment performance. According to Table 1 below, the average attendance across the module was 5 out of 10 sessions. The average final weighted grade was 49.48%, while the average CW01 and CW02 marks were 52.82% and 48.37%, respectively. The minimum and maximum values also indicate a wide spread of performance across the cohort. Final weighted grades ranged from 13.25% to 93.50%, while CW02 marks ranged from 7% to 98%. Attendance also varied across the full range of the module sessions, from 1 out of 10 sessions to 10 out of 10 sessions. Of the 60 students analysed, 32 students achieved the module pass mark of 40%, resulting in an overall pass rate of 53.33%.

Table 1 provides an overall descriptive profile of the dataset. It summarises average performance, minimum and maximum marks, and overall attendance distribution. Further analysis was conducted to recognize the attendance-based performance patterns, which are discussed separately in Section 4.2.

Table 1: Descriptive statistics of assessment performance and attendance.

Variable	Mean	Minimum	Maximum
CW01 Mark	52.82	29	87
CW02 Mark	48.37	7	98
Final Grade	49.48	13.25	93.50
Attendance	5/10	1/10	10/10

4.2 Attendance Patterns and Academic Performance

As shown in Table 2, student attendance varied across the ten scheduled teaching sessions. The table presents the number of students in each attendance category together with the corresponding average final grade and pass rate. The results indicate a consistent attendance-performance pattern, whereby students in higher attendance categories generally achieved stronger academic outcomes than students in lower attendance categories.

Students who attended one to three sessions achieved average final grades between 29.38% and 32.21%, with pass rates ranging from 14.29% to 20.00%. In contrast, students who attended seven to ten sessions achieved average final grades between 64.79% and 77.50%, with pass rates ranging from 76.92% to 100.00%.

To avoid overinterpreting individual attendance categories with small student numbers, the data were also analysed using three broader attendance bands. Students in the low-attendance group (1–3 sessions) achieved an average final grade of 30.94% and a pass rate of 16.67%, whereas students in the high-attendance group (7–10 sessions) achieved an average final grade of 67.23% and a pass rate of 85.71%. Students in the high-attendance group achieved average grades more than twice those of students in the low-attendance group, highlighting the substantial difference in academic outcomes between the two attendance categories. These findings indicate that students in the high-attendance group generally achieved substantially stronger academic outcomes than those in the low-attendance group.

While these descriptive findings suggest an association between attendance and academic performance within this cohort, they should not be interpreted as evidence of a statistically tested relationship or causal effect. Other factors, including prior academic ability, independent study habits, quality of engagement, confidence with measurement tasks, and access to additional learning support, may also have influenced student outcomes. Within Quantity Surveying measurement education, this pattern is pedagogically relevant because measurement learning requires students to interpret construction drawings, apply measurement principles, practise quantity take-off

Table 2: Attendance patterns and academic performance.

Attendance	No. of students	Average Final Grade (%)	Pass Rate (%)
1 Session	7	32.21	14.29
2 Sessions	5	31.05	20.00
3 Sessions	6	29.38	16.67
4 Sessions	6	50.54	66.67
5 Sessions	9	46.31	44.44
6 Sessions	6	46.67	50.00
7 Sessions	13	64.79	76.92
8 Sessions	4	70.00	100.00
9 Sessions	3	70.67	100.00
10 Sessions	1	77.50	100.00

procedures, and receive feedback on technical errors. These activities are often developed through repeated guided practice and tutor-supported learning. Therefore, the attendance-performance pattern observed in this module is consistent with wider literature that recognises attendance and participation as important contributors to learning in applied and technical disciplines.

4.3 Variations Between Coursework Components

The analysis identified notable differences in performance between CW01 and CW02 among some students. Several students achieved higher marks in CW01 than in CW02, with differences ranging from 25 to 60 percentage points between the coursework components, as shown in Table 3. While direct GenAI use was not measured in this study, these variations raise broader questions about assessment design, assessment authenticity, and the extent to which different coursework formats evidence students' applied technical understanding.

Table 3: Students demonstrating substantially higher CW01 performance relative to CW02

Student	CW01 (%)	CW02 (%)	Difference (CW01 − CW02)	Attendance
S1	81	21	+60	7/10
S2	80	20	+60	7/10
S3	61	22	+39	7/10
S4	56	21	+35	6/10
S5	51	16	+35	6/10
S6	54	20	+34	5/10
S7	51	21	+30	1/10
S8	71	41	+30	9/10
S9	48	20	+28	1/10
S10	32	7	+25	5/10

Alternative explanations may include differences in assessment format, student preparation strategies, communication skills, assessment weighting, and individual learning preferences. Therefore, the observed differences between CW01 and CW02 should not be attributed to any single factor. The cases presented in Table 3 indicate that performance was not always consistent across the two coursework components. This may partly reflect the different demands of CW01 and CW02. As outlined in the methodology, CW01 and CW02 had different assessment weightings and required students to demonstrate measurement-related learning in different ways. CW02 carried the higher weighting and required students to demonstrate applied technical understanding through measurement-related tasks. In Quantity Surveying education, such tasks require students to interpret construction information, apply measurement principles, undertake quantity take-off activities, and demonstrate technical reasoning linked to professional measurement practice.

The findings suggest that assessment design remains important in technical Quantity Surveying education. However, the present study was not designed to evaluate assessment effectiveness directly, and therefore these observations should be interpreted as exploratory rather than conclusive. Assessment formats that require students to demonstrate process, reasoning, and applied decision-making may provide stronger evidence of measurement competence than formats that primarily assess the final output or presentation of knowledge.

4.4 Interpretation of Findings in Relation to QS Measurement Education

The findings suggest that attendance and assessment design remain important considerations in Quantity Surveying measurement education within a GenAI-enabled learning environment. The attendance pattern presented in Section 4.2 suggests that students with higher attendance generally achieved stronger final grades and pass rates. This pattern is consistent with previous studies that associate attendance, participation and engagement with stronger academic performance in HE and technical learning contexts (Sanchez & Aleman, 2011; Bennett & Yalams, 2013; Fang *et al.*, 2024). The CW01–CW02 variation discussed in Section 4.3 further indicates that student performance was not always consistent across assessment components, highlighting the need to consider how different assessment formats evidence applied technical understanding.

This is particularly relevant to measurement education because Quantity Surveying students are required to develop procedural and applied competencies, including drawing interpretation, measurement sequencing, quantity take-off, application of measurement principles, and professional judgement. These competencies align with the technical requirements of detailed measurement practice set out in NRM2 (RICS, 2021). Within technical and professionally oriented disciplines, such competencies are commonly developed through guided practice, feedback, repeated application and engagement with problem-solving activities (Bennett & Yalams, 2013;

Qadir, 2023). While GenAI tools may support access to information, explanation and independent learning, existing literature also highlights concerns about over-reliance, reduced critical engagement and assessment authenticity in AI-enabled learning environments (Kasneci *et al*., 2023; Cotton *et al*., 2024; Rasul *et al*., 2024; Adebayo *et al*., 2025). The variation between CW01 and CW02 also reinforces the need to consider how assessment components capture different forms of learning. Assessment tasks that require students to explain, calculate, interpret, justify and demonstrate their measurement decisions may provide richer evidence of competency development than tasks that assess only final outputs. This is consistent with literature emphasising assessment authenticity and the need to evidence students' own reasoning, decision-making and applied competence in GenAI-enabled HE (Rasul *et al*., 2024). In AI-enabled learning environments, assessment authenticity depends not only on what students submit, but also on how clearly they demonstrate the process through which technical understanding has been developed.

Therefore, the findings contribute to discussions on QS pedagogy by showing that attendance, engagement with technical learning activities and assessment design remain closely connected to the development of measurement competence. More specific recommendations for teaching and assessment design are presented in the conclusion, in line with the scope of the empirical findings.

5. Conclusion and Further Research

This study investigated the relationship between student attendance and academic performance within a Level 4 Quantity Surveying Measurements module delivered at a UK HE institution.
The analysis identified a consistent attendance-performance pattern whereby students in higher attendance categories generally achieved stronger assessment outcomes and pass rates than students in lower attendance categories. Students attending seven to ten sessions achieved considerably higher average grades and pass rates than those attending one to three sessions. These findings suggest that regular attendance remains an important component of academic performance within Quantity Surveying measurement education. The study also identified variations in performance across different assessment components, suggesting that assessment format may influence how students demonstrate technical understanding and competency. Furthermore, the findings suggest that attendance alone does not guarantee academic success, highlighting the importance of meaningful engagement, participation, and active involvement in learning activities.

This study contributes to the Quantity Surveying education literature by providing empirical evidence of attendance-performance patterns within a technical measurement module. The findings support the continued importance of attendance, engagement, guided learning, and practical competency development within Quantity Surveying education.

Future research should investigate how emerging technologies, including Generative Artificial Intelligence (GenAI), may influence student engagement, attendance patterns, and assessment performance within built environment education. Such research should incorporate direct measures of student AI use to better understand the relationship between AI-supported learning behaviours and academic outcomes.

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Blockchain-Enabled Solutions in Construction Dispute Resolution: A Bibliometric and Thematic Analysis

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Abstract

This study systematically investigates blockchain-enabled dispute resolution within the construction domain. Notably, a gap still exists in systematic quantification and thematic mapping that directly addresses construction disputes. Thus, the study examines the key constructs, research directions, and theme development in blockchain-based approaches to construction dispute resolution, using a combined bibliometric and thematic analysis. The study employs a quantitative bibliometric design, based on peer-reviewed publications from the Scopus database, spanning 2017 to 2025. It also includes qualitative thematic interpretation of keyword clusters and key publications to support the bibliometric results. The search string TITLE-ABS-KEY (blockchain AND (construction OR "built environment") AND ("dispute resolution" OR claims OR arbitration OR litigation OR "smart contracts"). This study is limited to English-language publications indexed in Scopus, excluding industry and legal reports. A total of 147 documents were analysed for the study using VOSviewer software. The results show a steady increase in scholarly publications over time. The network visualisation demonstrates that four thematic pillars emanated from bibliometric analysis: decentralised digital governance for dispute prevention, blockchain-enabled supply chain and lifecycle accountability, smart contract–driven contractual automation in construction projects, and BIM-based information modelling. The study hereby concludes that integrating decentralised ledgers, automated contracts, secure information management, and lifecycle modelling, blockchain research in construction is increasingly positioned not merely as a technological innovation, but as a systemic mechanism for dispute prevention and resolution.

Keywords: Blockchain technology, Claims, Construction disputes, Dispute resolution, Smart contracts

Introduction

The construction industry is widely recognised as one of the most dispute-prone sectors due to its inherent complexity, fragmented delivery systems, multiplicity of stakeholders, and recurring contractual ambiguities (Kalogeraki & Antoniou, 2024). Disputes commonly arise from delayed payments, time overruns, scope variations, inconsistent records and disagreements over performance obligations (Kalogeraki & Antoniou, 2024). These conflicts generate significant economic and operational consequences, including cost overruns, project delays, reduced productivity, and deteriorating professional relationships (Nanayakkara *et al.,* 2021). Conventional mechanisms such as litigation, arbitration, and adjudication are often adversarial, time-consuming, and costly, thereby reinforcing inefficiencies rather than resolving them effectively (Kalogeraki & Antoniou, 2024). Consequently, there is a growing demand for digital solutions that enhance transparency, accountability, and enforcement in the construction contract administration.

Blockchain technology has emerged as a promising innovation capable of transforming contract management and dispute resolution practices (Celik *et al.,* 2024). As a decentralised and immutable ledger, blockchain enables secure and tamper-resistant recording of transactions, strengthening transparency and trust among stakeholders (Celik *et al.,* 2024). Smart contracts self-executing agreements embedded within blockchain networks extend this functionality by automatically enforcing predefined conditions when specified requirements are met (Wu *et al.,* 2022). Accordingly, scholars suggest that blockchain-enabled systems may decrease both the frequency and severity of disputes while reinforcing inter-organisational trust (Kalogeraki & Antoniou, 2024).

Despite this potential, existing reviews largely address blockchain applications from broader perspectives, focusing on supply chain management, payment efficiency, and data traceability rather than dispute resolution as a distinct domain (Celik *et al.,* 2024). Although Saygılı *et al.* (2021) proposed a decentralised online dispute resolution model, related research remains fragmented across empirical, conceptual, and legal strands.

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There is no integrated bibliometric and thematic review dedicated specifically to blockchain-enabled dispute resolution in the construction contract. Existing studies identify technological potentials and barriers (Wu *et al.,* 2022) but do not systematically map the research evolution, dominant themes, or influential contributors in this niche area. Addressing this gap, the present study employs a combined bibliometric and thematic approach to map publication trends, citation impact, thematic clusters, and emerging research directions. By integrating quantitative mapping with qualitative interpretations, the study consolidates dispersed knowledge and clarifies the blockchain's evolving role in dispute prevention, adjudication, and governance.

Blockchain-Enabled Dispute Resolution in Construction

The construction industry has increasingly adopted digital technologies to address persistent inefficiencies arising from fragmented information, contractual ambiguity, and coordination failures, conditions that frequently generate claims and disputes. Blockchain technology has emerged as a decentralised, tamper-resistant ledger that records transactions transparently and securely, fostering trust in environments often characterised by adversarial contracting and opportunistic behaviour (Perera *et al.,* 2020; Mahmudnia *et al.,* 2022). Early built environment research framed blockchain not as a speculative financial instrument but as a governance infrastructure providing a shared, verifiable source of truth across project stakeholders (Mahmudnia *et al*., 2022). Since 2019, scholarly attention has expanded to explore its capacity to enhance collaboration, accountability, and dispute mitigation through improved data integrity and lifecycle auditability (Celik *et al.,* 2024).

Blockchain's principal contribution lies in establishing a shared, immutable data environment that strengthens governance over contractual and performance information (Ye *et al*., 2022; Celik *et al.,* 2024). Although consensus exists regarding benefits such as traceability and transparency, much of the literature conceptualises blockchain primarily as a preventive mechanism rather than a direct dispute resolution tool, indicating the need for focused synthesis on its role in dispute dynamics.

In construction, smart contracts are associated with milestone verification, progress certification, and payment release processes that traditionally generate contention (Hamledari & Fischer, 2021). Studies suggest automation reduces human error, discretionary delays, and information asymmetry, addressing common conflict triggers (Mahmudnia *et al.,* 2022). However, limitations persist, including legal enforceability, jurisdictional variation, rigidity of coded logic, and tensions between deterministic systems and the interpretive nature of construction practice (Kalogeraki & Antoniou, 2024). Smart contracts should therefore be viewed as components of broader socio-technical governance systems.

Beyond automation, blockchain-enabled contract administration shows potential to improve transparency and traceability in variation management and certification (Kalogeraki & Antoniou, 2024). Payment automation, particularly when integrated with BIM verification, may reduce administrative delays (Hamledari & Fischer, 2021). Yet empirical studies directly measuring dispute outcomes remain limited. Existing gaps include the absence of dedicated bibliometric synthesis, insufficient outcome-based evaluations, and underexamined legal and institutional dimensions (Kalogeraki & Antoniou, 2024), justifying a focused thematic consolidation.

2.2 Theoretical Lens

Transaction Cost Economics (TCE) provides a theoretical foundation for understanding the relevance of blockchain-enabled solutions in dispute resolution. It argues that firms aim to minimise transaction costs arising from opportunism, uncertainty, bounded rationality, and asset specificity (Williamson, 1985).

Through TCE, blockchain provides a shift in contractual governance from centralization to decentralization. This lowers transaction costs and removes slow, opaque, and expensive traditional dispute resolution protocols. By providing a shared, immutable ledger, it mitigates opportunistic behaviours such as information withholding and delayed payments, aligning with TCE's emphasis on safeguarding transactions (Saberi *et al.*, 2019). The technological protocol substitutes centralized trust with cryptographic verification, automated monitoring, and code-based enforcement. This process lowers costs, eliminates opportunistic behaviour, and enhances speedy transactions. However, TCE might be limited in highly nuanced disputes where subjective judgement is required; human courts may be more cost-effective.

Research Methodology

Given its reliance on bibliometric indicators and qualitative thematic interpretation, this study adopts a post-positivist and pragmatic research paradigm (Celik et al., 2024). This paradigm is appropriate because it recognises objective patterns in publication data while allowing interpretive analysis of themes and research directions. The paradigm supports methodological pluralism and aligns with established practices in construction management and information systems research. A Post-positivist orientation is operationalized using quantitative and replicable metrics.

Scopus was selected for its broad, structured metadata needed for co-occurrence and citation analysis, and its

established use in prior construction-management bibliometric studies that support comparability with the existing literature. The search string TITLE-ABS-KEY (blockchain AND (construction OR "built environment") AND ("dispute resolution" OR claims OR arbitration OR litigation OR "smart contracts"). The authors searched the database on January 18, 2026, and found 842 relevant documents. 366 documents were found after using engineering and environmental science as subject areas, document type limited to articles and conference papers, final publication stage, document sources are journal publications and conference proceedings. Scopus indexes legal journals and professional articles were also considered. Only documents written in the English language were considered. Documents were further filtered by considering the relevance of the titles and abstracts to exclude irrelevant ones, thereby reducing them to 147 documents. This number is considered suitable because bibliometric reviews perform best with 50-200 articles. A very small dataset may limit the network analysis, thematic mapping, and trend detection. VOSviewer software was applied to visualise bibliometric mapping on 147 documents (Van Eck & Waltman, 2010). The study considered documents published spanning 2017 to 2025, reflecting the period during which blockchain applications in construction began to gain traction. Bibliometric analysis is particularly suitable because it systematically captures the intellectual structure and evolution of the domain. Bibliometric techniques provide a quantitative and reproducible approach to mapping scholarly output, identifying influential publications, and detecting thematic convergence over time (Donthu *et al.*, 2021).

Findings and Discussion

4.1 Publications Per Year

Out of the total 147 documents that were analysed, 98 were journal articles while 49 were conference proceedings. Figure 1 shows the publication trends from 2017-2025. It was obvious that between 2017 and 2018, there were no publications related to blockchain-enabled solutions in dispute resolution. However, a notable paradigm shifts in publications in this subject area began in 2019 with (7 documents), in 2020, it was increased to (11 documents), (16 documents) recorded in 2021, (28 documents) in 2022 and (30 documents) were produced in 2023. There was a sharp decline in 2024 with 21 documents and later rose again in 2025 to (34 documents). Though the reason for decline in the number of publications could not be ascertained, Figure 1 shows multiple peaks which portend an increase in the researchers interests in digitalizing dispute resolutions because of the inherent benefits.

4.2 Network Analysis of Publications per Country

The analysis of the network of publications per country, with a minimum of three documents and two citations per country, which eliminates possible overlapping where articles have more than one country's affiliation. Out of the thirty-six countries, twenty-one met the threshold. Figure 2 shows the network visualization of

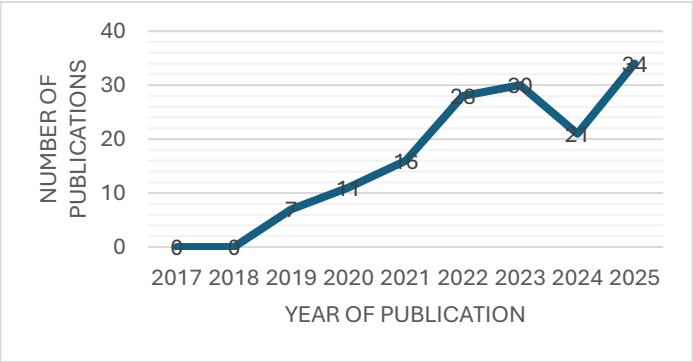

Figure 1: Publication Per Year (2017-2025)

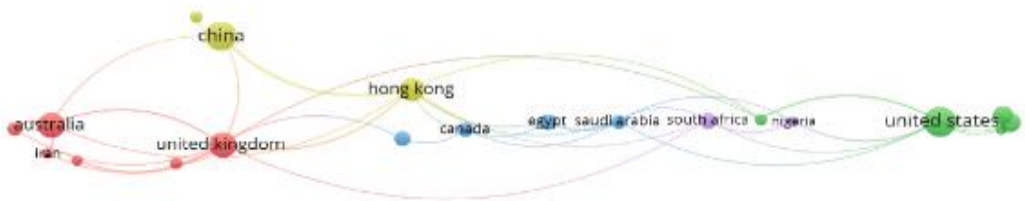

Figure 2: Network Visualisation of the number of publications per country

the number of documents per country. Twenty-one leading countries in Blockchain-enabled solutions in dispute resolution are listed in Table 1. It shows six leading countries in the subject area. United States (23 documents, 806 citations), China (22 documents, 494), Australia (17 documents, 1133 citations), United Kingdom (17 documents, 589 citations), Hong Kong (14 documents, 628 citations), and Turkey (10 documents, 478 citations). This is a testament that these countries have made notable contributions to the subject. The total link strength of countries reveals that the study conceptualizes the framework of blockchain application in dispute resolution is gaining acceptance. The network visualization reveals an international collaboration among the authors who have worked in this area. South Africa has collaborated with five countries (UK, USA, Hong Kong, Saudi-Arabia and Nigeria). The United Kingdom has the highest collaboration index with nine countries (China, Malaysia, Sweden, Australia, South Korea, Hong Kong, South Africa, Iran, and Singapore).

4.3 Publication per Document Source

A threshold of 3 publications per source was set for 13 publication sources as shown in Table 2. Automation in construction has published 22 documents (2248 citations). This revealed that this journal has published more blockchain technology than any other journal outlet. This is followed by Buildings 7 documents (189 citations), Engineering, Construction and Architectural Management with 5 documents (107 citations). The publication trend suggests that Automation in Construction dominates the field, with most documents and citations, indicating a strong technological

Table 1: Publications per Country

Country	Document	Citation	Total link Strength
United States	23	806	10
China	22	494	7
Australia	17	1133	9
United Kingdom	17	589	13
Hong Kong	14	628	12
Turkey	10	478	1
Italy	9	133	1
India	8	99	0
Egypt	7	105	5
South Africa	7	83	6
South Korea	6	83	2
Canada	6	11	4
Sri Lanka	5	69	4
Saudi Arabia	5	32	8
Germany	4	148	1
Malaysia	4	144	1
Singapore	4	76	5
Iran	3	146	4
Netherlands	3	73	1
Sweden	3	32	3
Nigeria	3	14	5

Table 2: Publication per Document Source

Source	Document	Citation	Impact Factor
Automation in Construction	22	2248	11.5
Buildings	7	189	3.1
Engineering, Construction and Architectural Management	5	107	3.9
Journal of Information Technology in Construction	4	167	3.8
World Construction Symposium	4	50	-
Proceedings of International Structural Engineering and Construction	4	31	-
IOP Conference Series: Earth and Environmental Science	4	10	0.402
Journal of Legal Affairs and Dispute Resolution in Engineering and Construction	3	145	1.5
Journal of Construction Engineering and Management	3	73	5.1
Journal Management in Engineering	3	68	5.3
Journal of Engineering, Design and Technology	3	33	2.7
IEEE Access	3	78	3.6
Proceedings of the European Conference on Computing in Construction	3	7	-

emphasis and scholarly contribution. Other journals, such as Buildings, Engineering, Construction, and Architectural Management, and the Journal of Information Technology in Construction, make moderate contributions, indicating consistent interdisciplinary interaction. Conference proceedings, such as the World Construction Symposium and the European Conference on Computing in Construction, have low citations, indicating that emergent research is still being consolidated into journal publications. In general, the area is technologically based but becoming more interdisciplinary, encompassing fields such as building innovation, management, legal, and digital engineering.

4.4 Co-authorship (Bibliographic Coupling) analysis per Country

The bibliographic coupling map reveals a globally interconnected research network structured into three main clusters as shown in Figure 3. The first (red cluster) is dominated by the United States and China, which exhibit the largest nodes and strongest coupling strength, indicating high publication output and substantial shared reference bases with countries such as Hong Kong, Italy, India, Singapore, Germany, Turkey, and South Korea. The second (green cluster) is anchored by the United Kingdom and Australia, closely linked with Malaysia, the Netherlands, Sweden, Sri Lanka, and Iran, reflecting a cohesive and regionally aligned intellectual grouping. The third (blue cluster) comprises South Africa, Nigeria, Saudi Arabia, Egypt, and Canada, with South Africa emerging as a central node within this grouping. Cross-cluster linkages involving the United States, the United Kingdom, China, and Australia demonstrate strong bridging roles and high intellectual centrality, indicating that the field shares a common global knowledge base despite regional clustering.

4.5 Thematic Analysis

A pragmatic orientation informs the cluster and themes inductively. Analysis of the keyword network (32 items, 338 links, total link strength = 1405) reveals four coherent and interrelated research themes for the study. While the clusters were algorithmically generated using VOSviewer (Van Eck & Waltman, 2010) as shown in Figure 4, the following themes represent an interpretive synthesis of their conceptual meaning. Four pillars are

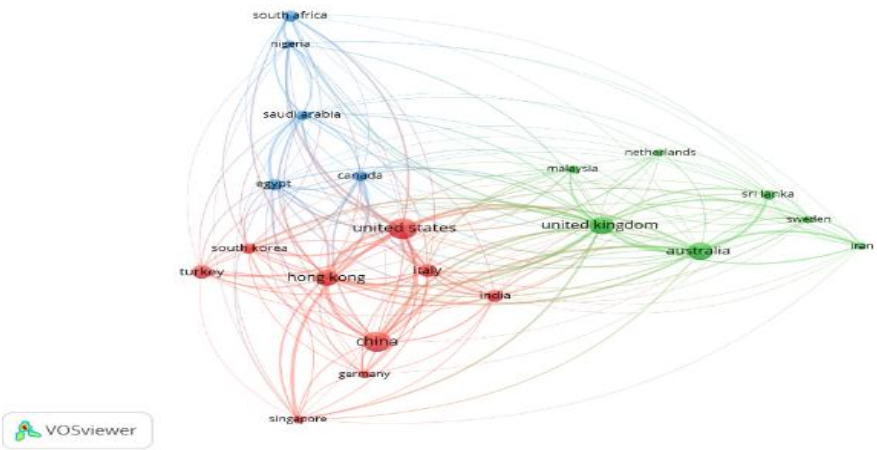

Figure 3: Network visualisation Co-authorship per country

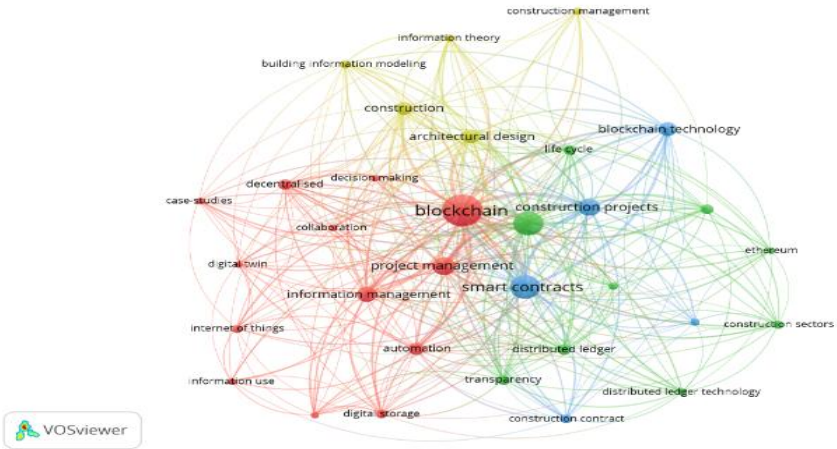

Figure 4: Network Visualisation Keyword Co-occurrence

explicitly empirically derived clusters groupings that emerged from keyword co-occurrence frequency in the retrieved literature rather than as validated theoretical constructs with defined boundaries, measurement properties, or causal relationships to one another.

Theme 1: Decentralised Digital Governance for Dispute Prevention

Theme 1 contains 13 keywords (automation, blockchain, case studies, collaboration, decentralised, decision-making, digital storage, digital twin, information management, information use, Internet of Things, network security, project management) that reflect the managerial and technological governance of construction processes. This theme reflects blockchain as a governance infrastructure for improving transparency, coordination, and accountability in construction projects. The co-occurrence of decentralised, collaboration, and decision-making suggests a shift from central control structures toward distributed trust architectures. Blockchain's decentralised ledger enhances tamper resistance and data integrity, which are essential in evidentiary contexts during disputes (Casino et al., 2019).

The presence of digital twin and IoT indicates integration with real-time monitoring systems, enabling objective verification of project performance. Such integration supports proactive dispute avoidance by reducing information asymmetry among stakeholders (Pan & Zhang, 2021). Information management and network security further reinforce the importance of reliable digital records in mitigating claims related to miscommunication, data manipulation, or incomplete documentation.

Theme 2: Blockchain-Enabled Supply Chain and Lifecycle Accountability

The following keywords are items in theme 2 (construction industry, construction sectors, construction supply chain, distributed ledger technology, Ethereum, lifecycle, supply chain management, transparency) with a focus on distributed ledger technology (DLT) as an infrastructural solution for lifecycle transparency. The presence of Ethereum indicates practical deployment platforms for smart contract execution. Blockchain's immutability has been widely associated with supply chain transparency (Saberi et al., 2019). In construction, lifecycle integration is critical because disputes frequently arise from fragmented information flows across project stages (Nawari & Ravindran, 2019). The co-location of transparency and supply chain management demonstrates that this stream positions blockchain as a tool for traceable procurement, payment flows, and material verification mechanisms directly linked to dispute prevention.

Theme 3: Smart Contract–Driven Contractual Automation in Construction Projects

Blockchain technology, construction contracts, construction projects, project participants and smart contracts form the contractual core of the network in theme 3. Smart contracts are self-executing code deployed on blockchain platforms that automate contractual obligations when predefined conditions are met (Szabo, 1997). In construction, they have been proposed to automate progress payments and reduce opportunistic behaviour among project participants (Hamledari & Fischer, 2021). The theme of construction contracts and project participants indicates strong thematic alignment with dispute resolution, as payment delays and contractual ambiguities are leading causes of construction disputes (Titus et al., 2023). This theme hereby represents the legal-technological interface where blockchain directly addresses contractual enforcement and payment security.

Theme 4: BIM-Based Information Modelling

Architectural design, building information modelling, construction management, and information theory reflect the informational and theoretical foundation of blockchain integration. Building Information Modelling (BIM) provides structured digital representations of project data, enabling interoperability and lifecycle information management (Succar, 2009). Prior research has identified the complementary relationship between BIM and blockchain for enhancing data reliability and process transparency (Nawari & Ravindran, 2019). The presence of information theory suggests a conceptual grounding in data transmission, integrity, and system coordination principles. This theme thus anchors blockchain-enabled dispute resolution within robust digital information ecosystems.

Conclusion and Further Research

A bibliometric review was conducted to visualise and map the research trends of blockchain and dispute resolution. Data mined from the Scopus database was mapped using VOSviewer software. A total of 147 documents were eventually used for the study after the initially mined documents had been filtered based on exclusion and inclusion criteria. The study mapped publications per country, documents per source, bibliographic coupling, co-authorship, and keyword co-occurrence. The network visualisation demonstrates that blockchain-enabled solutions in construction dispute resolution are organised around four interdependent pillars: (1) decentralised digital governance for dispute prevention, (2) blockchain-enabled supply chain and lifecycle accountability, (3) smart contract–driven contractual automation in construction projects, and (4) BIM-based information modelling. The density of connections and high total

link strength indicate a maturing research domain characterised by conceptual convergence rather than fragmentation. Crucially, the thematic core of the network aligns with known dispute drivers such as payment delays, contractual ambiguity, fragmented information, and lack of transparency. The study thus concludes that integrating decentralised ledgers, automated contracts, secure information management, and lifecycle modelling, blockchain research in construction is increasingly positioned not merely as a technological innovation, but as a systemic mechanism for dispute prevention and resolution.

This study advances knowledge by systematically mapping the intellectual structure, trends, and thematic evolution, integrating fragmented prior studies, identifying critical gaps in terms of legal enforceability and smart contracts limitations, and providing a theory-informed foundation to guide future empirical research, policy development, and industry adoption strategies

The study's scope is limited, given that it leverages only the Scopus library. Scopus, a database from Elsevier, is one of the largest and most inclusive databases that thoroughly records abstracts and citations of peer-reviewed literature as well as quality web sources covering various academic disciplines. Future work should supplement Scopus with a legal-domain database.

This approach can guide further research by identifying thematic gaps in legal enforcement, governance strategies, and practical implementation problems

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Assessing Organizational Readiness for AI-Enabled Total Quality Management in Nigerian Construction Firms

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Abstract

This study explores the organisational readiness of Nigerian construction contracting firms for the integration of Artificial Intelligence (AI) into Total Quality Management (TQM) systems. Adopting a quantitative approach, data were collected through a structured questionnaire and analysed using descriptive statistics and inferential statistics. The study evaluates key readiness dimensions, including technological infrastructure, data governance, workforce skills, leadership commitment, regulatory environment, cultural attitudes, and financial capacity. These dimensions are conceptualized within the Technology Organization Environment (TOE) framework as an organizing lens. Findings indicate a moderate level of readiness across the sector, with notable variation observed among small, medium, and large firms. Technological infrastructure and TQM maturity show comparatively higher readiness, while gaps exist in data management, workforce competencies, and regulatory clarity. Inferential analysis suggests differences across firm sizes in workforce skills, cultural attitudes, TQM practices, and supply chain integration. The study provides contextual, analytic perceptions from a developing economy setting and offers preliminary insights for industry stakeholders and policymakers seeking to support AI-enabled quality management in construction.

Keywords: Artificial Intelligence (AI); Total Quality Management (TQM); Organizational Readiness; Construction Industry, Nigeria

1. Introduction

The construction industry is undergoing a significant paradigm shift driven by rapid advancements in digital technologies, increasing demand for efficiency, and the imperative for sustainable infrastructure delivery (Eze & Chinedu, 2020). Within this evolving landscape, Artificial Intelligence (AI) has emerged as a transformative force with the potential to redefine traditional construction practices, particularly in the domain of quality management. In Nigeria, where the construction sector plays a critical role in economic development, employment generation, and infrastructure provision, persistent challenges such as cost overruns, project delays, poor quality outcomes, and inefficient processes continue to undermine performance (Ibrahim et al., 2024; Okwe, 2024). These systemic inefficiencies highlight the urgent need for innovative approaches to enhance productivity and quality assurance.

Total Quality Management (TQM), a well-established management philosophy centred on continuous improvement, customer satisfaction, and process optimisation, has been widely recognised as a critical driver of performance in construction organisations. However, the effectiveness of TQM in the Nigerian construction industry remains constrained by inconsistent implementation, limited data utilisation, and inadequate integration of digital technologies (Bamgbose et al., 2024). The integration of AI and TQM referred to as AI-enabled TQM offers a promising pathway to address these limitations by embedding intelligent automation, predictive analytics, and data-driven decision-making into quality management systems.

AI technologies such as machine learning, computer vision, and predictive analytics have demonstrated significant potential in enhancing construction processes, including automated defect detection, risk prediction, real-time monitoring, and optimisation of resource allocation (Adamu et al., 2024). Globally, the adoption of AI in construction is accelerating, driven by the need to improve efficiency, reduce waste, and enhance safety. However, despite growing awareness, the adoption of AI in the Nigerian construction sector remains at an early stage, hindered by infrastructural deficiencies, skills gaps, regulatory uncertainties, and cultural resistance to change (Onyia et al., 2024). Recent policy initiatives, including Nigeria's National Artificial Intelligence Strategy and the National Digital Economy Policy, underscore the government's commitment to fostering digital transformation and innovation across sectors (NITDA, 2025; Federal Ministry of Communications and Digital Economy, 2020). Nonetheless, translating these strategic ambitions into practical implementation within construction firms requires a comprehensive

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understanding of organisational readiness. This readiness extends beyond technological capability to encompass workforce competence, leadership commitment, regulatory alignment, and organisational culture.

This study therefore aims to assess the organisational readiness of Nigerian construction contracting firms for the adoption of AI-enabled TQM. By examining key readiness factors including technological infrastructure, data governance, workforce skills, leadership commitment, regulatory environment, cultural attitudes, and financial capacity the study provides a holistic evaluation of the factors influencing AI–TQM integration. Furthermore, it explores differences in readiness across firm sizes, offering critical insights into how small, medium, and large contractors can strategically position themselves for digital transformation.

2. Literature Review

2.1 Total Quality Management (TQM): Principles and Application in the Construction Industry

Total Quality Management (TQM) is widely recognised as a comprehensive management philosophy aimed at achieving long-term organisational success through continuous improvement, customer satisfaction, and the active involvement of all employees. Rather than functioning as a discrete set of tools, TQM represents an integrated system that embeds quality into organisational culture, processes, and strategic decision-making. The foundational principles of TQM, as articulated by quality pioneers such as Deming, Juran, Crosby, and Ishikawa, emphasise customer focus, process optimisation, employee involvement, fact-based decision-making, and continuous improvement.

Although TQM originated in the manufacturing sector, its application within the construction industry has gained increasing attention over the past two decades. The construction sector, characterised by project-based operations, fragmented supply chains, and bespoke outputs, has historically lagged manufacturing in adopting structured quality management systems. Nevertheless, empirical studies demonstrate that effective implementation of TQM in construction can significantly enhance project performance, reduce defects, improve client satisfaction, and increase organisational efficiency (Ibrahim et al., 2024; Okwe, 2024). The implementation of TQM in developing economies, particularly Nigeria, remains inconsistent. While awareness of TQM principles is relatively high (Olaleye, 2019), practical application is often limited by inadequate technical expertise, weak enforcement of standards, poor communication, and resistance to organisational change (Bamgbose et al., 2024). Furthermore, the limited use of data-driven decision-making within traditional TQM practices constrains its effectiveness, highlighting the need for integration with emerging digital technologies.

2.2 TQM in the Construction Industry: Global Perspectives

Historically, TQM found its earliest and most widespread application in manufacturing, particularly in Japan and later in the United States, where it led to significant gains in productivity, cost reduction, and product reliability. The construction industry, however, has traditionally lagged in adopting TQM, due to its project-based nature, fragmented supply chains, and the prevalence of bespoke, one-off projects. Key elements of TQM in construction include: Quality Assurance (QA): Systematic processes to ensure that project requirements are met, including the establishment of policies, procedures, standards, and training, Quality Control (QC): The specific implementation of QA through inspections, testing, and corrective actions to identify and rectify defects, Continuous Improvement: Regular review and refinement of processes to eliminate waste, reduce errors, and enhance value, Teamwork and Collaboration: Cross-functional teams involving clients, contractors, designers, and suppliers to foster shared responsibility for quality,

2.3 TQM in Nigerian Construction: Current State and Challenges

In Nigeria, the construction industry is a vital sector, contributing significantly to GDP and national development. However, it faces persistent challenges related to poor quality, structural failures, cost overruns, and project delays (Ibrahim et al, 2024). Literature consistently attributes many of these issues to the lack of strict compliance with TQM principles, inadequate quality management systems, and insufficient training of professionals. Purchasing quality materials, ensuring quality improvement processes, site management responsibility, and monitoring/control of quality are among the most practiced principles, but effective knowledge management and information sharing are less developed.

2.4 Artificial Intelligence in Construction: Global and Nigerian Trends

2.4.1 Global State of AI Adoption in Construction (2020–2025)

Artificial Intelligence (AI) is rapidly emerging as a transformative force in the construction industry worldwide. According to the Royal Institution of Chartered Surveyors (RICS) Artificial Intelligence in Construction Report (2025), the industry is at an inflection point, with growing data maturity, accessible tools, and mounting pressure for productivity gains creating the conditions for rapid AI adoption. The global AI in construction market is projected to grow from $4.86 billion in 2025 to $22.68 billion by 2032, at

a compound annual growth rate of 24.6% (MarketsandMarkets, 2024; Fortune Business Insights, 2024). Despite this optimistic outlook, actual adoption remains limited; as of 2025, approximately 45% of organisations report no use of AI, 34% are in early pilot phases, and less than 1% have achieved full organisation-wide integration (McKinsey & Company, 2024; Deloitte, 2025). While 56% of surveyed investors plan to increase AI-related investments compared to previous years, only about 20% of organisations are actively engaged in strategic planning or proof-of-concept development (PwC, 2024; KPMG, 2025). Key barriers to AI adoption in construction include a lack of skilled personnel (46%), poor data quality (30%), integration challenges (37%), high implementation costs (29%), and unclear return on investment (28%) (McKinsey & Company, 2024; Deloitte, 2025).

2.4.2. AI technologies being adopted in construction include:

Machine Learning: Used for predictive analytics, risk assessment, cost estimation, and schedule optimization. Computer Vision: Enables automated quality inspection, safety monitoring, progress tracking, and detection through analysis of images and video from drones and site cameras. Robotics and Automation: AI-powered robots perform repetitive tasks such as bricklaying, welding, and material handling, improving productivity and safety. Digital Twins and BIM Integration: AI enhances Building Information Modelling (BIM) and digital twins by enabling real-time monitoring, clash detection, and predictive maintenance.

2.4.3 AI Adoption in the Nigerian Construction Sector

In Nigeria, the adoption of artificial intelligence (AI) in the construction sector remains at a relatively nascent stage. Existing studies indicate that awareness and practical utilisation of AI technologies among construction firms are still limited, with applications such as computer vision and predictive analytics being the most recognised and adopted (Oke et al., 2023; Onyia et al., 2024). At the policy level, the Nigerian government has demonstrated increasing commitment to digital transformation through initiatives such as the National Digital Economy Policy and Strategy (2020–2030) and the Nigeria Artificial Intelligence Landscape Report (2025), both of which position AI as a strategic driver for economic growth, innovation, and workforce development (Federal Ministry of Communications and Digital Economy, 2020; NITDA, 2025). In practice, leading industry players such as Julius Berger Nigeria Plc have begun piloting AI-enabled solutions across areas including design optimisation, project management, and quality control, utilising tools such as generative design, predictive analytics, and digital twins to improve operational efficiency and sustainability outcomes (Julius Berger Nigeria Plc, 2024). Despite these developments, significant barriers continue to constrain widespread adoption, including inadequate digital infrastructure, limited technical expertise, high implementation costs, poor data quality, and organisational resistance to change (World Bank, 2025; Onyia et al., 2024).

2.5 Relationship Between AI and TQM: Enhancing Quality Management Practices

2.5.1 AI as an Enabler of TQM in Construction

Artificial intelligence (AI) is positioned to transform Total Quality Management (TQM) practices in construction by enhancing automation, improving decision-making, and enabling continuous improvement processes. By integrating AI into TQM frameworks, firms can address persistent challenges such as human error, process variability, and limited ability to extract insights from large and complex datasets (Sony et al., 2022; Oke et al., 2023). AI-enabled quality inspection tools such as computer vision for defect detection, drones and sensor-based monitoring systems, and real-time analytics are transforming traditional QA/QC processes by enabling early identification of defects and reducing rework (Zhang et al., 2023). Industry applications further demonstrate this potential; for example, platforms such as Buildots and Disperse.io utilize AI-driven site monitoring and analytics to improve project tracking and reduce delays. Overall, AI–TQM integration represents a critical pathway for improving construction quality, efficiency, and sustainability.

2.6 AI Readiness Factors in Construction Contracting Firms

Organizational readiness for AI adoption in construction is shaped by a complex interplay of organizational, technological, and environmental factors. This study draws on the Technology Organization Environment (TOE) framework, originally proposed by Tornatzky and Fleischer (1990), as a theoretical lens for organising and interpreting these readiness dimensions. The TOE framework suggests that technology adoption in organisations is simultaneously influenced by three contextual clusters: the technological context (the internal and external technologies relevant to the firm), the organisational context (the characteristics and resources of the firm), and the environmental context (the industry, market, and regulatory setting in which the firm operates). Although the TOE framework was originally developed in the context of information technology adoption, it has been widely applied and validated across sectors, including construction and project management, and is well suited to analysing multi-dimensional readiness for AI-enabled systems (Oliveira & Martins, 2011; Eze & Chinedu, 2020).

Within this framework, the eleven readiness factors examined in this study are mapped as follows. Technological **context** encompasses Technological Infrastructure (TI), Data Readiness & Governance (DG), and Cybersecurity & Risk Management (CY) factors that reflect the technical capacity of the firm and its digital environment. The **organisational context** covers Workforce Skills (WS), Leadership Commitment (LC), TQM Practices & Maturity (TQM), and Funding & Investment (FI) factors that reflect internal human, managerial, and financial readiness. The **environmental context** includes Regulatory Environment (RE), Cultural Attitudes (CA), Procurement & Contracts (PC), and Supply Chain & Vendor Ecosystem (SC) factors that capture the external conditions shaping adoption decisions. This mapping provides a theoretically grounded structure for the readiness assessment and guides the interpretation of findings in Section 4. Table 1 in Appendix 1 summarises the current status, challenges, and opportunities associated with each readiness factor.

3. Research Methodology

This study adopts a quantitative, exploratory approach to investigate organisational readiness for the integration of Artificial Intelligence (AI) and Total Quality Management (TQM) within Nigerian construction contracting firms. Findings are presented as preliminary evidence. The unit of analysis is the individual respondent, and factor-level means are aggregated across respondents within each firm-size category (large, medium, and small) for comparative purposes. The target population includes construction firms registered with FIRS with tax records within the last 3 years. Key respondents comprise project managers, quality assurance officers and IT managers. Purposive sampling was adopted to select major construction hubs (Lagos, Abuja, Port Harcourt). A minimum of 150 survey respondents was determined using Cochran's formula (95% confidence level, 5% margin of error). Quantitative data was collected using a structured questionnaire based on validated instruments, covering demographics, technological infrastructure, workforce skills, leadership commitment, regulatory environment, and organisational culture. Responses were measured on a 5-point Likert scale. The research instrument was pilot-tested and validated using expert review and exploratory factor analysis, while reliability was confirmed through Cronbach's alpha (≥0.70). Quantitative data were analysed using SPSS (descriptive statistics, regression, ANOVA).

4. Finding and Discussion

Quantitative Analysis of AI–TQM Readiness by Firm Size Using

This section presents an exploratory analysis of a Likert-scale dataset to assess readiness for integrating Artificial Intelligence (AI) into Total Quality Management (TQM) within Nigerian construction contracting firms, comparing large, medium, and small companies. The dataset contains 33 items mapped to 11 readiness factors (TI, DG, WS, LC, RE, CA, TQM, PC, SC, CY, FI), organised within the TOE framework as described in Section 2.6. The Overall Readiness Index (ORI) is calculated as the unweighted arithmetic mean of the 11 factor scores, with each factor score being the mean of its constituent Likert items. Equal weighting is adopted as a transparent baseline appropriate for exploratory work; it does not imply that all factors carry equivalent practical importance, and future studies with larger samples may apply theoretically motivated weighting. ORI values are: Large = 3.286; Medium = 3.386; Small = 3.365 on a 1–5 scale, indicating broadly moderate readiness across all firm types. The lowest mean factor score is Procurement & Contracts (overall mean = 3.103). Exploratory inferential analysis suggests possible between-group differences for Workforce Skills (WS), Cultural Attitudes (CA), TQM Practices & Maturity (TQM), and Supply Chain & Vendor Ecosystem (SC) ($p < .05$), though these patterns should be treated as indicative rather than confirmatory, given the aggregated data structure and small group sizes. However, many factors violate homogeneity of variance (Levene $p < .05$), so Welch ANOVA is reported where appropriate; exploratory differences remain for WS, CA, and TQM under Welch. Given the aggregated data structure ($n = 3$ groups), all inferential results should be treated as indicative patterns only. The dataset is presented under three headings: Group 1: large-scale construction company, Group 2: medium-scale construction company, Group 3: small-scale construction company (Table 2)

Table 2: Factor means (SD) by firm

Factor	Large	Medium	Small
TI	3.336 (0.172)	3.502 (0.062)	3.415 (0.340)
DG	3.337 (0.114)	3.817 (0.547)	3.337 (0.114)
WS	3.447 (0.091)	3.261 (0.045)	3.389 (0.110)
LC	3.283 (0.196)	3.381 (0.253)	3.243 (0.091)
RE	3.134 (0.225)	3.223 (0.312)	3.500 (0.124)
CA	3.231 (0.340)	3.527 (0.108)	3.143 (0.163)
TQM	3.576 (0.045)	3.385 (0.096)	3.277 (0.243)
PC	2.894 (0.563)	3.068 (0.217)	3.347 (0.070)
SC	3.502 (0.062)	3.345 (0.038)	3.502 (0.062)
CY	3.033 (0.466)	3.367 (0.118)	3.506 (0.080)
FI	3.377 (0.075)	3.363 (0.211)	3.361 (0.069)
Overall Readiness Index	**3.286 (0.057)**	**3.386 (0.073)**	**3.365 (0.060)**

Source (Field Survey, 2025)

Key descriptive patterns
Large firms score highest on TQM and SC, and lowest on PC and CY, Medium firms show particularly high DG and CA, but lower WS and SC, Small firms show comparatively high CY, RE, and PC in the post-coded readiness metrics.

Inferential results: one-way ANOVA across firm sizes
Assumption checks: Levene's test (homogeneity of variance) is significant ($p < .05$) for several factors (DG, WS, CA, TQM, PC, CY, FI), indicating unequal variances, Where Levene is significant, Welch ANOVA is reported as the primary inference statistic (Table 3).

Table 3: One-way ANOVA across firm sizes (Large vs medium vs Small)

Factor	Primary test	F	p (used)	η^2	Interpretation
TI	ANOVA	0.694	0.519	0.104	Not significant
DG	Welch	1.728	0.244	0.372	Not significant (Welch)
WS	**Welch**	**9.009**	**0.012**	**0.502**	**Significant**
LC	ANOVA	0.692	0.520	0.103	Not significant
RE	ANOVA	3.338	0.070	0.357	Not significant (trend)
CA	**Welch**	**9.407**	**0.010**	**0.397**	**Significant**
TQM	**Welch**	**9.971**	**0.011**	**0.449**	**Significant**
PC	Welch	4.616	0.062	0.261	Not significant (trend)
SC	**ANOVA**	**13.390**	**0.001**	**0.691**	**Significant**
CY	Welch	4.084	0.068	0.384	Not significant (trend)
FI	Welch	0.057	0.945	0.003	Not significant
Readiness Index	ANOVA	3.390	0.068	0.361	Not significant (trend)

Source (Field Survey, 2025)

Effect size interpretation: η^2 (effect size) values for WS, CA, TQM, SC range from approximately 0.40 to 0.69. Conventional benchmarks would classify these as large effects; however, as the analysis operates on aggregated group means ($n = 3$ groups) rather than individual respondent data (Table 4)

Table 4: Post-hoc pairwise differences (significant results only)

Factor	Method	Significant pair	Direction
WS	Games–Howell	Large vs Medium ($p \approx 0.016$)	Large > Medium
CA	Games–Howell	Medium vs Small ($p \approx 0.008$)	Medium > Small
TQM	Games–Howell	Large vs Medium ($p \approx 0.018$)	Large > Medium
SC	Tukey HSD	Large vs Medium ($p \approx 0.002$); Small vs Medium ($p \approx 0.002$)	Large & Small > Medium

Source (Field Survey, 2025)

Technological Infrastructure scores are moderate to high across firm sizes (3.34–3.50). While this pattern is broadly consistent with national-level indicators of improving broadband penetration and expanding digital infrastructure (NCC, 2024; World Bank, 2025), the study data alone cannot confirm that these national trends have been realised at the firm level. It is also worth noting that moderate TI scores do not automatically translate into AI-readiness: even where basic connectivity exists, the reliability, bandwidth, and interoperability requirements of AI-driven quality monitoring systems may exceed what current infrastructure provides (Onyia et al., 2024). Data Governance and AI Readiness (TOE: Technology context). Data readiness outcomes are mixed, with medium firms showing an unusually high DG score (mean = 3.817) compared to large and small firms (3.337). While the pattern of data fragmentation identified broadly parallels concerns raised in Nigeria's National AI Strategy regarding data quality and standardisation (NITDA, 2025. TQM Maturity and Firm Size (TOE: Organisational context). TQM factor scores are relatively high and show exploratory evidence of size-group differences (Large > Medium, $p < .05$ under Welch ANOVA). This is broadly consistent with prior Nigerian contractor research suggesting that TQM-practising firms achieve stronger performance outcomes (Ibrahim et al., 2024; Okwe, 2024. The inference that firms with stronger TQM structures are better positioned to embed AI into their processes (Sony et al., 2022) is theoretically probable but remains untested in the present study and should be the subject of future longitudinal or case-study research

5. Conclusion and Further Research

This exploratory study indicates that Nigerian construction firms demonstrate a moderate level of readiness for AI–TQM integration, with comparatively

stronger capabilities in technological infrastructure and TQM maturity but notable gaps in data governance, workforce skills, regulatory clarity, and procurement systems. Readiness varies by firm size, highlighting uneven digital transformation across the sector. The findings are broadly consistent with the Technology Organisation Environment (TOE) framework as a conceptual lens: the pattern of readiness gaps aligns with the framework's proposition that adoption is shaped by technological capacity, organisational resources, and environmental conditions simultaneously. Limitations related to aggregated data, small group sizes, and a cross-sectional design restrict the depth and generalisability of the findings. Future research should use larger, respondent-level datasets, advanced methods (e.g., SEM), and longitudinal designs, while also exploring factor interrelationships, firm-level case studies, emerging technologies (e.g., generative AI), and the role of policy frameworks. Overall, effective AI–TQM adoption requires coordinated efforts in technology, skills development, leadership, and institutional reform.

6. Recommendations

1. Nigerian construction firms should prioritise investment in robust digital infrastructure and structured data management systems to support AI–TQM integration. Without this foundation, AI adoption will remain limited and ineffective.

2. Firms should implement continuous professional development programmes, collaborate with academic and training institutions, and promote digital literacy across all organisational levels.
3.

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Appendix 1

Table 1: AI Readiness Factors

Readiness Factor	Current Status	Challenges	Opportunities
Technological Infrastructure (TI)	Broadband penetration at 48.15%; expanding fibre optic and mobile networks; limited AI-specific infrastructure in construction (Nigerian Communications Commission [NCC], 2024; World Bank, 2025)	High cost of AI tools and infrastructure; unreliable power; urban-rural digital divide; integration complexity (Berha & Khemani, 2026; Onyia et al., 2024)	Government and donor investments (e.g., BRIDGE Project); cloud/edge computing; sector-specific AI development (Federal Ministry of Communications, 2026; NITDA, 2025)
Data Readiness & Governance (DG)	Fragmented, often unstructured data; NDPR in place; limited data governance capacity (NITDA, 2019; NDPC, 2025)	Poor data quality; lack of structured databases; privacy and security concerns; limited compliance (NITDA, 2019; Federal Republic of Nigeria, 2023)	Open data initiatives; alignment with international standards; capacity building in data management (NITDA, 2020; World Bank, 2025)
Workforce Skills(WS)	Significant skills gap in AI and digital construction; moderate TQM awareness in large firms (Bamgbose et al., 2024; Ibrahim et al., 2024)	Shortage of skilled professionals; brain drain; limited access to training; resistance to	3MTT, Microsoft AI Skill Navigator, online courses, integration of AI/TQM in curricula, artisan training

Readiness Factor	Current Status	Challenges	Opportunities
		upskilling (World Bank, 2025; Onyia et al., 2024)	partnerships (NITDA, 2025; 3MTT, n.d.)
Leadership Commitment (LC)	Varies; stronger in large firms and government; growing policy support (NITDA, 2025)	Short-term ROI expectations; limited awareness of AI-TQM synergies; resource constraints (Onyia et al., 2024)	Leadership training; government incentives; pilot projects to build confidence (World Bank, 2025; NITDA, 2025)
Regulatory Environment (RE)	National AI Strategy and NDPR in development; ISO standards referenced; fragmented enforcement (NITDA, 2025; NITDA, 2019)	Overlapping jurisdictions; weak enforcement; lack of sector-specific AI guidelines; legal uncertainty (World Bank, 2025)	Unified AI governance frameworks; alignment with global standards; public–private regulatory sandboxes (NITDA, 2025; World Bank, 2025)
Cultural Attitudes (CA)	Mixed perceptions; growing youth engagement; resistance in SMEs and older workforce (NITDA, 2025)	Fear of job loss; scepticism; low digital literacy; trust and transparency concerns (Onyia et al., 2024)	Awareness campaigns; success stories; participatory stakeholder engagement; youth-driven innovation (World Bank, 2025)
TQM Practices & Maturity (TQM)	Moderate to high in large firms; low in SMEs; linked to improved performance (Ibrahim et al., 2024; Okwe, 2024)	Inadequate technical expertise; policy inconsistency; lack of incentives; cultural resistance (Okwe, 2024)	Framework development; capacity building; AI integration to amplify TQM impact (Adamu et al., 2024)
Procurement & Contracts (PC)	Traditional, rigid systems; limited e-procurement adoption (Federal Republic of Nigeria, 2007)	Lack of flexibility and transparency; legal and liability issues (Onyia et al., 2024)	E-procurement, smart contracts, legal reforms (Federal Ministry of Information, 2025)
Supply Chain & Vendor Ecosystem (SC)	Emerging local and international vendors; integration challenges (Onyia et al., 2024)	Interoperability, vendor lock-in, support for local standards (Bamgbose et al., 2024)	Innovation hubs, vendor partnerships, open-source platforms (NITDA, 2025)
Cybersecurity & Risk Management (CY)	NDPR and Cybercrimes Act in place; capacity developing (NITDA, 2019; Federal Republic of Nigeria, 2015)	Rising cyber threats; limited risk management capacity (NDPC, 2025)	ISO/IEC 27001 adoption; regular training; risk assessments (World Bank, 2025)
Funding & Investment (FI)	Government and donor programs; private investment in large firms (World Bank, 2025)	Limited access for SMEs; high cost of digital transformation (Onyia et al., 2024)	Grants, concessional loans, public–private partnerships (World Bank, 2025; Federal Ministry of Communications, 2026)

Leveraging Artificial Intelligence Driven Predictive Analytics for Sustainable Airfield Maintenance: A Project Management Perspective from Air Force Base Waterkloof, South Africa

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Abstract

Airfield infrastructure in the defence industry is increasingly hindered by outdated facilities, reactive maintenance strategies, and disconnected data management systems, compromising future operational readiness. This paper analyses the main operational challenges related to airfield maintenance in Air Force Base Waterkloof in South Africa, as well as stakeholder readiness to embrace AI-driven predictive analytics. A quantitative survey-based research design was employed with the selected 316 maintenance actors. Data analysis involved descriptive statistics and significance tests. Findings suggest that existing maintenance activities are carried out using an unconnected hybrid strategy, with a focus on reactive maintenance and frequent emergency repairs. Despite certain structural challenges (such as ageing facilities, disconnected databases, and a lack of technical skills), stakeholders showed a high level of readiness to embrace AI predictive analytics. High levels of receptivity were found for machine learning (predictive maintenance and scheduling), computer vision (automatic defect detection), and intelligent decision-making tools that can facilitate the shift to proactive asset management. The study offers actionable insights for construction and project managers by identifying priority areas for adopting AI-driven predictive analytics in maintenance systems. It highlights the need for improved data integration, workforce upskilling, and strategic alignment to facilitate the transition from reactive to predictive maintenance practices in complex, resource-constrained environments.

Keywords: Artificial Intelligence; Airfield Maintenance; Construction Project Management; Infrastructure; Predictive Maintenance.

1 Introduction

Airfield infrastructure is a critical enabler of military readiness, operational safety, and national security. Air Force Base Waterkloof plays a strategic role in supporting both defence operations and government air transport. However, like many legacy infrastructure systems globally, airfields are increasingly challenged by ageing assets, constrained budgets, skills shortages, and growing operational demands. Air transport infrastructure is essential for national economic development and defence capability (Zhang & Graham, 2020; Kölker, Stoebke & Lütjens, 2025). Traditionally, airfield maintenance has been undertaken using reactive or time-based methods, leading to inefficiency. Studies in infrastructure and asset management have consistently highlighted that reactive maintenance practices lead to suboptimal performance and increased long-term expenditure (Al-Turki, 2011; Mobley, 2002). Pavement surfaces, lighting systems, and navigation aids play an important role in the aviation industry when maintained. In addition, the lack of information management and data integration makes it difficult for project managers to manage their resources efficiently (Love et al., 2016). Over the last few years, AI has become an innovative solution for infrastructure management (predictive analytics, anomaly detection) and a decision-making tool.

AI-based maintenance management utilises both past and real-time information to anticipate potential breakdowns, optimise maintenance scheduling, and increase the effectiveness of the assets (Zonta et al., 2020). Research indicates that the application of AI leads to greater forecasting efficiency and better results in the field of construction and project management (Pan and Zhang, 2021). The introduction of AI-driven predictive analytics solutions in maintenance is associated with various technological shortcomings. Organisational preparedness, technological readiness, staff expertise, and other aspects affect the implementation of new technologies (Oesterreich and Teuteberg, 2016). The use of AI is influenced by various restrictions in a military context due to data privacy and confidentiality. This study investigated the role of AI-driven predictive analytics in addressing airfield maintenance challenges within the specific context of Air Force Base Waterkloof in Gauteng Province, South Africa. This survey-based research was informed by literature and case evidence. The study explores managerial, technical, organisational,

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and project-related drivers affecting maintenance outcomes. Focus is specifically placed on aspects like the state of assets, budget limitations, skill sets, and technology readiness. Connectivity of an airport is influenced by passenger routes and destination airports (Kölker, Stoebke, and Lütjens, 2025). These results are expected to advance theory and practice by contributing to understanding the use of AI for prediction, planning, and decision-making in such an environment. For project/construction managers, the study offers a contextualised understanding of how AI-driven predictive analytics adoption strategies can be prioritised to address maintenance challenges. The research also contributes to digital transformation in infrastructure management, within resource-constrained and security-sensitive settings.

2 Literature Review

2.1 Traditional Airfield Maintenance Challenges and Operational Constraints

Airfield infrastructure, comprising pavement networks, lighting systems, and navigation aids, demands continuous operational reliability and strict adherence to safety regulations. However, airfields in developing nations face severe structural constraints, including ageing assets, chronic budgetary limits, and technical skill shortages. Historically, airfield asset management has relied on reactive and time-based maintenance practices, which are widely recognised as inefficient and ineffective at preventing sudden operational failures (Al-Turki, 2011; Love et al., 2016).

Managing complex airfield infrastructure requires robust scheduling, integrated governance, and accurate data collection. Inadequate planning and decision-making lead to compounding lifecycle costs and asset degradation (Love et al., 2016). Furthermore, an inability to collect high-quality operational data restricts asset management optimisation, locking facilities into purely reactive operational cycles (Ucar, Karakose & Kırımça, 2024). Beyond technical barriers, organisational capacity plays a pivotal role in maintenance efficiency. Transitioning to intelligent asset management requires both technical competence and organisational digital readiness; however, widespread skill shortages continue to impede the adoption of Industry 4.0 technologies in infrastructure management (Oesterreich & Teuteberg, 2016).

2.2 Shift Toward Intelligent Maintenance and AI-Driven Subfields

To overcome the limitations of legacy corrective strategies, maintenance practices are undergoing a paradigm shift toward condition-based and predictive maintenance. Predictive maintenance relies on data analytics to foresee asset failure and optimise maintenance interventions prior to functional breakdown, thereby enhancing resource efficiency and operational decision-making.

Artificial Intelligence (AI) serves as the primary engine driving this transition, enabling the processing of complex, multi-source datasets—such as real-time sensor streams, Non-Destructive Testing (NDT) structural evaluations, and mechanistic pavement stress data (Gkyrtis, Plati & Loizos, 2022, 2025; Madhukar, 2024). Modern literature highlights that incorporating AI into predictive analytics substantially improves the accuracy, effectiveness, and reliability of infrastructure management systems (Ucar et al., 2024). Rather than applying AI as an overarching concept, digital transformation in infrastructure relies on specific AI subfields:

- **Machine Learning & Deep Learning:** Applied to evaluate structural health, identify anomalous degradation patterns, and perform predictive failure modelling across critical transport networks (Bris-Peñalver, Verdecia-Peña & Alonso, 2026; Plevris & Papazafeiropoulos, 2024; Savaş, 2025).
- **Computer Vision Systems:** Utilised via camera-based object and defect detection to identify surface anomalies, pavement cracking, and runway foreign object debris (FOD) with greater speed and precision than manual inspection (Priyadharsini, Jagatheesaperumal, Alkhamees & Hassan, 2025).
- **Integrated CMMS and Life-Cycle Cost Frameworks:** Leveraging Computerised Maintenance Management Systems alongside Life Cycle Cost Analysis (LCCA) allows managers to evaluate Net Present Values (NPV) and select optimal long-term economic interventions (Orabi & Shatila, 2025).

2.3 Data Integration and Cross-Domain Governance

Achieving sustainable infrastructure performance requires moving away from siloed departmental approaches toward integrated, cross-domain maintenance architectures (Lahna, Kamsu-Foguem & Abanda, 2023). Integrating fragmented data systems—such as linking real-time Computer Vision defect logs and sensor streams with CMMS databases—provides a unified spatial overview of asset condition. This holistic data integration is essential for supporting intelligent decision-support tools and maximising long-term asset resilience across complex transport networks (Bris-Peñalver et al., 2026; Lahna et al., 2023).

2.4 Research Gap and Contextual Novelty

While the global literature establishes a clear shift toward data-driven, intelligent maintenance strategies, significant empirical gaps remain:

1. **Defence Sector Infrastructure Decline:** In South Africa, broader defence capability and planning frameworks have experienced severe long-term decline and budgetary pressure (Gopaul, Van der Lingen & Oosthuizen, 2024; Louw & Esterhuyse, 2022). Strategically vital installations like Air

Force Base Waterkloof operate under persistent budget constraints and severe operational strain, yet research on digital transformation in these environments is minimal.

2. **Contextual & Security Gap:** Deploying AI-driven predictive analytics in security-sensitive military settings raises unique challenges regarding data confidentiality, security governance, and institutional readiness. Existing predictive maintenance models are predominantly tailored to commercial airports in high-income economies, leaving a distinct gap regarding military airfields in developing African contexts.

This study fills this empirical gap by adopting a project management perspective to evaluate the operational factors influencing airfield maintenance at Air Force Base Waterkloof and to assess stakeholder readiness to adopt AI-driven predictive analytics within complex, security-sensitive infrastructure systems.

3 Research Methodology

This study adopts a quantitative, cross-sectional survey design to investigate the factors influencing airfield maintenance performance and to evaluate the perceived role of AI-driven predictive analytics in improving maintenance practices at Air Force Base Waterkloof, South Africa. The methodological approach is grounded in a prior review of the literature and case-based evidence, which informed the identification of key constructs and variables examined in the study.

3.1 Data Collection

A survey approach was adopted to collect data from the airfield workers/participants. Due to the cross-sectional nature of this study, the data were used to assess the current state of affairs. The questionnaire covered demographics, maintenance strategies, maintenance challenges, current operational activities, and AI-enabled maintenance operations. A five-point Likert scale was used for collecting the responses. The instrument consisted of closed-ended questions organised into themes such as demographic variables, types of maintenance strategies, maintenance problems, current maintenance activities, and the use of AI-driven predictive analytics in maintenance activities. The responses were captured using a scale from 1 (strongly disagree) to 5 (strongly agree), thus capturing opinions. Only people with airfield experience participated. Participation was voluntary, and respondents were informed of the study's purpose, anonymity, and confidentiality. Due to the sensitive military context, no classified or operationally restricted information was collected.

A questionnaire survey was conducted among 316 airfield participants at Air Force Base Waterkloof to collect data. The respondents comprised General Workers, Artisans, Civil Technicians, Electrical Technologists, Civil Engineers, Project Managers, Facility Managers, Environmentalists, and Runway Management personnel. The data collection process ensured that the sample adequately reflected the operational workforce responsible for maintenance activities, thereby enhancing the practical relevance of the findings. The questionnaire was formulated based on the constructs identified in the literature review and aligned with the study's objective and variables, such as maintenance operations and Artificial Intelligence.

3.2 Data Analysis

A combination of descriptive and inferential statistical techniques was used to address the research objectives. Descriptive statistics were used to summarise the respondents' demographic characteristics and perceptions regarding maintenance strategies, operational activities, maintenance challenges, and AI-enabled maintenance practices. These included frequencies, percentages, means, and standard deviations. To determine whether the observed response distribution differed significantly from the expected distribution, chi-square goodness-of-fit tests were performed for each questionnaire item. The chi-square goodness-of-fit test examined whether the frequencies of responses across the five-point Likert scale differed significantly from the expected frequencies under the null hypothesis. Statistical significance was evaluated using two-tailed p-values at the 5% level ($p < 0.05$). The combined use of descriptive and inferential statistics enabled the identification of dominant maintenance practices, operational challenges, and stakeholder perceptions regarding the adoption of AI-driven predictive analytics.

This further helps in making sure that the results and conclusions arrived at are accurate and representative of the population under investigation. Analysis helped identify the dominant maintenance types and current maintenance activities practised, their relative prevalence, key operational and organisational challenges affecting maintenance performance, and the perceived effectiveness of AI-driven predictive analytics applications in improving maintenance activities. Analyses were conducted in a structured, systematic manner to ensure consistency and accuracy. The integration of descriptive and inferential methods provided both exploratory insights and empirical validation, supporting a comprehensive interpretation of the data in the context of airfield maintenance and AI adoption.

4. Findings and Discussion

4.1 Respondents Profile

The respondent profile provides essential context for interpreting the study's findings, particularly regarding the operational activities of airfield maintenance at Air

Force Base Waterkloof. Table 1a and 1b present the respondents' profile. The sample is predominantly male (84.2%), with females comprising only 15.8%. Utete (2021) observed that understanding the gender profile of technical and operational staff was essential for workforce diversity and planning targeted capacity-building interventions. This reflects the traditionally male-dominated nature of technical and military maintenance environments. While expected, this imbalance constrains the diversity of perspectives, particularly on technology adoption and organisational practices, and may limit the generalisability of perceptual findings across a more gender-balanced workforce. Age distribution indicates a largely mid-career cohort.

A majority of the respondents range between 31-40 years (47.8%) and 41-50 years (29.4%), implying that over three-quarters of the respondents are within the age group of 31-50 years. There were no respondents aged below 25 years, while only 8.6% were aged between 25 and 30 years. It shows a relatively experienced workforce but a lack of participation by young professionals. This may have an impact on the results since younger individuals are more receptive to innovations such as AI. Nevertheless, the dominance of experienced individuals ensures that the findings are based on practical knowledge. In terms of educational level, the workforce is mostly skills-based. A large percentage of the respondents have completed secondary education (matriculation), at 57.0%, while very few individuals have advanced degrees.

Table 1a: Profile of Respondents

Attributes	Frequency	Percentage
Gender		
Male	266	84.2%
Female	50	15.8%
Total	**316**	**100.00**
Age Group in Years		
18–24	0	0
25–30	27	8.6%
31–40	151	47.8%
41–50	93	29.4%
50–60	45	14.2%
Total	**316**	**100.00**
Education Level		
Sec Grades	65	20.6%
Matric	180	57.0%
Diploma	40	12.7%
Postgrad Dipl	15	4.7%
B-Tech	10	3.2%
BEng Degree	6	1.9%
Total	**316**	**100**

Table 1b: Profile of Respondents

Attributes	Frequency	Percentage
Professional Role1		
Gen/Workers	81	25,64%
Artisans	163	51,58%
Technicians	47	14,87%
Technologists	10	3,16%
Pr Consultants	5	1,58%
Engineering	6	1,90%
Management	4	1,27%
Total	**316**	**100**
Experience (Years)		
4–6 years	7	2.2%
7–10 years	12	3.8%
11–13 years	18	5.7%
14–16 years	42	13.3%
17–20 years	99	31.3%
21–25 years	94	29.7%
26–30 years	43	13.6%
Above 30 years	1	0.3%
Total		**100**

This may affect the extent of familiarity with complex theories and frameworks, but also ensures that the answers are based on experience and practical knowledge. Professionally, the respondents belong to the operations department, with artisans being the most dominant group (51.58%), followed by general workers (25.64%), and technicians (14.87%). The number of respondents is not large within the engineering and management cadre. The level of experience is quite high, as 61.0% have between 17 and 25 years of experience. This increases the dependability of evaluation since the knowledge gained is substantial, but it could lead to bias against new innovations and processes. Despite limitations, gender imbalance, limited youth representation, and fewer highly educated or managerial respondents, its strengths lie in operational expertise and experience. Thus, the sample is appropriate for the study's objectives, as in applied infrastructure research, functional relevance outweighs strict demographic balance.

4.2 Maintenance Activities (Current Practice)

Table 2 presents the distribution of respondents' perceptions regarding the maintenance strategies

Table 2: Types of Maintenance

Maintenance Type	Mean	SD	p-value	Remarks
Preventive Maintenance	3.95	0.82	0.024	Maintenance Strategy Analysis
Reactive Maintenance	3.96	0.80	0.005	Maintenance Strategy Analysis
Predictive Maintenance	3.92	0.83	0.003	Advanced Maintenance Practices
Corrective Maintenance	3.94	0.81	0.042	Maintenance Operations Review
Condition-Based Maintenance	3.97	0.79	0.015	Technology-Driven Maintenance

currently employed at Air Force Base Waterkloof. Descriptive statistics indicate a relatively uniform prevalence across all maintenance strategies, with mean scores ranging narrowly from 3.92 to 3.97. Condition-based maintenance (Mean = 3.97, SD = 0.79) and reactive maintenance (Mean = 3.96, SD = 0.80) recorded the highest average ratings, followed closely by preventive maintenance (Mean = 3.95) and corrective maintenance (Mean = 3.94). The similarity in these mean scores suggests that no single maintenance strategy is consistently prioritised, reflecting a hybrid maintenance approach rather than a clearly defined strategic maintenance framework. Ideally, maintenance management should emphasise proactive and predictive maintenance strategies over reactive interventions.

The continued prominence of reactive maintenance suggests that maintenance activities remain largely failure-driven, with corrective actions frequently initiated only after equipment or infrastructure failures occur. The relatively low standard deviations (0.79–0.83) indicate a high level of consistency in respondents' perceptions across all maintenance strategies. The chi-square goodness-of-fit test showed that the distribution of responses for each maintenance strategy differed significantly from the expected distribution ($p < 0.05$), indicating that respondents exhibited clear patterns of agreement rather than randomly distributed opinions. In particular, the significant result for predictive maintenance ($p = 0.003$) reflects a strong recognition of its importance as a modern maintenance approach. Overall, the findings suggest that Air Force Base Waterkloof is operating within a transitional maintenance environment in which legacy reactive practices coexist with emerging technology-driven maintenance strategies, although full integration of predictive maintenance has yet to be achieved.

Table 3 shows that maintenance activities at Air Force Base Waterkloof are predominantly reactive. Emergency repairs (Mean = 4.18, SD = 0.58) and runway inspections (Mean = 4.12, SD = 0.77) recorded the highest ratings, reflecting a strong emphasis on immediate operational readiness. The prominence of emergency repairs supports the findings in Table 2, confirming continued reliance on reactive maintenance, which is likely to increase lifecycle costs through unplanned repairs.

Routine maintenance of pavements (Mean = 4.09) and drainage systems (Mean = 4.10) was also rated highly, whereas lighting maintenance (Mean = 3.82) and equipment servicing (Mean = 3.80) received comparatively lower ratings, suggesting potential weaknesses in auxiliary systems. The chi-square goodness-of-fit test indicated that the response distributions for all maintenance activities differed significantly from the expected distribution ($p < 0.05$), demonstrating consistent respondent perceptions. Overall, the findings suggest that maintenance remains largely reactive despite regular execution of routine activities.

4.3 Challenges of Maintenance

Table 4 indicates that the principal constraints affecting maintenance performance are ageing infrastructure (Mean = 4.12, SD = 0.77) and a reactive maintenance culture (Mean = 4.11, SD = 0.73), highlighting asset deterioration and reactive practices as major barriers to effective maintenance planning. Fragmented data systems (Mean = 3.85, SD = 0.83) and technical skills shortages (Mean = 3.84, SD = 0.82) further constrain decision-making and the transition to predictive maintenance. Equipment downtime (Mean = 3.71, SD

Table 3: Maintenance Activities (Current Practice)

Maintenance Activity	Mean	SD	p-value	Remarks
Runway Inspections	4.12	0.77	0.006	Routine Maintenance Activities
Pavement Repairs	4.09	0.74	0.013	Maintenance Operations
Lighting Maintenance	3.82	0.86	0.022	Electrical Systems Maintenance
Drainage Maintenance	4.10	0.75	0.033	Infrastructure Support Systems
Emergency Repairs	4.18	0.584	0.004	Reactive Maintenance Activities
Equipment Servicing	3.80	0.87	0.047	Equipment Maintenance

Table 4: Challenges of Maintenance

Maintenance Challenge	Mean	SD	p-value	Remarks
Ageing Infrastructure	4.12	0.77	0.002	Infrastructure Constraints Analysis
Budget Constraints	3.81	0.85	0.009	Resource Constraints Analysis
Skills Shortage	3.84	0.82	0.018	Workforce Capacity Analysis
Reactive Maintenance Culture	4.11	0.73	0.004	Maintenance Strategy Gaps
Fragmented Data Systems	3.85	0.83	0.003	Data Management Challenges
Equipment Downtime	3.71	0.92	0.029	Operational Efficiency Analysis

= 0.92) received the lowest rating, with greater variation in responses across operational units. The chi-square goodness-of-fit test showed that the response distributions for all maintenance challenges differed significantly from the expected distribution ($p < 0.05$), indicating broad agreement that these are the key structural, organisational, and technological constraints affecting maintenance performance.

4.4 Perspectives of AI-Enabled Maintenance Activities

Table 5 presents stakeholders' perceptions of integrating Artificial Intelligence into airfield asset management. Overall, respondents expressed strong support for AI-enabled maintenance practices. Automated inspections (Mean = 4.11, SD = 0.73), decision support systems (Mean = 4.10, SD = 0.75), and predictive maintenance (Mean = 4.09, SD = 0.74) received the highest ratings, reflecting confidence in AI's ability to improve maintenance planning, detect defects early, and reduce unplanned downtime.

Table 5: AI-Enabled Maintenance Activities

AI-Enabled Activity	Mean	SD	p-value	Remarks
Predictive Maintenance	4.09	0.74	0.001	AI in Maintenance Optimisation
Automated Inspections	4.11	0.73	0.004	AI-Based Inspection Systems
Fault Detection	3.95	0.82	0.003	Intelligent Fault Detection
Scheduling Optimisation	3.96	0.80	0.002	AI for Planning Efficiency
Resource Optimisation	3.79	0.88	0.010	Resource Management AI
Data Integration (Digital Twin)	3.85	0.83	0.001	Data-Driven Decision-Making
Decision Support	4.10	0.75	0.002	AI for Strategic Decisions

AI-driven scheduling optimisation (Mean = 3.96) and fault detection (Mean = 3.95) were also rated positively, while data integration through Digital Twins (Mean = 3.85) and resource optimisation (Mean = 3.79, SD = 0.88) received comparatively lower, but favourable, ratings. The higher variation in resource optimisation suggests differing levels of technical familiarity among respondents. The chi-square goodness-of-fit test indicated that the response distributions for all AI-enabled maintenance activities differed significantly from the expected distribution ($p \leq 0.01$), demonstrating broad agreement on the potential of AI to enhance maintenance performance and address existing operational challenges.

4.5 Synthesis and Critical Discussion

Evaluating the findings across Tables 2–5 indicates that airfield maintenance at Air Force Base Waterkloof operates within a hybrid maintenance framework that remains largely reactive. Although condition-based maintenance received the highest rating (Mean = 3.97), the similarly high ratings for reactive maintenance (Mean = 3.96) and emergency repairs (Mean = 4.18) suggest that maintenance activities continue to be driven by equipment failures rather than proactive planning. This finding is consistent with previous studies showing that reactive maintenance increases lifecycle costs and reduces asset reliability (Mobley, 2002; Muchiri et al., 2011; Swanson, 2001; Wireman, 2004).

The findings further identify ageing infrastructure (Mean = 4.12), a reactive maintenance culture (Mean = 4.11), fragmented data systems (Mean = 3.85), and technical skills shortages (Mean = 3.84) as the principal barriers to effective maintenance management. These challenges support previous research highlighting that fragmented information systems constrain predictive maintenance and informed decision-making (Lahna et al., 2023; Ucar et al., 2024).

Despite these operational constraints, the chi-square goodness-of-fit test indicated that respondents consistently expressed positive perceptions of AI-enabled maintenance activities ($p < 0.05$). Automated inspections (Mean = 4.11), decision support systems (Mean = 4.10), and predictive maintenance (Mean = 4.09) received the strongest support, suggesting that the principal barrier to AI adoption is not stakeholder acceptance but organisational readiness, integrated data systems, and workforce capacity building (Bris-Peñalver et al., 2026; Jardine et al., 2006; Madhukar, 2024; Savaş, 2025). Bridging this implementation gap is essential for improving operational reliability and achieving sustainable airfield maintenance.

5 Conclusion, Contributions, and Further Research

5.1 Synthesis of Findings

This paper explores the factors influencing the performance of maintenance activities in Air Force Base Waterkloof. It measures stakeholders' perceptions of the use of AI to transform asset operations. Evidence shows that the current maintenance environment at Air Force Base Waterkloof is characterised by a transitional maintenance regime that adopts a hybrid approach, using both reactive and condition-based methods, with emergency maintenance taking precedence over planning. Architectural limitations in the form of ageing infrastructure, data silos, and a lack of technical competencies make up the core barriers in this operation. At the same time, operational stakeholders have displayed very high levels of receptiveness to various forms of AI technologies such as predictive

analytics, computer vision, and intelligent decision-support systems.

5.2 Contributions to Knowledge

Theoretical Contributions: This research contributes to the body of literature on infrastructure asset management and digital transformation in defence environments through the development of a socio-technological model of the 'Implementation Gap'. The existing literature has attributed the slow adoption of 4IR technology in military and public sector organisations to user resistance and technophobia. This research proves that the operational staff members of military organisations accept the need for transformative technologies like AI.

The critical theoretical contribution of this research is that the key barrier to digital transformation in high-security defence infrastructure is organisational-architectural in nature rather than user resistance: operational readiness is hindered not by user unwillingness but by a lack of integrated data models and data silos.

Practical and Operational Implications: The research provides a tangible blueprint for the shift from failure-based repair to proactive asset management for airfield managers, defence engineers, and facility operators. Importantly, the research shows that the use of AI through the implementation of standalone predictive algorithms over isolated systems fails because of data silos.

In order to overcome this issue, an enterprise Digital Twin architecture is required for operationalising AI technologies. Digital Twin is an architecture that acts as an integration layer by combining all data silos into one three-dimensional digital representation of the asset, such as Pavement Condition Indices (PCI) results from computer-vision-based automated inspection of the airfield, wheel load information from the structural data of past incidents, meteorological analysis, and Computerised Maintenance Management System (CMMS) data. Integration of those operational data silos into the data streams allows Machine Learning algorithms to implement failure prediction models in interdependent airfield sub-systems (such as pavement, drainage, and airfield lighting). Thus, the infrastructure managers get a detailed step-by-step blueprint on how to eliminate data silos before implementing any large-scale predictive models.

Social, Policy and Governance Implications: At the societal level and from a policy perspective, the modernisation of military infrastructure affects national security readiness and strategic air mobility capabilities, as well as the effective management of public capital assets. The research provides evidence-based guidelines for military procurement policies, recommending institutional frameworks to focus on 4IR compliance of infrastructure standards, cybersecurity issues, and capacity building. Alignment of the South African military airfield management with digital twin and AI standards will increase its tactical capabilities while ensuring a sustainable infrastructural base in the long run.

5.3 Limitations and Future Research

There are some limitations in this research. The data set is based mostly on cross-sectional survey data from the operational and technical personnel rather than executive policymakers. Data collection has been restricted by the security classification of the military, thus restricting access to real-time telemetry and confidential asset degradation records.

The further scope of research includes:

- Longitudinal empirical studies measuring the changes in post-implementation metrics such as MTBF, maintenance cycle times, and lifecycle cost reduction after pilot deployment of Digital Twin or AI.
- Integrating real-world sensor telemetry and CMMS log data along with managerial interviews to enrich the data triangulation.
- Development of policy and governance frameworks such as institutional governance, specialised defence procurement processes, data ownership, and cybersecurity requirements for management of digital twins of strategic military assets.

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Factors influencing construction firms' decision-making processes regarding the adoption of digital technology in the Gauteng construction industry, South Africa.

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Abstract

The adoption of digital technology has the potential to improve efficiency, productivity, and competitiveness within the construction industry; however, adoption levels among construction firms in South Africa remain uneven. This study examines factors influencing construction firms' decision-making processes regarding digital technology adoption within the Gauteng construction industry, South Africa. The study aims to identify organisational, technological, and environmental factors shaping adoption decisions. A quantitative research design was employed using a structured questionnaire administered to construction professionals in Gauteng Province. A total of 112 valid responses were obtained and analysed using descriptive statistics, exploratory factor analysis (EFA), and chi-square tests. The findings reveal that the availability of skilled personnel and the cost of implementation are the most influential factors affecting adoption decisions. Furthermore, factor analysis identified three major components influencing decision-making: organisational and strategic factors, external and human resource factors, and cost considerations. The study contributes empirical evidence specific to Gauteng Province and provides insights for policymakers and industry stakeholders to improve digital transformation strategies within the construction industry.

Keywords*:* Digital technology adoption; Decision-making processes; Construction firms; Gauteng construction industry; Technology adoption factors; Construction innovation.

1. Introduction

The construction industry plays a critical role in economic development and infrastructure delivery globally. Despite advancements in digital technologies such as Building Information Modelling (BIM), Internet of Things (IoT), and cloud computing, adoption within the South African construction industry remains uneven and relatively slow (Aghimien et al., 2022).

The slow uptake of digital technologies has been attributed to several factors, including limited organisational readiness, lack of skilled personnel, and high implementation costs (Umar, 2021). Understanding the factors influencing decision-making processes is essential for improving adoption rates and enhancing industry performance. However, limited empirical studies have focused specifically on decision-making dynamics within the South African construction context. Despite the growing global emphasis on digital transformation within the construction sector, the adoption of digital technologies among construction firms in South Africa remains relatively slow and inconsistent. While technologies such as Building Information Modelling (BIM), cloud computing, artificial intelligence, and Internet of Things (IoT) systems offer significant benefits in improving productivity, project coordination, and operational efficiency, many firms continue to experience challenges in adopting these technologies effectively. Existing studies have primarily focused on technological implementation and innovation adoption in developed economies, with limited empirical attention given to the decision-making dynamics influencing digital technology adoption within the South African construction industry. Furthermore, there is insufficient understanding of how organisational, technological, and environmental factors collectively influence construction firms' adoption decisions, particularly within Gauteng Province. This study therefore seeks to address this gap by examining the factors influencing construction firms' decision-making processes regarding digital technology adoption in Gauteng Province, South Africa.

This study therefore aims to examine the factors influencing construction firms' decision-making processes regarding digital technology adoption.

2. Literature Review

Digital technology adoption within the construction industry has increasingly become an important area of research due to its potential to improve productivity,

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efficiency, communication, and project delivery. Technologies such as Building Information Modelling (BIM), cloud computing, drones, artificial intelligence, and Internet of Things (IoT) systems are transforming construction processes globally. However, the adoption of these technologies remains uneven, particularly within developing countries such as South Africa.

The Technology-Organisation-Environment (TOE) framework developed by Tornatzky and Fleischer provides a useful theoretical foundation for understanding technology adoption within organisations. According to the TOE framework, technology adoption is influenced by technological, organisational, and environmental contexts.

Technological factors relate to the characteristics of the technology itself, including complexity, compatibility, usability, and perceived benefits. Besklubova et al. (2021) explain that technologies perceived as highly complex are less likely to be adopted because firms may lack the technical capabilities required for implementation. Compatibility with existing organisational systems and workflows also plays a significant role in determining whether firms adopt digital technologies successfully.

Cost of implementation is another important technological factor affecting adoption decisions. Digital technologies often require substantial financial investment for software acquisition, employee training, infrastructure development, and maintenance. Umar (2021) found that many construction firms in developing economies struggle to adopt digital technologies due to financial constraints and uncertainty regarding return on investment.

Organisational factors include management support, organisational readiness, firm culture, and availability of skilled personnel. Top management support has consistently been identified as a critical driver of successful digital transformation because leadership influences strategic priorities, resource allocation, and organisational commitment toward innovation adoption. Attencia and Mattos (2022) state that firms with strong leadership support are more likely to implement digital transformation initiatives successfully.

Organisational readiness refers to the extent to which firms possess the necessary financial resources, infrastructure, and technical expertise to implement digital technologies effectively. The availability of skilled personnel is particularly important because digital technologies require employees with specialised technical knowledge and digital competencies. Aghimien et al. (2022) emphasised that lack of skilled personnel remains one of the major barriers to digital technology adoption within the construction industry.

Environmental factors include competitive pressure, client demand, industry trends, and regulatory requirements. Competitive pressure often encourages firms to adopt digital technologies to maintain market relevance and improve competitiveness. In addition, increasing client expectations regarding project efficiency, sustainability, and innovation have motivated construction firms to invest in digital solutions.

Regulatory requirements and government policies also influence technology adoption decisions. Supportive policies, industry standards, and digital transformation initiatives can encourage firms to adopt innovative technologies more effectively. However, limited policy support and inadequate industry regulations may slow adoption rates, particularly in developing economies.

Although several studies have investigated digital technology adoption within the construction industry, limited research has specifically focused on the factors influencing construction firms' decision-making processes within the Gauteng construction industry. This study therefore seeks to contribute to the existing body of knowledge by examining the organisational, technological, and environmental factors influencing digital technology adoption decisions among construction firms in Gauteng Province, South Africa.

2.1. Conceptual Framework

This study is grounded in the Technology-Organisation-Environment (TOE) framework, which explains how technological, organisational, and environmental factors influence organisational technology adoption decisions.

In this study, technological factors include implementation cost, system complexity, and expected return on investment. Organisational factors include management support, organisational readiness, project complexity, and availability of skilled personnel. Environmental factors include competitive pressure and regulatory requirements.

The framework proposes that these factors collectively influence construction firms' decision-making processes regarding digital technology adoption within the Gauteng construction industry.

3. Research Methodology

This study adopted a quantitative research approach to investigate the factors influencing construction firms' decision-making processes regarding digital technology adoption within Gauteng Province, South Africa. A quantitative approach was considered appropriate because it allows for the collection and statistical analysis of numerical data from a large sample of respondents.

Gauteng Province was selected for the study because it is South Africa's economic hub and contains a high concentration of construction firms and infrastructure development projects. The province also represents one of the most technologically advanced regions within the South African construction industry, making it suitable for investigating digital technology adoption.

The target population consisted of construction professionals including project managers, quantity surveyors, construction managers, engineers, and architects working within construction firms operating in Gauteng Province.

Data were collected using a structured questionnaire designed based on existing literature relating to digital technology adoption factors within the construction industry. The questionnaire included sections relating to respondent demographics and factors influencing digital technology adoption.

A total of 112 valid responses were obtained and used for data analysis. The collected data were analysed using descriptive statistics, including Mean Item Score (MIS) and standard deviation, to determine the relative importance of the identified factors. Exploratory Factor Analysis (EFA) was further conducted to identify the underlying components influencing decision-making processes. In addition, chi-square tests were performed to examine whether statistically significant relationships existed between demographic variables and the identified adoption factors.

The selected statistical techniques were considered appropriate because they provide empirical insight into the patterns and relationships associated with digital technology adoption decisions within construction firms.

4. Findings and Discussion

4.1. Descriptive Analysis Results

Table 1 presents the ranking of factors influencing construction firms' decision-making processes regarding digital technology adoption.

The findings reveal that the availability of skilled personnel and the cost of implementation are the most influential factors affecting digital technology adoption decisions among construction firms in Gauteng Province.

These findings suggest that construction firms place significant emphasis on technical capacity and financial capability when considering digital transformation initiatives. The results further indicate that firms are increasingly influenced by external market competition and project-related complexities.

4.2. Exploratory Factor Analysis (EFA)

The EFA results are presented in Table 2. Table 2 identified three major components influencing decision-making.

4.2.1. Factor 1: Organisational and Strategic Factors

This factor includes management support, project complexity, and competitive pressure. These findings confirm that internal organisational dynamics significantly influence adoption decisions (Attencia & Mattos, 2022).

4.2.2. Factor 2: External and Human Resource Factors

This includes availability of skilled personnel, expected ROI, and regulatory requirements. The importance of human capital in digital transformation is consistent with findings by Aghimien et al. (2022).

Table 1: Ranking of factors for decision-making in construction firms for digital technology adoption

Factors	Mean Score	Standard Deviation	Rank
Availability of skilled personnel	1.43	0.52	1
Cost of implementation	1.45	0.56	2
Competitive pressure	1.61	0.64	3
Project complexity	1.68	0.71	4
Management support	1.74	0.75	5
Regulatory requirements	1.83	0.79	6
Expected return on investment	1.91	0.82	7

Table 2: EFA Results

Variables	Component 1	Component 2	Component 3
Management support	0.812		
Project complexity	0.756		
Competitive pressure	0.701		
Skilled personnel		0.793	
Expected ROI		0.741	
Regulatory requirements		0.688	
Cost of implementation			0.851

4.2.3. Factor 3: Cost Considerations

Cost of implementation emerged as a standalone factor, highlighting its critical role as a barrier to adoption. This is consistent with literature indicating that high initial investment costs discourage adoption in developing economies (Umar, 2021). The three factors collectively explained approximately 61.72% of the total variance, indicating strong explanatory power.

4.3. Chi-Square Test Results

The chi-square analysis (Table 3) revealed no statistically significant differences across demographic variables such as age, professional role, employer type, and years of experience. This suggests that the identified factors are widely experienced across the construction industry.

Table 3: Chi-square analysis results

Demographic Variable	Chi-Square Value	p-value	Interpretation
Age	2.143	0.342	Not significant
Professional role	3.287	0.218	Not significant
Employer type	1.974	0.417	Not significant
Years of experience	2.651	0.276	Not significant

4.4. Discussion

The findings of this study indicate that digital technology adoption decisions within construction firms are primarily influenced by the availability of skilled personnel and the cost of implementation. The prominence of skilled personnel highlights the importance of human capital and technical expertise in supporting successful digital transformation initiatives within the construction industry.

This finding aligns with Aghimien et al. (2022), who found that limited technical skills remain one of the major barriers to digital technology adoption within developing construction industries. Construction firms require employees with adequate digital competencies to effectively implement and manage emerging technologies such as BIM, cloud computing, and digital project management systems.

The study also found that implementation cost significantly influences adoption decisions. This finding is consistent with Umar (2021), who reported that financial constraints and high initial investment costs discourage many construction firms from adopting advanced digital technologies. The financial burden associated with software acquisition, training, infrastructure, and maintenance remains a major challenge, particularly for small and medium-sized construction firms.

In addition, organisational factors such as management support and project complexity were found to influence adoption decisions. Firms with strong leadership support are generally more willing to invest in innovation and technological transformation. This finding supports Attencia and Mattos (2022), who emphasised the critical role of leadership commitment in facilitating successful digital transformation.

Environmental factors such as competitive pressure and regulatory requirements also influence decision-making processes. Increasing competition within the construction industry encourages firms to adopt digital technologies to improve efficiency, productivity, and market competitiveness.

Overall, the findings validate the Technology-Organisation-Environment (TOE) framework by demonstrating that digital technology adoption decisions are influenced by a combination of technological, organisational, and environmental factors.

5. Conclusion and Further Research

This study examined the factors influencing construction firms' decision-making processes regarding digital technology adoption within Gauteng Province, South Africa. The findings revealed that the availability of skilled personnel and the cost of implementation are the most influential factors affecting adoption decisions within construction firms.

The study further identified organisational, environmental, and financial considerations as critical determinants influencing digital technology adoption. These findings confirm that successful digital transformation within the construction industry depends on both internal organisational readiness and external environmental conditions.

The study contributes to the existing body of knowledge by providing empirical evidence relating to digital technology adoption within the Gauteng construction industry. Furthermore, the findings provide practical insights for policymakers, industry stakeholders, and construction firms seeking to improve digital transformation strategies.

It is recommended that construction firms invest in digital skills development and employee training to improve organisational readiness for digital transformation. In addition, government and industry stakeholders should develop supportive policies and financial support mechanisms aimed at reducing the cost barriers associated with digital technology adoption.

Future research should focus on longitudinal studies investigating how digital technology adoption evolves

over time within construction firms. Comparative studies involving other South African provinces and international contexts are also recommended to provide broader insights into digital transformation within the construction industry.

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Impediments to Readiness to Adopt Building Information Modelling for Health and Safety Among Small and Medium Contractors in KwaZulu-Natal

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Abstract

The construction industry remains one of the most hazardous economic sectors, with persistently high accident and fatality rates worldwide. Building Information Modelling (BIM) has emerged as a valuable tool for strengthening health and safety (H&S) management through improved visualisation, early hazard detection, and enhanced project collaboration. While large construction firms have progressively adopted BIM, Small and Medium Enterprises (SMEs), which constitute many South African construction companies, continue to lag in adopting digital technologies. Although SME readiness for BIM is known to depend on the alignment of strategy, leadership, culture, people, and technology, far less is known about the impediments that prevent this alignment in practice. This study, therefore, aimed to identify the impediments to SME readiness for BIM-enabled H&S management in KwaZulu-Natal (KZN), South Africa. Using a positivist, deductive, and quantitative design, a simple random sample of 130 SMEs registered with the Construction Industry Development Board (CIDB) in KZN completed questionnaires measuring 13 potential impediments. Respondents agreed that these impediments significantly constrain SME readiness for BIM-enabled H&S management (overall mean = 4.00), with limited infrastructure, restricted training, and a shortage of skilled personnel identified as the most significant. Insufficient standardisation, resistance to organisational change, software incompatibility and inadequate funding were also rated highly. Targeted initiatives, including affordable training, SME-specific implementation frameworks, leadership awareness campaigns, government incentives, and industry collaboration, are needed to address these impediments and accelerate BIM uptake for H&S management among South African SMEs.

Keywords: Building Information Modelling, Health and Safety, Impediments to Readiness, Small and Medium Contractors

1. Introduction

The construction industry plays a pivotal role in economic growth and infrastructure development across both developed and developing economies (Ofori, 2021). Despite this importance, the sector continues to be characterised by significant safety risks and recurring project management inefficiencies that undermine its performance and public standing (Tixier *et al.*, 2017). Construction remains among the most hazardous industries globally, with workers routinely exposed to physical, mechanical and organisational hazards that translate into high rates of injury and fatality. Addressing these persistent health and safety (H&S) challenges requires approaches that move beyond traditional, paper-based site management practices towards more proactive, technology-enabled risk management.

Building Information Modelling (BIM) has been widely promoted as a collaborative digital platform capable of addressing many of these challenges through improved visualisation, earlier hazard identification, and more effective coordination among project stakeholders (Succar, 2009). However, the uptake of BIM among South African small- and medium-sized contractors, particularly for H&S purposes, remains limited. This is a concern, given that small and medium enterprises (SMEs) constitute the majority of registered construction firms in South Africa (CIDB, 2022). While BIM has been shown to enhance the competitiveness of construction firms that adopt it (Ambe *et al.*, 2020), SMEs continue to face considerable impediments, including resource constraints, limited awareness, and resistance to changing established ways of working. These obstacles are compounded by the fact that SMEs typically lack the dedicated capacity to institutionalise new technologies that larger firms can more readily absorb.

Overcoming these obstacles is essential if BIM is to make a meaningful contribution to improving H&S practices within the SME segment of the industry. Doing so requires more than a general sense of how ready SMEs are to adopt the technology. It requires a clear understanding of the specific impediments that prevent SMEs from reaching that readiness level. Bowen and Ndlovu (2017) suggested that organisational culture and leadership play a particularly important role in shaping how firms' receptiveness to

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new technology, and that readiness levels can vary considerably between provinces (Modise, 2016). Yet while the organisational factors associated with readiness are reasonably well established, the specific impediments that obstruct SMEs from developing this readiness within the KZN construction sector remain poorly understood. This study, therefore, aimed to examine the impediments to SME readiness to adopt BIM for H&S management in KZN.

To achieve this aim, the study adopted a positivist, deductive and quantitative research design, surveying a random sample of CIDB-registered SME contractors operating in KZN. The remainder of this paper is structured as follows: Section 2 reviews the literature on BIM, organisational readiness, and the impediments that shape construction H&S management; Section 3 outlines the research methodology adopted; Section 4 presents the findings and discusses their implications in relation to the existing body of knowledge; and Section 5 concludes the paper and proposes directions for further research.

2. Literature Review

This section reviews the literature on BIM, construction H&S, and SME development in South Africa, moving from an overview of BIM to its application in H&S management, the role of SMEs in the South African construction economy, the organisational factors associated with BIM readiness, and finally, the specific impediments that prevent SMEs from developing this readiness.

2.1. BIM Overview

Building Information Modelling (BIM) is a technology-driven approach that supports the design, construction and operation of the built environment throughout the asset lifecycle. Rather than functioning merely as a three-dimensional drawing tool, BIM operates as a digital model of a facility's physical and functional characteristics, providing project stakeholders with a shared, continuously updated information resource from inception through to deconstruction (Park & Park, 2015). This shared model underpins construction-phase simulation, advanced visualisation, and resource management, which in turn enhance both safety performance and cost-estimation accuracy (Toyin & Mewomo, 2023). BIM also fosters more effective collaboration and project management across an asset's lifecycle, extending well beyond traditional 3D modelling by embedding intelligent data within the model and improving communication among architects, engineers, contractors and clients (Wang *et al*., 2024). For SMEs, these capabilities are potentially transformative, provided the technology can be implemented in a manner that is affordable, accessible and compatible with existing ways of working.

2.2. BIM for Health and Safety in Construction SMEs

Construction safety encompasses a wide range of procedures intended to manage physical risks such as falls and unguarded machinery, chemical hazards, biological threats such as exposure to harmful bacteria, and psychosocial issues such as stress and harassment. Effective H&S management requires strict adherence to safety regulations and active employee participation in identifying and mitigating risks (Labaran *et al.*, 2024). The technologies associated with the Fourth Industrial Revolution, which combine digital, physical and biological systems, have introduced tools such as smart personal protective equipment (helmets, gloves and high-visibility clothing) and immersive training methods that further enhance site safety (Abina *et al.*, 2024). Sound safety management, supported by regular reviews and continuous improvement, has been shown to enhance workplace quality and reduce accident rates. Within this context, BIM serves as a collaborative digital tool for project planning, design, construction, and management, enabling better systems integration, more proactive risk management, and real-time hazard tracking on-site (Azhari *et al.*, 2011). Despite these documented benefits, BIM has not been widely adopted by construction SMEs operating in KZN. This study examines the impediments to SMEs' readiness to adopt BIM for H&S management in KZN.

2.3. The Role of SMEs in the South African Construction Economy

SMEs occupy a critical position within the South African construction economy. Hove (2016) emphasises the importance of small-scale emerging contractors for the country's economic development, noting that government support programmes have historically sought to foster their growth and create employment opportunities for previously disadvantaged groups. SMEs are estimated to contribute a substantial share of national GDP while simultaneously creating jobs, stimulating economic growth, and expanding infrastructure delivery capacity (CIDB, 2022). Beyond their direct economic contribution, SMEs empower marginalised communities through entrepreneurship and skills development, although they continue to face persistent challenges, including financial constraints, skills shortages, and intense competition from larger, more established firms (Hove, 2016), while also indirectly increasing household incomes and broader economic activity through the infrastructure they help to deliver. Given this combination of economic importance and structural vulnerability, understanding how SMEs can be supported to adopt safety-enhancing technologies such as BIM is of practical significance.

2.4. Readiness to Adopt BIM for Health and Safety

BIM adoption in the construction industry has been consistently linked to improvements in project

efficiency, cost control and H&S outcomes; however, the readiness of South African SMEs to adopt the technology remains comparatively under-researched. Chen *et al.* (2013) propose that readiness for BIM adoption can be conceptualised as the degree to which an organisation's strategy, people, processes and technology are aligned and capable of supporting implementation, a framework that has informed how the present study operationalised readiness. Existing evidence suggests that SMEs in KZN face a combination of financial, skills, and training-related constraints that limit their readiness (Olatunji, 2022), a pattern that echoes earlier South African findings indicating that mandatory or incentivised initiatives may be needed to accelerate adoption (Chimhundu, 2015). The literature further indicates that successful BIM adoption depends on the alignment of five interrelated organisational factors, namely strategy, leadership, culture, people and technology (Abbasnejad, et al., 2021; Bowen & Ndlovu, 2017), with anticipated benefits including improved H&S compliance once these factors are adequately developed (Sila *et al.*, 2024). These five factors provided the conceptual basis for the present study, which offers little insight into the specific impediments that prevent South African SMEs from developing them in practice, a gap addressed next.

2.5. Impediments to BIM Readiness for Health and Safety

Despite its considerable benefits, BIM implementation continues to be constrained by high costs, organisational resistance, skills shortages and inadequate digital infrastructure (Bowen & Ndlovu, 2017), challenges that are particularly pronounced among SMEs, where regulatory enforcement and institutional support remain limited. Comparable findings have been reported among SMEs in other developing-country contexts, including Nigeria (Saka, 2022), suggesting that the constraints facing KZN SMEs reflect a broader pattern affecting resource-constrained contractors rather than a uniquely local problem. Financial constraints, reluctance to change established practices, insufficient training opportunities (Olatunji, 2022), and the absence of clear implementation standards collectively hinder the adoption of BIM-enabled H&S measures, underscoring the need for more supportive government and industry policies, particularly for SMEs that may otherwise be left behind as larger firms continue to digitalise.

Overcoming these impediments is vital if the sector is to realise BIM's full potential for improving safety outcomes. Chen *et al.* (2024) note that BIM improves construction performance and H&S by enabling design optimisation, advanced visualisation and early hazard detection. The technology assists architects, engineers and contractors in assessing sites and identifying hazards before construction begins (Azhar, 2017), thereby strengthening overall risk management practices. This is particularly relevant for KZN construction firms, including SMEs, which continue to record high rates of occupational injury (Federated Employers Mutual Assurance Company [FEM], 2024); for these firms, BIM offers tangible benefits in terms of hazard detection, safety testing and risk management (Chen *et al.*, 2024). Taken together, the literature suggests that while the benefits of BIM for SME health and safety management, and the organisational factors associated with readiness, are well established, the specific impediments that prevent South African SMEs from translating this potential into practice remain insufficiently understood. Identifying these impediments forms the empirical focus of the present study.

3. Research Methodology

This study adopted a positivist research philosophy, on the basis that the impediments to SME readiness for BIM adoption can be objectively measured through a structured, replicable instrument. A deductive approach was followed, whereby existing theory on organisational readiness and BIM adoption (Chen *et al.*, 2013) informed the variables measured, rather than allowing themes to emerge inductively from the data. Data collection followed a mono-method quantitative approach, as recommended by Creswell & Creswell (2017).

The research strategy was a cross-sectional questionnaire survey, as suggested by Saunders *et al.* (2019), which collects data at a single point in time rather than tracking change longitudinally (Bryman & Bell, 2015). This strategy was considered appropriate given the exploratory, baseline nature of the investigation and the practical constraints of surveying a geographically dispersed population of SME contractors. Simple random sampling was used to facilitate efficient and representative data collection. The target population comprised CIDB-registered general building contractors in grades 1 to 6 operating in KZN, a category dominated by SMEs (CIDB, 2022). From a population of 1,634 such contractors, a sample size of 180 SMEs was established. 130 SMEs participated using a simple random sampling method, yielding a sample considered adequate for the descriptive statistical analysis undertaken. An electronic questionnaire was distributed via email, with follow-up reminders sent to non-respondents to improve the response rate.

The questionnaire measured perceived impediments to BIM adoption for H&S management using a five-point Likert scale (1 = Strongly Disagree to 5 = Strongly Agree). Mean scores (MS) were interpreted using the following ranges: strongly disagree (≥1.00–≤1.80), disagree (≥1.81–≤2.60), neutral (≥2.61–≤3.40), agree (≥3.41–≤4.20), and strongly agree (≥4.21–≤5.00), adopted from the study of Renault et al., (2018). Data

were analysed using SPSS version 29, with descriptive statistics, including frequencies, means, and standard deviations, computed for each impediment item. Content validity was established by having the questionnaire reviewed by experts familiar with BIM and construction H&S management prior to distribution, while internal consistency reliability was assessed using Cronbach's alpha, with a coefficient of 0.70 or higher regarded as acceptable for newly developed multi-item constructs (Nunnally, 1978).

Ethical approval for the study was obtained from the Tshwane University of Technology Research Ethics Committee prior to data collection, ensuring that the research was conducted with due regard for integrity, respect for participants, and trust between researchers and the SMEs who responded. Participation was voluntary, and respondents were assured of the confidentiality and anonymity of their responses.

4. Findings and Discussion

This section presents the empirical findings of the survey of 130 KZN-based SME contractors and discusses their implications in relation to the literature reviewed in Section 2. The discussion is organised around the reliability of the measurement instrument, the specific impediments identified, and the broader factors that explain why these impediments continue to constrain SME readiness to adopt BIM for H&S management.

4.1. Reliability of the BIM Readiness Impediments Construct

Reliability was assessed using SPSS to compute Cronbach's alpha for the thirteen items comprising the impediments construct. As shown in Table 1, the construct returned an unstandardised alpha of 0.919 and a standardised alpha of 0.920, both comfortably exceeding the 0.70 threshold generally regarded as acceptable for multi-item scales (Nunnally, 1978). This high level of internal consistency indicates that the thirteen impediment items measured a coherent underlying construct and that the subsequent mean scores can be interpreted with confidence.

4.2. Impediments to the Adoption of BIM Technology for Health and Safety

Table 2 presents the descriptive results for the thirteen impediments to BIM adoption for H&S management among KZN SMEs. Overall, respondents agreed that these impediments significantly hinder SME readiness, with an overall mean score of 4.00 and a standard deviation of 0.761, placing the construct firmly within the 'agree' band of the interpretation scale. The most strongly endorsed impediments were limited access to the infrastructure and technological resources required for effective BIM use (mean = 4.16), limited access to BIM-specific training and education (mean = 4.14), and a shortage of personnel skilled in using BIM for H&S purposes (mean = 4.11). Insufficient standardisation and the absence of clear implementation protocols

Table 1: Internal Reliability Test for the Impediments Construct

Factor	N	Unstandardised Cronbach's Alpha	Standardised Cronbach's Alpha
Impediments to BIM readiness for H&S	13	0.919	0.920

Source: Authors' construction, 2026

Table 2: Impediments to the Adoption of BIM Technology for H&S

Item	Mean	Std. Dev.	Ranking
Limited infrastructure and technological resources	4.16	0.724	1
Limited access to BIM-specific training and education	4.14	0.723	2
Shortage of personnel skilled in BIM for health and safety	4.11	0.760	3
Lack of standardisation and clear H&S protocols	4.08	0.743	4
Resistance to changing organisational culture	4.07	0.759	5
Incompatibility of BIM software with existing systems	4.03	0.777	6
Insufficient financial resources for BIM investment and training	4.00	0.807	7
Regulatory barriers and lack of government incentives	3.96	0.772	8
Limited awareness of BIM benefits for health and safety	3.92	0.832	9
Data security and privacy concerns	3.92	0.743	10
Interoperability and compatibility concerns with existing software	3.90	0.714	11
Perceived complexity of integrating BIM into project processes	3.88	0.722	12
Difficulty identifying information for transfer to FM software	3.86	0.814	13
Overall mean and std. dev.	**4.00**	**0.761**	

Source: Authors' construction, 2026 (n = 130). SD = Strongly Disagree; D = Disagree; N = Neutral; A = Agree; SA = Strongly Agree.

(mean = 4.08), resistance to changing established organisational practices (mean = 4.07), and incompatibility between BIM software and existing systems (mean = 4.03) were also rated highly. The comparatively low standard deviations recorded across most items, generally below 0.83, indicate a strong degree of consensus among respondents rather than polarised views.

4.3. Discussion: Impediments to SME Readiness for BIM Adoption

Seven of the thirteen impediments returned mean scores of 4.00 or higher, including limited infrastructure, limited training, and a shortage of skilled personnel, as well as insufficient standardisation, resistance to change, software incompatibility, and insufficient funds. This pattern corroborates research by Olatunji (2022), who found that South African SMEs face considerable compliance challenges with H&S regulations that BIM could help mitigate through better documentation, compliance tracking and project management once the underlying impediments are addressed. The prominence of infrastructure and training-related impediments is also consistent with international evidence: comparable studies among SMEs in Nigeria (Saka, 2022) likewise identify cost, skills shortages and limited access to enabling infrastructure as the dominant constraints on BIM uptake, suggesting that the impediments facing KZN SMEs are not unique to the local context but reflect a broader pattern affecting resource-constrained contractors internationally.

The strong endorsement of training and skills-related impediments is particularly noteworthy given that most South African SMEs lack documented strategies for technology adoption, largely owing to limited managerial knowledge of what such strategies should entail. Without a clear strategic intent, it becomes considerably more difficult for SMEs to justify the investment required to implement BIM-enabled H&S measures, even where leadership recognises their potential value. This is compounded by evidence that a lack of leadership capacity and managerial competence contributes to high SME failure rates in their first five years of operation (Hove, 2016), leaving many firms without the leadership continuity needed to drive technology adoption to completion. Resistance to change, the fifth highest rated impediment in this study, further underscores the cultural dimension of readiness: Ghaffarianhoseini *et al.* (2016) emphasise the need for a culture of innovation within SME construction firms, yet such firms typically retain traditional, paper-based workflows that actively resist the introduction of digital tools.

The high ratings for software incompatibility and a lack of standardisation point to a further structural impediment: the absence of sector-wide BIM protocols tailored to SMEs' scale and capacity. Where standards and guidance exist, they are often designed with large contractors in mind, leaving many smaller firms to navigate implementation largely alone. For H&S management specifically, this is a wasted opportunity, since BIM-enabled hazard detection and risk visualisation have been shown to directly support compliance and reduce site-level injury rates when properly implemented (Azhar, 2017), benefits that are especially relevant given the elevated occupational injury rates recorded among KZN's construction workforce (FEM, 2024).

Taken together, the findings show that SME readiness for BIM-enabled H&S management in KZN is constrained by a specific, identifiable set of impediments spanning resource limitations, underdeveloped strategy and leadership capacity, persistent cultural resistance, and structural gaps in standardisation and infrastructure. These impediments map closely onto the five-factor readiness framework by Chen *et al.* (2013), suggesting that readiness is unlikely to improve until relevant factors corresponding to impediments are directly addressed. This reinforces the case for SME-specific, rather than one-size-fits-all, interventions to overcome these impediments to BIM readiness for H&S management (Chimhundu, 2015).

5. Conclusion and Further Research

The construction sector remains one of the most dangerous industries in which to work, and BIM continues to offer considerable promise for improving health and safety (H&S) outcomes through better visualisation, earlier hazard identification, and more collaborative planning. While large firms have progressively adopted BIM, most South African SMEs continue to face substantial impediments to its adoption. This study set out to identify the impediments to SME readiness to adopt BIM for H&S management in KwaZulu-Natal and found 13 such impediments spanning strategy, leadership, culture, people, and technology, 7 of which were rated by respondents as particularly significant constraints on readiness.

BIM's benefits for SME health and safety management, including improved risk management and project efficiency, are widely acknowledged but remain largely unrealised in practice. The most significant impediments identified, namely limited infrastructure, restricted access to training, a shortage of skilled personnel, insufficient standardisation, resistance to change, software incompatibility, and inadequate funding, mirror challenges documented among SMEs in other developing-country contexts, suggesting that the constraints facing KZN contractors are structural rather than unique to the province.

To overcome these impediments and raise readiness levels, SMEs require affordable training programmes,

implementation frameworks tailored to their scale, leadership awareness campaigns, government incentives that lower the cost of entry, and stronger industry partnerships that allow smaller firms to learn from early adopters. Software vendors and industry bodies also have a role to play in providing accessible education, technical support and SME appropriate licensing models.

This study is not without limitations. The cross-sectional design captures impediments to readiness at a single point in time, while the focus on KZN limits the extent to which the findings can be generalised to other provinces. Further research should consider longitudinal designs that track how these impediments evolve over time, comparative studies across provinces, and qualitative investigation of the leadership and cultural dimensions of BIM adoption identified here. Future work could also evaluate the effectiveness of specific interventions, such as subsidised training or government incentives, in reducing these impediments and strengthening SME readiness
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Assessment of BIM Awareness and Perceived Benefits for High-Rise Project Delivery in Lagos and Port Harcourt, Nigeria

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Abstract

Abstract: This study assessed the level of Building Information Modelling (BIM) awareness and quantifies the perceived benefits of its adoption for effective high-rise building project delivery in Lagos and Port Harcourt, Nigeria. A quantitative cross-sectional survey was conducted with a calculated sample size of 392 registered construction professionals (architects, engineers, builders, and quantity surveyors) in the two cities. A total of 298 valid questionnaires were retrieved and analysed using descriptive statistics, mean scores (1–5 scale), and the Relative Importance Index (RII). Eight refined variables measured BIM awareness: Technical Proficiency, Software Accessibility, Regulatory Framework, Educational Integration, Collaborative Readiness, Cost-Time Perception, Management Support, and Design Integration. Nine refined variables captured perceived benefits: Cost Efficiency, Schedule Optimization, Quality Enhancement, Risk Reduction, Stakeholder Communication, Sustainability Performance, Data Integrity, Lifecycle Management, and Competitive Advantage. Awareness analysis revealed that Collaborative Readiness ranked highest (Mean=3.18, RII=0.636), while Design Integration ranked lowest (Mean=1.82, RII=0.364). Technical Proficiency (Mean=2.43, RII=0.486) and Software Accessibility (Mean=2.01, RII=0.402) showed moderate but insufficient levels. Benefit analysis showed Cost Efficiency (Mean=4.77, RII=0.954) and Schedule Optimization (Mean=4.70, RII=0.940) as the most recognised benefits, whereas Competitive Advantage ranked lowest (Mean=4.46, RII=0.892). A critical perception gap of approximately 40–50% was identified across all variables – professionals perceive BIM as highly beneficial but demonstrate low practical awareness and implementation. Nigerian construction professionals are aware of BIM, but its potential benefits remain underutilised due to systemic barriers: inadequate software access, weak regulatory frameworks, and insufficient technical training. Strategic interventions include mandatory BIM policies for high-rise projects exceeding ten stories, integration of BIM into university curricula, government-subsidised software licences, and the establishment of regional BIM competence centres in Lagos and Port Harcourt.

Keywords: Awareness; Building Information Modelling (BIM); Construction Industry; High-Rise Buildings; Perceived Benefits; Project Delivery; Nigeria

1. Introduction

The global construction industry has witnessed a paradigm shift toward digitalization, with Building Information Modelling (BIM) emerging as the most transformative innovation since computer-aided design (CAD) (Azhar, 2011). BIM represents a holistic digital representation of built assets, integrating geometric, spatial, geographic, and quantitative data into a collaborative environment accessible to all stakeholders throughout a project's lifecycle (Eastman *et al.*, 2011; Sacks *et al.*, 2018). Unlike traditional two-dimensional drafting, BIM enables parametric modeling, clash detection, automated quantity takeoffs, 4D scheduling, 5D cost estimation, and 6D facility management—capabilities that directly address persistent industry challenges of cost overruns, schedule delays, and coordination failures (Azhar, 2011).

High-rise construction projects, defined as buildings exceeding ten stories or 35 meters in height, present unique complexities that magnify the value of BIM adoption (ICC, 2025). These projects involve multiple interdependent systems (structural frames, mechanical-electrical-plumbing, facades, vertical transportation), numerous specialty contractors, extensive supply chains, and prolonged construction durations (ICC, 2025). The absence of integrated digital coordination in such contexts frequently results in design clashes, rework, material waste, budget overruns exceeding 30%, and schedule delays averaging 40% beyond initial projections (Azhar, 2011; Olawumi and Chan, 2019).

Nigeria's construction sector, valued at approximately $45 billion annually and growing at 8-10% due to rapid urbanization (NBS, 2023), presents a paradoxical scenario. Lagos and Port Harcourt (the nation's

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economic hubs) are experiencing unprecedented high-rise construction booms. Lagos alone has over 300 ongoing high-rise projects, including the Eko Atlantic City development and numerous residential-commercial TOWERS (NBS, 2023). Port Harcourt follows with significant vertical expansion driven by oil and gas sector demands.

However, despite this construction surge, maximizing BIM's benefits in Nigeria remains below 15% among construction firms, compared to over 70% in the United Kingdom, 60% in Singapore, and 50% in South Africa (McGraw-Hill Construction, 2020; NBS, 2022). This deficit manifests in tangible project failures: documented design errors causing rework costs averaging 12% of contract values, coordination failures leading to schedule extensions of 6-18 months, and post-construction defects requiring expensive remediation (Eze *et al*., 2020; Onungwa and Uduma-Olugu, 2017).

The critical gap this study addresses is the disconnect between awareness and perceived benefits. While previous studies (Uduma-Olugu and Onungwa, 2017; Aibinu and Venkatesh, 2018) have noted growing BIM awareness among Nigerian professionals, none have systematically quantified this gap or identified specific variables driving this resistance. This study therefore poses three research questions: (1) What is the current level and dimensional distribution of BIM awareness among construction professionals? (2) What specific benefits are mostly associated with BIM adoption? (3) What recommended strategies can bridge the awareness-perception gap?

2. Literature Review

2.1. Theoretical Framework: Diffusion of Innovation Theory and Technology Acceptance Model (TAM).

This study is anchored in Rogers' (2003) Diffusion of Innovation (DOI) theory, which explains how new technologies spread through populations based on five key attributes: relative advantage, compatibility, complexity, trialability, and observability. In the context of BIM awareness and perceived benefits for high-rise project delivery in Lagos and Port Harcourt, DOI suggests that Nigerian construction professionals' adoption decisions are shaped by their assessment of BIM's superiority over traditional methods (relative advantage), alignment with existing workflows (compatibility), perceived difficulty of use (complexity), opportunities for hands-on experimentation (trialability), and visible success stories (observability). The theory is complemented by the Technology Acceptance Model (TAM) (Davis, 1989), which posits that perceived usefulness and perceived ease of use are direct determinants of technology adoption. Applying TAM, this study posits that BIM awareness translates into adoption when professionals strongly believe that BIM improves high-rise project outcomes (perceived usefulness) and view the technology as manageable despite resource constraints (perceived ease of use). Together, DOI and TAM provide a robust lens for examining the gap between BIM awareness and actual adoption, as well as for interpreting the perceived benefits reported by practitioners in Nigeria's rapidly urbanizing high-rise construction sector.

2.2. BIM Awareness: Conceptual Dimensions

Awareness of BIM extends beyond simple recognition of the acronym. Olawumi and Chan (2019) proposed a multidimensional awareness framework comprising: (a) conceptual awareness (understanding BIM principles and capabilities); (b) technical awareness (knowledge of specific software and work flows); (c) strategic awareness (appreciation of BIM's business and project management implications); and (d) collaborative awareness (recognition of BIM's role in stakeholder coordination). This study operationalizes awareness through eight refined variables that capture these dimensions (Table 1).

Table 1: Refined BIM Awareness Variables and Operational Definitions

Variable	Operational Definition	Measurement Focus
Technical Proficiency (V1)	Self-reported competence in BIM software operation	Revit, ArchiCAD, Navisworks familiarity
Software Accessibility (V2)	Availability of licensed BIM tools in workplace	Legal vs. Pirated copies, version currency
Regulatory Framework (V3)	Existence of government BIM mandates or incentives	Policy awareness, enforcement level
Educational Integration (V4)	Formal BIM training in academic/professional programs	Curriculum content, certification availability
Collaborative Readiness (V5)	Organizational capacity for multi-stakeholder digital coordination	Interoperability standards, common data environment
Cost-Time Perception (V6)	Beliefs about BIM's impact on project economics	ROI expectations, implementation cost assessment
Management Support (V7)	Leadership commitment to BIM adoption	Budget allocation, champion presence, change management
Design Integration (V8)	Application of BIM in schematic and detailed design	3D modeling, clash detection, design review frequency

2.3. Empirical Evidence on BIM Benefits

Meta-analyses of BIM benefit studies (Olawumi and Chan, 2019) consistently report: (1) cost reduction (5-15% decrease in construction costs primarily through reduced rework and optimized procurement); (2) schedule compression (7-20% reduction in project duration through 4D sequencing and clash avoidance); (3) quality improvement, 30-50% reduction in requests-for-information (RFIs) and field coordination issues; (4) safety enhancement (20-40% reduction in site incidents through construction simulation identifying hazard exposures); (5) sustainability (10-25% improvement in energy performance through integrated analysis).

However, these benefits are context-dependent. In developing economies, adoption barriers substantially moderate outcomes (Olawumi and Chan, 2019; Enegbuma *et al*., 2016). Primary barriers identified in Nigerian studies include: high software costs ($2,000-5,000 per license annually), inadequate internet infrastructure for cloud collaboration, shortage of trained professionals (estimated deficit of 5,000 BIM-literate practitioners), and absence of national BIM standards or mandates.

2.4. Research Gap Synthesis

Existing literature demonstrates two critical gaps: (1) Measurement inadequacy: most Nigerian studies use generic awareness questions (e.g., "Are you aware of BIM?") rather than dimensional assessments; (2) Sector specificity: few studies focus exclusively on high-rise projects despite their unique coordination demands.

3. Materials and Methods

A cross-sectional quantitative survey design was employed, appropriate for measuring current awareness levels and perceived benefits across a defined population. This design enables statistical generalizability while capturing professional perspectives unaffected by observational or experimental biases.

3.1. Population of the Study

Lagos and Port Harcourt were selected as Nigeria's most intensive high-rise construction markets. Lagos contributes approximately 60% of Nigeria's high-rise construction volume, while Port Harcourt contributes 15%. The two cities provide complementary contexts: Lagos represents the commercial, mixed-use high-rise market; Port Harcourt represents oil-sector and residential high-rise development.

According to available records, the Table 2 gives a detailed analysis of construction professionals in Lagos and Rivers State.

Table 2: Construction Professionals

Profession	Lagos State	Rivers State
Architects	1,489	261
Builders	415	159
Structural Engineers	10,585	3,706
Quantity Surveyors	1277	323
TOTAL	**13,766**	**4,449**

Source: *NIA, NIOB, NSE and NIQS (2024) – Membership registers obtained directly from each professional body; not publicly archived.*

Hence, the population of the research is 18,215 construction professionals.

3.1.1. Sampling Size

The sample size for the study population was calculated using the Taro Yamane formula.

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

$$N = \frac{18{,}215}{1 + 18{,}215(0.05)^2} = 392$$

3.1.2. Sampling Technique

Stratified purposive sampling was employed. Stratification by profession ensured proportional representation. Purposive selection required: (a) minimum 5 years construction experience; (b) involvement in ≥2 high-rise projects; (c) current employment with design or construction firm. Within strata, convenience sampling distributed questionnaires to accessible professionals during industry meetings and via professional networks.

3.2. Method of Data Collection

A structured questionnaire comprising three sections was developed. Questionnaire face validity was established through review by three BIM experts (two academics, one industry practitioner). The experts rated all 17 items (8 awareness, 9 benefits) as 'relevant' or 'highly relevant' (content validity index = 0.94). They suggested minor wording changes to improve clarity for respondents (e.g., replacing 'common data environment' with 'shared project folder'), and confirmed that the 5-point Likert scale was appropriate. No items were deleted or added. Reliability was tested through pilot study (n=30 professionals in Abuja),

yielding Cronbach's alpha coefficients of 0.87 (awareness section) and 0.91 (benefits section), exceeding the 0.70 acceptability threshold.

4. Results and Discussion

Upon carrying out basic analysis of the data gathered, the descriptive statistics were used to analyze the questions addressing the research questions raised earlier in the study.

Table 3 shows the level of awareness of Building Information Modelling (BIM) in high-rise construction projects. Collaborative Readiness (RII=0.636): Respondents demonstrated moderate awareness of BIM's role in stakeholder coordination, document sharing, and integrated project delivery. This suggests that professionals recognize BIM as primarily a communication tool rather than a comprehensive management platform. Regulatory Framework (RII=0.388) and Design Integration (RII=0.364): Very low awareness of government BIM policies (unsurprising given Nigeria's absence of BIM mandates) and minimal application in actual design workflows. Only 11.4% of respondents reported using BIM for clash detection or parametric modeling.

Table 4 presents the perceived benefits most associated with the adoption of Building Information Modelling (BIM) in high-rise construction projects, Cost Efficiency (RII=0.954): 97.6% of respondents agreed/strongly agreed that BIM reduces construction costs. This aligns with international literature but contrasts with Nigeria's actual implementation rates, suggesting a disconnect between perceived potential and realized outcomes. Sustainability ranked 3rd (RII=0.938): Surprisingly high recognition of BIM's environmental benefits (energy analysis, material optimization, waste reduction) given low sustainability focus in Nigerian construction codes. This indicates evolving professional values potentially driven by international client demands. Competitive Advantage (RII=0.892): While still strong, this relative ranking suggests that professionals perceive BIM benefits as primarily project-level rather than firm-level market differentiators.

4.1. Discussion of Results

Interpretation of Awareness Findings

The finding that Collaborative Readiness ranks highest (RII=0.636) while Design Integration ranks lowest (RII=0.364) reveals a critical paradox in Nigerian BIM perception. Professionals understand BIM's communication benefits but do not translate this understanding into technical application. This aligns with Rogers' DOI theory's "knowledge-persuasion gap" the stage where innovation awareness exists but adoption decisions remain pending due to insufficient trialability and observability (Rogers, 2003).

Comparatively, this awareness profile differs from developed economies. In the UK, where BIM Mandate

Table 3: Level of awareness of Building Information Modelling (BIM)

Variables	Mean	RII	Ranking	Category
Collaborative Readiness (V5)	3.18	0.636	1st	Moderate
Technical Proficiency (V1)	2.43	0.486	2nd	Low
Educational Integration (V4)	2.37	0.474	3rd	Low
Management Support (V7)	2.30	0.460	4th	Low
Cost-Time Perception (V6)	2.05	0.410	5th	Low
Software Accessibility (V2)	2.01	0.402	6th	Low
Regulatory Framework (V3)	1.94	0.388	7th	Very Low
Design Integration (V8)	1.82	0.364	8th	Very Low
Composite	2.260	0.453	-	Low

**Interpretation: RII; 0.8 = High, 0.6-0.79 = Moderate, 0.40-0.59 = Low, <0.40 = very low*

Source: Researcher's Field work, 2026

Table 4: Perceived Benefits of BIM

Variables	Mean	RII	Ranking
Cost Efficiency (B1)	4.77	0.954	1st
Schedule Optimization (B2)	4.70	0.940	2nd
Sustainability Performance (B3)	4.69	0.938	3rd
Risk Reduction (B4)	4.66	0.932	4th
Stakeholder Communication (B5)	4.65	0.930	5th
Quality Enhancement (B6)	4.56	0.912	6th
Data Integrity (B7)	4.53	0.906	7th
Lifecycle Management (B8)	4.47	0.894	8th
Competitive Advantage (B9)	4.46	0.892	9th
Composite	4.61	0.922	-

Source: Researcher's Field work, 2026

Level 2 has been compulsory for public projects since 2016, technical proficiency and design integration consistently rank highest (NBS, 2022). In Singapore, where the Building and Construction Authority mandates BIM for projects exceeding 5,000 m², regulatory framework awareness is near-universal. Nigeria's profile; high collaboration awareness but low technical awareness, represents an early-stage diffusion pattern where professionals have been exposed to BIM concepts through conferences and literature but lack hands-on experience.

The very low regulatory framework awareness (RII=0.388) is particularly significant. Without government mandates, BIM remains voluntary, and voluntary adoption rarely exceeds 15-20% of any industry (Rogers, 2003). This explains the perception gap (Table 5): professionals see no immediate consequence for non-adoption, no client requiring BIM deliverables, and no competitor penalized for lacking BIM capability.

However, the gap between benefit perception (RII=0.922) and current adoption (evidenced by awareness of technical variables at RII=0.453) represents a classic "value-action gap" documented in behavioral economics (Sheeran and Webb, 2016). Professionals believe BIM valuable but do not act due to perceived adoption barriers outweighing individual benefits. This explains the third-place ranking of Competitive Advantage (RII=0.892)—without widespread adoption, BIM does not yet differentiate firms in the Nigerian market, reducing the business case for early investment.

Synthesis: The Implementation Ecosystem

Integrating findings reveals that BIM adoption in Nigeria requires simultaneous, coordinated interventions across four ecosystem dimensions:

1. Technical Infrastructure: Software accessibility (RII=0.402) is insufficient. The average BIM software license costs $2,500 annually (NBS, 2022), comparable to a junior engineer's annual salary in Nigeria. Pirated software lacks updates, technical support, and interoperability, perpetuating low proficiency.

2. Human Capital: Technical proficiency (RII=0.486) exceeds software access, indicating motivated professionals learning through online resources (YouTube tutorials, MOOCs) despite workplace constraints (NBS, 2022). However, without formal certification pathways, proficiency remains unverified and non-transferable.

3. Regulatory Environment: Absent government policy (RII=0.388) removes adoption pressure. Countries with successful BIM diffusion (UK, Singapore, Finland) all implemented phased mandates with 3-5 year lead times, enabling industry preparation while creating adoption necessity.

4. Educational Integration: Educational integration (RII=0.474) shows limited university BIM instruction. Most Nigerian construction graduates complete degrees without BIM training (NBS,

Table 5: Perception Gap

Dimensions	Benefits RII	Awareness RII	Gap
Collaboration	0.930	0.636	+0.294
Cost-Time	0.947	0.410	+0.537
Design Integration	0.912	0.364	+0.548
Technical	0.906	0.486	+0.420
Composite	0.922	0.453	+0.469

The composite gap of +0.469 means benefit recognition is 103% higher than actual awareness

Source: Researcher's Field work, 2026

Interpretation of Perceived Benefit

Universal strong agreement with all nine benefit variables (RII range 0.892-0.954) suggests that Nigerian professionals are not skeptical about BIM's potential value. This finding contradicts earlier studies (Aibinu and Venkatesh, 2018) that reported moderate benefit perceptions. The difference likely reflects increased international exposure; Nigerian professionals now work on projects with international partners (Chinese, Lebanese, European contractors) who bring BIM workflows, demonstrating observable advantages.

The highest ranking of Cost Efficiency (RII=0.954) is theoretically consistent. High-rise projects in Nigeria commonly experience 20-40% cost overruns (Uduma-Olugu and Onungwa, 2017), primarily due to design changes, rework, and material waste, all directly addressable by BIM capabilities (clash detection, quantity takeoffs, visualization). Professionals who have witnessed projects with 15-20% lower rework costs due to basic clash detection understand BIM's financial value intuitively (Azhar, 2011).

2023), entering workforce requiring retraining an inefficient human capital development model.

5. Conclusion and Recommendations

This study examined BIM awareness and benefits for high-rise project delivery in Lagos and Port Harcourt. Three principal findings emerge:

First, BIM awareness in Nigeria is dimensional and uneven, moderate for collaboration (RII=0.636) but very low for regulatory frameworks (RII=0.388) and design integration (RII=0.364). The composite awareness level (RII=0.453) indicates that while BIM is not an unknown concept, practical implementation capability remains severely underdeveloped.

Second, perceived benefits are universally strong (RII=0.922 composite), with cost efficiency (RII=0.954) and schedule optimization (RII=0.940) most recognized. This high benefit perception coexists paradoxically with lesser maximization of benefits, defining an awareness-perception gap of +0.469 RII points, representing unfulfilled potential rather than resistance to BIM concepts.

Third, the awareness-percieved benefit gap is not monolithic but varies by variable. Collaboration shows moderate gap (+0.294), suggesting near-term adoption feasibility, while design integration shows large gap (+0.548), indicating deeper structural barriers requiring systemic intervention.

6. Recommendations

Based on the findings and conclusions of this study, it is evident that to bridge the gaps and improve BIM awareness and benefits for project delivery, the following recommendations are proposed:

1. Mandate BIM for public-funded high-rise projects above ten storeys: The Federal and State Governments (Lagos and Rivers) should issue a phased mandate requiring BIM Level 1 (3D modeling with clash detection) for all new public high-rise buildings by 2027, and BIM Level 2 (collaborative common data environment) by 2030. This will directly address the very low regulatory framework awareness (RII=0.388) and create institutional pressure that turns perceived benefits into actual implementation.

2. Establish regional BIM competence centres in Lagos and Port Harcourt: Professional bodies (NIA, NIOB, NSE, NIQS) should partner with universities and private firms to set up two BIM competence centres – one in Lagos (Ikeja or Victoria Island) and one in Port Harcourt (Trans-Amadi). Each centre shall offer: (a) subsidised licensed BIM software for SMEs, (b) hands-on training on design integration (currently the lowest awareness variable, RII=0.364), and (c) a certification pathway (Awareness, Practitioner, Manager). This will close the technical proficiency and software accessibility gaps.

3. Integrate BIM into university curricula and mandatory CPD: All construction-related degree programmes in South-South and South-West Nigeria must include a compulsory BIM course with at least 30 hours of practical software training. Additionally, the Architects Registration Council of Nigeria (ARCON), Council of Registered Builders of Nigeria (CORBON), and other regulators should require 10 hours of BIM-focused Continuing Professional Development (CPD) annually for license renewal by 2028. This will raise educational integration (RII=0.474) and sustain long-term awareness.

4. Launch a BIM subsidy and pilot project programme: The Nigerian Content Development and Monitoring Board (NCDMB) and Lagos State Infrastructure Asset Management Agency should co-fund a two-year BIM subsidy scheme covering 50% of software license costs for indigenous construction SMEs involved in high-rise projects. Concurrently, at least five pilot high-rise projects (three in Lagos, two in Port Harcourt) should be designated as "BIM demonstration projects" with publicised cost, schedule, and quality outcomes. The observable success of these pilots will dramatically improve the trialability and observability attributes (Rogers, 2003), converting high benefit perception into widespread adoption.

Finally, This study demonstrates that Nigerian professionals recognize BIM's value but lack the enabling ecosystem of accessible software, formal training, and supportive policy. Bridging the gap requires coordinated action across government, professional bodies, universities, and firms. The cost of inaction is measurable: continued project inefficiencies, unnecessary rework, and missed opportunities for sustainable, predictable, high-quality construction delivery. The path forward is clear implementation must begin now.

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BIM adoption strategies for SMEs to Manage Construction Project Risk in the Western Cape Province of South Africa

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Abstract

The construction industry plays an important role by creating jobs through small and medium-sized enterprises (SMEs). Despite their importance, construction SMEs in South Africa continue to face substantial project risks. The purpose of this research was to determine Building Information Modelling (BIM) adoption strategies that can be implemented by construction SMEs in the Western Cape Province of South Africa to manage construction project risks. A quantitative methodological approach using a structured online questionnaire survey was used. The research data was analysed using only descriptive (percentages, mean, standard deviation, etc.) statistics. The sample population was construction SMEs registered on the Construction Industry Development Board (cidb) register of contractors between Grade 1 and 6 under the General Building (GB) and/or Civil Engineering (CE) categories. The sample size was 25 construction SMEs selected using the voluntary response sampling method. The top perceived BIM strategies include: government grants that support small businesses; offering of continuous professional development and certification programmes and, collaboration between SMEs and larger construction companies and universities. The findings can assist construction SMEs in the Western Cape to understand the relationship between the strategies for adopting BIM and how it can improve the management of project risks contributing to long-term business growth.

Keywords: Building Information Modelling, Construction Project Risks, Small Medium-Sized Enterprises (SMEs)

1. Introduction

The construction industry is a major contributor to global economic development, accounting for approximately 13–15% of global Gross Domestic Product (GDP) and generating significant employment, also through SMEs (McKinsey and Company, 2024). In South Africa, the National Development Plan (NDP) Vision 2030 positions SMEs at the centre of economic growth and job creation. Despite their importance, SMEs in the South African construction sector continue to face substantial project risks, including cost overruns, schedule delays, quality failures, and occupational health and safety incidents (Chiswanda, 2021). The industry remains one of the country's highest-risk sectors, and research indicates that structured risk management practices are underutilised, directly affecting project performance and organisational sustainability (Masea, *et al*, 2025).

According to Sarvari *et al*., (2020), BIM as a digital innovation can improve project coordination, reduce rework, enhance transparency, and proactively manage construction project risks through improved visualisation, information sharing, and decision-making processes. Research published by Hall, *et al.*, (2023) has established that BIM adoption in construction SMEs can improve operational efficiency, collaboration, and project performance; however, adoption remains uneven and often constrained by limited financial resources, inadequate technical skills, organisational resistance, and lack of implementation support (Mashinini *et al*., 2025). While studies have examined barriers to BIM adoption and broad implementation strategies, insufficient attention has been given to how BIM adoption strategies can specifically support structured construction project risk management within SMEs, particularly in developing country contexts such as South Africa (Makabate *et al*., 2022; Tsokodayi, 2025).

The Western Cape Province provides an important analytical setting for this study due to its relatively active construction sector, concentration of registered SMEs, and increasing infrastructure and urban development activities, which expose firms to diverse project risks while simultaneously creating opportunities for digital transformation. Despite these developments, limited empirical research exists on BIM adoption strategies for construction SMEs in the province. This knowledge gap constrains SMEs from leveraging BIM as a strategic project risk mitigation tool. Therefore, this study aimed to establish BIM adoption strategies that can be implemented by construction SMEs to manage construction project risk in the Western Cape Province of South Africa.

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A quantitative research method was adopted, utilising an online structured questionnaire, with the link to the questionnaire emailed to construction SMEs who are registered on the Construction Industry Development Board (cidb) register of contractors between Grade 1 and 6 under the General Building (GB) and/or Civil Engineering (CE) work categories, in the Western Cape Province of South Africa. The distribution of the questionnaire was guided using voluntary response sampling, and the data was analysed using only descriptive (mean, standard deviation, etc.) statistics.

The following BIM adoption strategies: government grants that support small businesses in adopting digital construction technologies such as BIM; continuous professional development and certification programmes; collaboration between SMEs and larger construction companies, universities, or BIM experts; the creation of clear, standardised BIM protocols across the construction sector; and peer-to-peer learning, where SMEs learn from other SMEs about BIM's ability to manage construction project risks, contribute to closing the existing research gap.

These strategies may assist SME owners, managing directors, operations managers, and project managers in minimising construction project risks, enhancing organisational competitiveness, and supporting innovative growth within the construction industry.

2. Literature Review

2.1. BIM adoption strategies to manage construction project risks within SMEs

Although there have been a few studies highlighting that BIM has significant potential to manage construction project risks, SMEs still face challenges in adoption due to financial constraints, lack of in-house technical expertise and training, lack of awareness, resistance to change, legal and contractual issues and, integration with existing systems (Bamgbose, *et al.*, 2024). Tackling such barriers requires a strategic approach to successfully implement BIM, to address construction project risk as well as investigating the organisational and cultural factors that impact the adoption. To overcome some of these challenges, international strategies and policies have proven effective and could be applied in the South African context. Some of these international strategies will be discussed next.

2.1.1. Government grants

Government grants support small businesses in adopting digital construction technologies through programs that are innovative. They are also effective strategies to support the adoption of BIM within SMEs. These grants minimise the financial weight associated with the setup, training, and acquisition of software (Canada Digital Adoption Program, 2022). Countries like the United Kingdom and Singapore have government led initiatives that have accelerated BIM adoption amongst SMEs by offering financial assistance, tax incentives, and access to innovation hubs (Enterprise Singapore, 2025). Applying similar initiatives in South Africa could have a major impact on SMEs in overcoming financial and capacity-related challenges relative to BIM adoption.

2.1.2. Development of centralised platforms

These platforms provide open-access to tools like BIM and the delivery of free or affordable training workshops and webinars customised to the needs of small contractors and consultants. Ongoing professional development and certification opportunities can help strengthen internal skills and boost confidence in using BIM. (Maradza and Aigbavboa, 2023). This primarily reduces the risks associated with technical competency and skill deficiencies, which leads to improvements in construction project coordination, time, cost, and quality (Rane, 2023).

2.1.3. Fostering collaboration

Partnerships encourage mentorship opportunities, promote knowledge sharing and provide SMEs with access to essential BIM tools and professional expertise. Encouraging collaboration between small, medium, large construction firms, universities and BIM specialists can support the adoption of BIM. (Gerges, *et al.*, 2021). This strategy mitigates coordination and communication risks, while also indirectly reducing capability-related risks in construction projects (Saka and Chan, 2023).

2.1.4. Clear and standardised BIM protocols

The creation of clear, standardised BIM protocols across the construction sector can simplify the implementation process for SMEs and reduce the confusion surrounding adoption (Akinradewo, *et al.*, 2022). When SMEs operate without a defined set of standards, there is often confusion regarding roles, responsibilities, data formats, and levels of detail required at each stage of the project lifecycle. Applying this strategy reduces coordination and information management risks, while also improving efficiency and reliability across construction project delivery processes (Waqar *et al*, 2023).

2.1.5. Sharing success stories

Sharing real-life experiences and successful project stories can assist SMEs to fully understand the value of BIM and build confidence in its use (Mvududu, *et al.*, 2023). Platforms such as knowledge hubs funded by governments, conferences and webinars can serve as effective channels for sharing these stories. Peer-to-peer learning where SMEs learn directly from other SMEs is also an effective way to reduce fear and uncertainty around BIM implementation (Ferreira, *et al.*, 2022). To effectively use BIM to manage construction project risks, SMEs need to make strategic

investments and encourage a cultural shift within their organisation (Saka and Chan, 2021). This reduces resistance to BIM adoption by improving awareness, building confidence, and encouraging better project performance through shared experiences (Olanrewaju *et al*, 2022).

3. Research Methodology

The study utilised a quantitative methodological approach in the form of a structured online questionnaire survey, supported by a positivism philosophy and deductive reasoning. The justification for the research philosophy stems from the fact that positivism views reality as objective and measurable, which seeks to find laws and regularities that apply universally using systematic and quantitative methods (Ali, 2024). The justification for deductive reasoning is that this top-down approach helps explore cause-and-effect links, (Bell, *et al*, 2022), linking very well with the positivism philosophy and the quantitative methodological approach adopted. The research population for this study was 70 construction SMEs who are registered on the Construction Industry Development Board (cidb) register of contractors between Grade 1 and 6 under the General Building (GB) and/or Civil Engineering (CE) work categories, in the Western Cape Province of South Africa. Seventy, (70) questionnaires were distributed utilising the voluntary response sampling method as described by McCombes (2023), with 25 construction SMEs indicating their willingness to participate and submitting the completed structured online questionnaire. This is a 36% response rate, which according to Akintoye (2000) is acceptable for construction research. Although voluntary response sampling is usually criticised for bias, it was utilised due to its ease and speed of implementation that was required due to time constraints.

Because voluntary response sampling can introduce self-selection bias, steps were taken to minimise its impact. The survey questions were standardised to avoid leading responses, and anonymity was ensured to reduce social desirability effects. Taking into consideration the scope of the study, data was collected from a range of participants to improve representativeness, and findings were interpreted with caution, acknowledging the limitations of the sampling method. By being transparent about these measures, the study aimed to reduce bias and enhance the credibility of its conclusions. The research data was analysed using only descriptive statistics (percentages, mean, standard deviation, etc.). Mean score ranges were as follows: 1.00-1.75 (strongly disagree); 1.76-2.50 (disagree); 2.51-3.25 (agree); 3.26-4.00 (strongly agree). Standard deviation was used to report the variability (how concentrated the data is around the mean) in ranking items that have the same mean score. Only the mean scores of the items were used to show the central tendency and to rank the perceived BIM strategies in order of having the most effect to having the least effect.

4. Findings and Discussion

4.1. Analysis of respondents' demographic information

Analysis of Table 1 (Appendix 1) shows that 56% of respondents were male and 44% were female. The table further indicates that most respondents occupy managerial or leadership positions with responsibilities related to operational oversight and strategic decision-making. In terms of education, participants possess varied academic backgrounds, reflecting strong technical expertise and relevant qualifications. Overall, the findings highlight a strong presence of SMEs involved in general building activities that demonstrates a degree of operational flexibility within the sector.

4.2. BIM Adoption Strategies for SMEs to Manage Construction Project Risk.

The analysis of the descriptive data in Table 2 (Appendix 2) outlines the perceived strategies for enhancing BIM adoption among SMEs to manage construction project risks, with MS values between 3.26 and 4.00 (strongly agree), and the remainder of the variables with MS values between 2.51 and 3.25 (agree), indicating a strong sense of agreement amongst SMEs. The top MS value related to "Government grants" emerging as "Government led initiatives that accelerate BIM adoption amongst SMEs by offering financial assistance, tax incentives, and access to innovation hubs" ranked first, receiving a mean score (MS) of 3.28. This strategy allows SMEs to overcome financial barriers associated with software acquisition, staff training, and digital infrastructure by providing funding support, tax incentives, and access to innovation ecosystems (Algahtany *et al.*, 2023). The same level of agreement was recorded for "Government grants that support small businesses in adopting digital construction technologies like BIM to manage construction project risks through programs that are innovative" (MS = 3.28). Having the same MS, the ranking of these findings were determined by the standard deviation (SD) score, where the factor with lower SD ranking first. These findings are consistent with existing literature which emphasises that government financial incentives, subsidies, and policy initiatives play a critical role in accelerating BIM adoption among construction SMEs by reducing financial barriers and encouraging digital transformation within the sector (Algahtany *et al.*, 2023). The high ranking of government grant-related strategies suggests that SMEs view financial and institutional support as essential for overcoming BIM adoption barriers and improving construction project

risk management through better collaboration, decision-making, and project efficiency.

With reference to "The development of centralised platforms" the top ranked strategy, "Offering continuous professional development and certification programmes" ranked highest (MS = 3.36), highlighted the importance of building capacity and technical competence in promoting BIM adoption (Saka and Chan, 2023). This was followed by "Open-access to tools like BIM to help manage construction project risks" (MS = 3.32), strengthening the need to make BIM resources more available to SMEs. The ISO 19650 framework highlights the importance of developing organisational competence through training and professional development to ensure that project stakeholders can effectively manage and exchange digital construction information (ISO, 2018).

The top two strategies in the section relating to "Fostering collaboration" was "Collaboration between SMEs and larger companies, universities, or BIM experts" (MS = 3.20) ranked first and "Partnerships encouraging mentorship and knowledge exchange" (MS = 3.08) second, indicating that knowledge sharing and resource pooling can improve BIM implementation. These findings are consistent with the ISO 19650 framework that highlights the importance of coordinated information sharing and structured collaboration between organisations involved in construction projects to improve efficiency and reduce risks (ISO, 2018). The findings suggest that collaboration and mentorship enhance SMEs' BIM capabilities through knowledge sharing, improving coordination and risk management, while reducing risks linked to poor communication, fragmented information, and weak planning.

"Clear and standardised BIM protocols" was identified as operational, with the strategy , "The creation of clear, standardised BIM protocols across the construction sector" (MS = 3.16) ranked first and "When SMEs operate without a defined set of standards, there is often confusion regarding roles and responsibilities." (MS = 3.12) ranked last. Similarly, BIM guidelines developed by the National Institute of Building Sciences stress that standardised protocols help organisations operate more efficiently by ensuring consistency in BIM processes and communication across the construction supply chain (National Institute of Building Sciences, 2021). This indicates that clear guidelines and standardisation can reduce confusion and make implementation more efficient throughout the sector. Standardised BIM protocols can therefore improve risk management in SMEs by clarifying roles, ensuring consistent information flow, and streamlining workflows, which reduces communication issues, fragmented processes, and operational inefficiencies (Alashwal *et al.*, 2023)

Finally, "Sharing success stories" was recognised as an influential strategy, with "Peer-to-peer learning, where SMEs hear from other SMEs about the ability of BIM to manage construction project risks," (MS = 3.24) ranked first, and "Platforms such as knowledge hubs funded by governments, conferences and webinars that can serve as effective channels for sharing success stories" (MS = 3.20) ranked second. Studies show that sharing case studies and experiences between industry participants helps organisations, particularly SMEs, learn from practical BIM applications and encourages wider adoption of digital construction practices (Chance and McAuley, 2023). The findings indicate that showcasing real-world cases of these benefits can help build trust, ease uncertainty and encourage adoption amongst SMEs. Peer learning and sharing BIM success stories reduce uncertainty, support informed implementation, and strengthen planning, collaboration, and risk mitigation, ultimately lowering construction project risks (Saka and Chan, 2023).

5. Conclusion and Recommendations for Further Research

This research endeavoured to establish BIM adoption strategies that can be implemented by construction SMEs in the Western Cape Province of South Africa to manage construction project risk. The study was motivated by the continued exposure of SMEs to cost overruns, delays, safety risks, and weak risk management practices, despite the growing recognition of BIM as a tool that can support better project outcomes. A quantitative methodological approach in the form of a structured online questionnaire was used to gather data from construction SMEs registered on the Construction Industry Development Board (cidb) register of contractors between Grade 1 and 6 under the General Building (GB) and/or Civil Engineering (CE) categories, in the Western Cape Province, South Africa., particularly from the leadership structure of these organisations.

The main findings indicated that SMEs recognise the importance of financial investment in developing skills and providing training, as these are key factors in building confidence and enhancing the technical expertise required for effective BIM implementation. The results also suggest that financial support mechanisms are critical in helping SMEs overcome the high initial costs associated with BIM adoption, including software, equipment, and training. Therefore, strengthening investment in capacity building and providing targeted financial assistance can significantly support SMEs in adopting BIM technologies, ultimately improving their ability to manage construction project risks. The study has practical implications for industry stakeholders and policymakers by emphasising the need for support initiatives that can strengthen SMEs digital transformation and improve construction project

delivery. Societally, increased BIM adoption among SMEs may contribute to a more efficient, competitive, and sustainable construction industry, supporting economic growth and improved infrastructure outcomes.

The following limitations for the study in line with BIM adoption are as follows:

- The study was limited to the Western Cape region in South Africa, and
- Only a quantitative method was used.

Recommendations for future research

- Research could be expanded to a national scale across all South African provinces to provide broader insights;
- Studies could adopt a mixed-method approach, and
- Additional research could focus on developing a scenario based and practical framework that guides construction organisations through the adoption of BIM by implementing steps and integration with industry standards to manage construction project risks.

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Appendix 1

Table 1: Respondents' Demography

S/N	Variable	Category	Frequency	(%)
1	**Gender**	Male	14	*56%*
		Female	11	*44%*
	Total		**25**	***100%***
2	**Age Bracket**	20 - 30 years	14	*56%*
		31 - 40 years	5	*20%*
		41 - 50 years	6	*24%*
		51 - 65 years	0	*0%*
	Total		**25**	***100%***
3	**Designation**	Owner	7	*28%*
		Managing Director	5	*20%*
		Operations Manager	2	*8%*
		Project Manager	11	*44%*
	Total		**25**	***100%***
4	**Construction-related Education & Training**	Matric Certificate	1	*4%*
		Diploma in Civil Engineering	2	8%
		Diploma in Construction Management	3	12%
		Advanced Diploma in Construction	3	12%
		Advance Diploma in Quantity surveying	3	12%
		BEng Civil Engineering	1	4%
		BTech Civil Engineering	1	4%
		PGDip in Construction	1	4%
		PGDip in Quantity Surveying	2	8%
		BSc in Quantity Surveying	1	4%
		BSc in Civil Engineering	2	8%
		MSc Quantity Surveying	1	4%
		Master's in environmental design	3	12%
		Master's in construction management	1	4%
	Total		**25**	***100%***
5	**CIDB Class of Work**	General Building (GB)	13	*58%*
		Civil Engineering (CE)	7	*22%*
		Both (GB & CE)	5	*20%*
	Total		**25**	***100%***
6	**CIDB Grade**	Grade 1	5	20%
		Grade 2	4	16%
		Grade 3	4	16%
		Grade 4	6	24%
		Grade 5	2	8%
		Grade 6	4	16%
	Total		**25**	***100%***

Table 2: BIM adoption strategies that can be implemented by construction SMEs to manage construction project risk.

Variables		Response %				Mean	Std. Dev.	Rank
		Strongly Disagree	Disagree	Agree	Strongly Agree			
		1	2	3	4			
A	**Government grants**							
1	Government led initiatives that accelerate BIM adoption amongst SMEs by offering financial assistance, tax incentives, and access to innovation hubs.	0%	12%	48%	40%	3.28	0.68	1
2	Government grants that support small businesses in adopting digital construction technologies like BIM to manage construction project risks through programs that are innovative.	4%	8%	44%	44%	3.28	0.79	2
3	Grants that minimise the financial weight associated with setup, training, and acquisition of BIM to manage construction project risks.	0%	12%	56%	32%	3.20	0.65	3
B	**Development of Centralized platforms**							
1	Offering continuous professional development and certification programmes can help build internal capacity and confidence in BIM use.	0%	8%	48%	44%	3.36	0.64	1
2	Open-access to tools like BIM to help manage construction project risks	0%	4%	56%	40%	3.32	0.69	2
C	**Fostering Collaboration**							
1	Collaboration between SMEs and larger construction companies, universities, or BIM experts can help in adopting BIM.	0%	16%	48%	36%	3.20	0.71	1
2	Partnerships encourage mentorship opportunities, promote the exchange of knowledge, and provide SMEs with access to essential BIM tools and professional expertise.	0%	16%	60%	24%	3.08	0.64	2
D	**Clear and standardized BIM protocols**							
1	The creation of clear, standardised BIM protocols across the	0%	12%	60%	28%	3.16	0.62	1

Variables		Response %				Mean	Std. Dev.	Rank
		Strongly Disagree	Disagree	Agree	Strongly Agree			
		1	2	3	4			
	construction sector can simplify the implementation process for SMEs and reduce the confusion surrounding adoption.							
2	When SMEs operate without a defined set of standards, there is often confusion regarding roles and responsibilities.	0%	12%	64%	24%	3.12	0.60	2
E	**Sharing success stories**							
1	Peer-to-peer learning, where SMEs hear from other SMEs about the ability of BIM to manage construction project risks, is effective in overcoming fear, uncertainty, and misconceptions about BIM implementation.	0%	8%	60%	32%	3.24	0.60	1
2	Platforms such as knowledge hubs funded by governments, conferences and webinars can serve as effective channels for sharing success stories.	4%	8%	52%	36%	3.20	0.76	2
3	Sharing real-life BIM success stories in project risk mitigation and peer experiences would increases confidence in adopting BIM to manage construction risks.	0%	8%	68%	24%	3.16	0.55	3

Strategies for improving the adoption of digital technologies in the construction industry

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Abstract

The construction industry can significantly boost productivity, efficiency, collaboration, and project performance through the adoption of digital technology. Despite these advantages, integration in many provinces of South Africa remains slow and inconsistent. This study aims to develop a strategy for improving digital technology adoption within the constrtuction industry. A qualitative research design was employed, and data were collected through semi-structured interviews with 17 construction professionals in South Africa's Free State Province. Thematic analysis was used to identify and interpret key themes related to digital technology adoption. Findings indicated diverse levels of familiarity and engagement with digital technologies among participants, alongside several influencing factors. Based on these insights, a four-step strategy was developed: (1) Defining clear goals for digital technology implementation; (2) Investing in appropriate digital technologies; (3) Fostering collaboration and communication among project stakeholders; and (4) Prioritizing education and skills development. This proposed strategy offers a practical, context-specific framework for construction organizations to facilitate digital transformation and enhance operational efficiency. By moving beyond merely identifying adoption barriers, this study contributes to the growing knowledge on construction digitalization by providing an empirically grounded strategy to support effective digital technology implementation, ultimately promoting improved productivity, competitiveness, and long-term industry development.

Keywords: Construction industry; Digital technology adoption; Digital transformation; Technology implementation strategy; South Africa

1 Introduction

The construction industry is vital for national development, providing essential infrastructure that supports economic growth and societal well-being. As Pheng and Hou (2019) note, it spans all three economic sectors: natural resource extraction (primary), manufacturing and transformation of materials (secondary), and professional services like project management and engineering (tertiary). This broad involvement means that the industry's performance is intrinsically linked to a nation's overall economic health. Therefore, sustained economic growth requires the construction industry to prioritize and adopt digitalization.

Digitalization involves transitioning to digital business models or, more broadly, integrating digital technologies to transform operations, enhance value creation, and expand revenue streams (Nikmehr et al., 2021). For the construction industry, adopting digital technologies is crucial for improving performance and productivity (Parusheva and Aleksandrova, 2021). This digital transformation is being driven by recent advancements in innovative building materials, sophisticated software, and modern construction techniques (Akinshipe et al., 2022). Furthermore, the growing interest in automation has fueled the adoption of digital technologies due to their potential to optimize processes and reduce inefficiencies (Cardinali & De Giovanni, 2022). Empirical evidence confirms that these technologies enhance productivity, safety, and sustainability in construction (Nucci et al., 2023).

Historically, technological advancements have correlated with increased productivity across industries, particularly since the mid-twentieth century (Perera et al., 2023). In the context of the Fourth Industrial Revolution (Industry 4.0), industries are expected to leverage digital technologies to create safer, more resilient, intelligent, and sustainable systems. Despite this global trend, construction remains one of the least digitalized industries worldwide, ranking second to last (Rinchen et al., 2024). While digital technologies have significantly transformed sectors like manufacturing, agriculture, and retail, construction has been comparatively slow to adopt these innovations (Perera et al., 2023).

This slow adoption rate is exacerbated by the construction industry's inherent structural and operational challenges. Daniel et al. (2024) observe that many firms still rely on traditional practices that have remained unchanged for decades. Brozovsky et al. (2024) attribute the limited uptake of digital technologies to factors such as industry fragmentation,

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the project-based nature of construction, and the temporary and dynamic composition of supply chains. These characteristics hinder the standardization and scalability necessary for effective digital transformation.

The South African construction industry continues to face significant challenges, including inefficiencies, project delays, cost overruns, and safety concerns, despite its important contributions to employment and economic growth (Aigbavboa et al., 2022). The limited adoption of digital technologies further constrains the industry's ability to improve project delivery, enhance productivity, and remain globally competitive (Aghimien et al., 2023). Although previous studies have highlighted the benefits of digitalization and identified barriers to its adoption, such as high implementation costs, inadequate technical skills, limited organizational readiness, and resistance to change these studies have largely focused on diagnosing challenges rather than developing practical strategies to address them. Moreover, there is a scarcity of research proposing context-specific frameworks or strategies for promoting digital technology adoption within South African construction firms, particularly in provinces like the Free State, where digital transformation remains relatively underexplored.

Against this backdrop, the central problem addressed in this study is the slow and uneven adoption of digital technologies within the South African construction industry, which continues to undermine operational efficiency, productivity, and long-term sustainability. While existing research has improved understanding of the barriers to digital adoption, limited attention has been given to translating these insights into actionable strategies that industry stakeholders can implement. To address this gap, this study develops a strategy for enhancing digital technology adoption in the construction industry, derived from empirical evidence obtained from construction professionals in the Free State Province. Beyond merely identifying barriers, the proposed strategy provides a structured and practical guide for overcoming adoption challenges, supporting organizational readiness, and facilitating the transition toward more digitally enabled construction processes. In doing so, the study contributes both theoretical and practical insights to the growing discourse on digital transformation in the South African construction sector.

2 Literature Review

Digital technologies offer the potential for application across all stages of a construction project, from inception through operation and maintenance (Schnell et al., 2023). Integrating these technologies into construction processes has been linked to improved efficiency in project delivery, manifesting as reduced time, enhanced decision-making, lower material costs, and more effective resource utilization. Moreover, the adoption of digital technologies across various industries has yielded significant benefits, such as cost reduction, improved service delivery, process optimization, and faster turnaround times (Aghimien et al., 2023). These advantages are particularly pertinent given the construction industry's ongoing struggles with inefficiencies, delays, and cost overruns.

The primary goal of applying digital technology in construction is to enhance performance and productivity. Kineber et al. (2023) further emphasize that digital technologies are crucial for achieving these objectives by optimizing construction processes while upholding necessary performance standards. Consequently, there has been increasing research into the impact of digital technologies within the construction industry (Zhang et al., 2023). These studies consistently show that digital technologies contribute to multiple aspects of construction performance, including planning and design, productivity, project management, health and safety, sustainability, and cost and time efficiency.

For example, Building Information Modeling (BIM) has become a fundamental digital tool in the planning and design phase. BIM enables the creation of integrated digital models that improve collaboration, visualization, and analysis throughout the project lifecycle (Sompolgrunk et al., 2024). These models go beyond three-dimensional representations to incorporate scheduling (4D), cost estimation (5D), energy performance (6D), and facility management (7D). Complementing BIM, Virtual Reality (VR) allows stakeholders to interact with simulated project environments before construction begins, thereby improving comprehension and facilitating more informed decisions (An et al., 2023).

Digital technologies have significantly enhanced construction site operations by improving productivity and efficiency. Unmanned aerial vehicles (UAVs), or drones, provide rapid and accurate data collection for surveying, progress monitoring, and safety inspections (Jeelani and Gheisari, 2021). Automation and robotics have introduced new capabilities for tasks such as bricklaying, concrete placement, and material handling, increasing precision, safety, and operational efficiency (Liu et al., 2024).

Digital technologies have also transformed construction project management. The Internet of Things (IoT), utilizing networked sensors, enables real-time data collection and monitoring across construction sites. This facilitates improved safety management systems, offering enhanced resource allocation, performance monitoring, and real-time safety surveillance (Khurshid et al., 2023; Mollo, 2024b). In health and safety, wearable technologies like smart helmets, smartwatches, and exoskeletons monitor

workers' health and site conditions, improving safety outcomes and communication (Nnaji et al., 2021; Mollo, 2024a). Furthermore, artificial intelligence (AI) supports advanced applications such as predictive maintenance, real-time monitoring, generative design, and automated equipment operation, leading to better decision-making and safer construction environments (Daniel et al., 2024).

From a sustainability perspective, digital technologies like 3D printing and smart materials offer innovative solutions for more efficient and environmentally responsible construction. 3D printing enables rapid, cost-effective production of building components, reducing material waste and construction time (Puzatova et al., 2022). Smart materials enhance building performance with features such as self-healing properties, improved energy efficiency, and real-time structural monitoring (Nilimaa and Zhaka, 2023). For cost and time performance, prefabrication and modular construction methods facilitate off-site production, which improves quality control, reduces on-site labor, and accelerates project timelines (Li et al., 2023). Digital twins further strengthen project delivery by providing dynamic, data-driven virtual representations of construction projects, supporting planning, monitoring, and execution (Opoku et al., 2021).

The literature demonstrates that digital technologies significantly enhance construction project performance through improved planning and design, productivity, project management, health and safety, sustainability, and cost and time efficiency. However, despite these recognized benefits, digital technology adoption in the South African construction industry faces organizational, financial, and skills-related challenges. While previous studies have extensively identified the benefits and barriers to digital technology adoption, limited attention has been given to developing practical, context-specific strategies for implementation. Therefore, this study proposes a conceptual framework to enhance digital technology adoption based on four interrelated strategic pillars: defining clear goals for digital technology implementation, investing in appropriate digital technologies, fostering collaboration and communication among stakeholders, and prioritizing education and skills development. These pillars are expected to collectively support digital transformation and, consequently, improve project performance, productivity, sustainability, and competitiveness within the South African construction industry.

3 Research Methodology

This study aims to develop a strategy for enhancing the adoption of digital technologies in the construction industry. To achieve this, a qualitative research approach, as recommended by Saunders et al. (2023), was employed. This approach provided an in-depth understanding of construction professionals' perceptions, experiences, and practical insights regarding digital technology adoption. Consequently, this study adopted an interpretivist research paradigm, seeking to interpret participants' views within their real-world contexts (Saunders et al., 2023). Furthermore, a cross-sectional research design (Creswell & Creswell, 2023) was used, with data collected over three months (July–September 2024) from construction professionals in the Free State Province of South Africa.

Qualitative data were collected through semi-structured interviews, a method well-suited for exploring participants' experiences, perceptions, and insights in depth (Creswell & Creswell, 2023). The interview guide was developed from themes identified in the literature on digital technology adoption in construction. It focused on current digital practices, perceived benefits, adoption barriers, and strategies for improving technology uptake within the South African construction industry. The guide consisted of two sections: the first collected demographic information, while the second explored issues related to digital technology adoption. A total of 17 construction professionals were interviewed at their respective workplace environments (construction site offices) to ensure responses were informed by active project experiences. Interviews lasted approximately 30 minutes, were audio-recorded with participants' consent, and continued until data saturation was achieved, as no new themes or insights emerged from subsequent interviews. Participants were informed about the study's purpose and assured of confidentiality and anonymity to encourage candid responses.

A purposive sampling technique was adopted to select information-rich participants who possess relevant knowledge and experience regarding the phenomenon under investigation (Saunders et al., 2023). Accordingly, participants were selected based on their direct involvement in construction project execution and their familiarity with digital technologies in the Free State construction sector. The inclusion of professionals occupying diverse roles within the construction industry enhanced the breadth and richness of perspectives obtained. To ensure the trustworthiness of the findings, all interviews were transcribed verbatim and subjected to thematic analysis. The coding process (Table 1) involved repeated review of the transcripts, systematic theme development, and verification of the consistency of interpretations through continuous comparison of emerging themes with the original data, thereby enhancing the credibility and dependability of the findings.

Thematic analysis, following Creswell & Creswell's (2023) recommendations, was employed to analyze the collected qualitative data. This approach was chosen

Table 1: Demographic profile of interviewees

Interviewees	**Coding**	**Number (No)**
GIS Operators	DSP 1	1
Quantity Surveyors	DSP 2	6
Project Managers	DSP 3	3
Electrical Engineers	DSP 4	1
Civil Engineers	DSP 5	3
Construction Managers	DSP 6	1
Safety Officers	DSP 7	1
Town Planners	DSP 8	1
Total		**17**

for its ability to facilitate the identification and interpretation of patterns within the data. The analytical process began with transcribing recorded interviews, followed by systematically coding the transcripts to identify meaningful data segments (Creswell & Creswell, 2023). These codes were then grouped into broader categories and refined into key themes, which represented recurring patterns in participants' responses. This process ultimately revealed two principal themes, highlighting critical issues concerning digital technology adoption in the construction industry. Consequently, the thematic analysis yielded contextually grounded insights, informing the study's contribution to identifying strategies for enhancing digitalization within the South African construction sector. Prior to data collection, ethical clearance for the study was obtained from the relevant institutional ethics committee. All participants received an informed consent form detailing the study's purpose, their voluntary participation, confidentiality provisions, and their right to withdraw at any stage before the interviews were conducted.

4 Findings and Discussion

This research yielded results that fall into two main themes: first, the construction industry's current level of digital technology awareness; and second, a strategy for improving digital technology adoption within the industry.

4.2. The construction industry's current level of digital technology awareness

During the interviews, participants described their involvement in construction projects using digital technologies. This allowed for an assessment of their familiarity, which was then classified as slight, fair, or substantial. The distribution of these classifications is presented in Figure 1.

As Figure 1 illustrates, most participants reported substantial familiarity with digital technology. Specifically, 59% (n = 10) indicated substantial involvement in construction projects incorporating digital technologies. In comparison, 24% (n = 4) reported fair involvement, and 18% (n = 3) reported slight involvement. These results suggest that while most construction professionals have considerable experience with digital technologies, a segment still has limited exposure.

Interviewees were asked to elaborate on their self-assessed familiarity with digital technology in the construction industry. Key comments include:

DSP_2, a quantity surveyor at a cost consulting firm, rated his familiarity with digital technology as slight. "*He noted that his company recently acquired an Autodesk BIM 360 license. While his knowledge of the software is limited to basic functions, he finds it useful.*

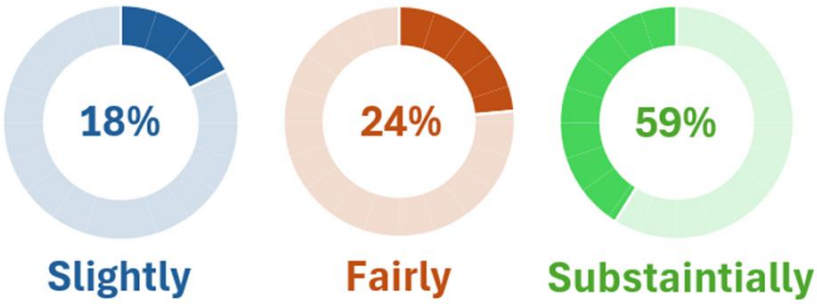

Figure 1: Level of digital technology familiarity among construction professionals.

The cloud-based storage of cost information enhances his efficiency, allowing him to access project data, review activities, and advise clients on project costs without extensive tender documentation."

DSP_8, a town planner, assessed her level of involvement as fair. "*She explained that she received drone operation training and applies this technology in her work, using drones to conduct aerial surveys for site layout plans on construction projects*."

DSP_5, a civil engineer, reported substantial involvement in projects utilizing digital technology. "*He described his experience operating a wastewater treatment plant, stating that sensors are crucial for monitoring water quality, as visual assessment alone is insufficient*."

These responses suggest a growing recognition of the benefits of digital technologies within the South African construction industry. This is further supported by 59% of interviewees reporting substantial participation in projects involving digital technology, as well as by DSP_5's example of using sensors for water quality evaluation.

4.3. A strategy for improving the adoption and use of digital technologies in the construction industry

Clear guidelines for digital technology implementation are crucial in the South African construction industry, which involves multiple stakeholders and remains highly labour-intensive. Collaboration and communication frequently emerged as key factors influencing digital technology adoption. For example, DSP_3 emphasized digital technologies for improving collaboration among consultants and contractors, while DSP_5 highlighted leveraging digital tools for enhanced coordination among project teams. Supporting this, DSP_2 noted that BIM improves collaboration via a shared cloud-based platform, facilitating timely and cost-effective project delivery. These findings informed the inclusion of fostering collaboration and communication as a strategic component of the proposed framework.

Interviews also revealed concerns regarding the suitability and implications of specific digital technologies within the South African context. DSP_6 highlighted that the construction industry is a major employer of low-skilled and unskilled workers, cautioning that increased automation and robotics may reduce employment opportunities. This suggests that digital technology adoption should balance productivity improvements with socioeconomic realities. Consequently, defining clear goals for digital technology implementation emerged as the first strategic step, aligning technology adoption with project requirements, organizational priorities, and broader employment considerations. Similarly, the recommendation to invest in appropriate digital technologies" stemmed from participants' emphasis on adopting technologies that provide immediate and practical value. For instance, DSP_6 recommended starting with affordable technologies like Autodesk BIM 360 before progressing to more advanced solutions, emphasizing phased and context-sensitive investment decisions.

Another recurring theme was the need for capacity building and digital skills development. Despite acknowledging the potential benefits of technologies like BIM, artificial intelligence, and real-time monitoring, concerns were raised regarding limited training opportunities and inadequate organizational support. DSP_6 specifically argued that clients and contractors should actively promote digital technology training and expressed personal interest in acquiring digital skills despite limited employer support. Furthermore, DSP_1 and DSP_7 highlighted the value of digital technologies for enhancing health and safety management through real-time monitoring, artificial intelligence, and CCTV-based compliance tracking. However, participants recognized these benefits are only realized if employees possess the necessary competencies. These findings directly informed the inclusion of "education and skills development" as the fourth strategic component of the framework.

Based on these empirically derived themes, Figure 2 presents a four-step strategy for enhancing digital technology adoption in the construction industry. This

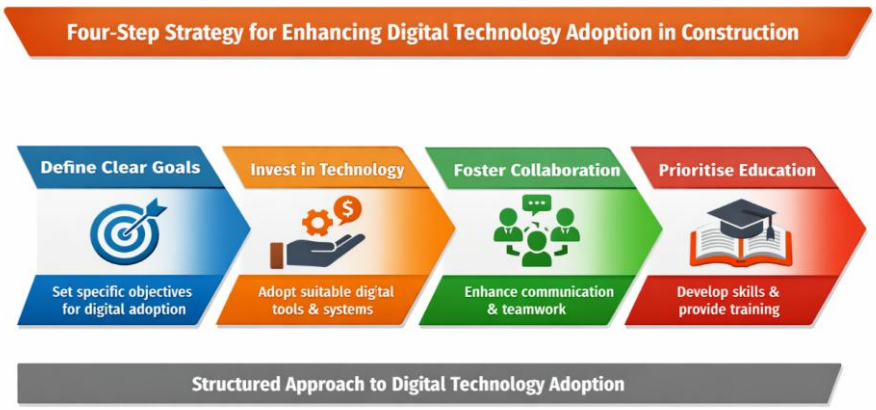

Figure 2: Four-step strategy for enhancing digital technology adoption in the construction industry.

strategy emerged from participants' experiences and recommendations regarding digitalization challenges and opportunities, rather than being a generic model. The first step, "defining clear goals for digital technology implementation," addresses aligning technology adoption with organizational objectives and local labor market realities. The second step, "investing in appropriate digital technologies," responds to calls for practical, phased technology investments matching organizational capabilities. The third step, "fostering collaboration and communication," reflects the widespread recognition of digital technologies as enablers of information sharing and coordination among project stakeholders. Finally, "prioritizing education and skills development" addresses the critical need to build workforce capacity and support effective technology utilization. Collectively, these interconnected steps provide a contextually grounded strategy to assist construction organizations in overcoming adoption barriers and achieving a more coordinated transition towards digitalization.

The strategy outlined in Figure 2 was developed directly from the themes and recommendations that emerged from the interview data. Through thematic analysis, participants consistently highlighted four critical requirements for successful digital technology adoption in the construction industry. First, concerns regarding the selection, purpose, and potential implications of digital technologies particularly their impact on employment underscored the need for clearly defined implementation goals. Second, participants emphasized the importance of investing in suitable and affordable technologies that align with organizational capabilities and project needs. This led to the "investment" component of the strategy. Third, the recurring emphasis on BIM, cloud-based information sharing, and coordination among consultants and contractors demonstrated the importance of collaboration and communication in facilitating digital transformation. Finally, participants repeatedly identified inadequate training and limited digital competencies as major barriers to adoption, resulting in the inclusion of "education and skills development" as a core strategic pillar. Therefore, the proposed strategy is not a generic framework drawn solely from the literature; rather, it is an empirically grounded model developed from the lived experiences, challenges, and recommendations of construction professionals operating within the South African construction industry.

5 Conclusion

This study aimed to develop a strategy for enhancing the adoption of digital technologies in the construction industry. The results revealed the level of familiarity with digital technologies among construction professionals, with most interviewees demonstrating familiarity. For example, one respondent described how their water treatment facility utilizes sensors to assess water quality. A strategy was established to improve digital technology adoption in the construction industry, comprising the following key actions: (1) defining clear goals for digital technology implementation; (2) investing in appropriate digital technologies; (3) fostering collaboration and communication; and (4) prioritizing education and skills development. A limitation of this study is that the qualitative data was derived from only seventeen interviews. Therefore, future research should prioritize action research with a larger sample to validate the proposed strategy for improving digital technology adoption in the construction industry and provide recommendations for its implementation in South Africa.

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An Evaluation of Automated Tendering Systems as a Solution to Challenges in Traditional Tendering Processes

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Abstract

Traditional tendering processes are frequently associated with prolonged procurement timelines, high administrative costs, limited transparency, and vulnerability to human error and corruption. Although digital procurement and e-tendering have received increasing attention, there remains limited integrated analysis of how automated tendering can address the operational and governance weaknesses of traditional tendering while accounting for the conditions that shape successful implementation, particularly in developing contexts. This study evaluates automated tendering systems as a digital solution to challenges in traditional tendering processes and examines the main barriers that may limit their effectiveness. A qualitative exploratory research design was adopted using a structured systematic literature review and thematic content analysis of peer-reviewed journal articles, conference papers, policy documents, and practitioner-oriented sources relevant to e-procurement, e-tendering, digital transformation, and procurement performance. The literature was examined through recurring themes concerning procurement efficiency, transparency, accountability, technological readiness, human capacity, regulation, and organisational change. The findings indicate that automated tendering can reduce manual intervention, improve procurement efficiency, strengthen transparency and accountability, and improve access to procurement information. However, these benefits are constrained by inadequate technological infrastructure, limited digital literacy, regulatory uncertainties, and resistance to organisational change. The study's novelty lies in integrating these technological, human, institutional, and organisational dimensions through the Technology Acceptance Model (TAM), rather than treating implementation barriers as isolated factors. The study therefore contributes an integrated perspective showing that successful automation depends not only on the availability of digital systems, but also on users' perceptions, institutional readiness, and the wider procurement environment. The study concludes that investment in infrastructure, regulatory support, capacity development, and change management is required to realise the full benefits of automated tendering.

Keywords: automated tendering, e-procurement, procurement efficiency, transparency, digital transformation, technology acceptance

1. Introduction

Tendering is a fundamental component of procurement, functioning as the formal process through which organisations invite, evaluate, and award contracts for goods, services, and works (Waruguru, 2015). Traditionally, tendering has relied heavily on manual and paper-based processes involving physical document submission, administrative checking, evaluation, and contract award. Although such processes remain widely used, they have been associated with inefficiencies, prolonged timelines, high administrative costs, human error, and opportunities for bias and information asymmetry (Waruguru, 2015). These weaknesses are particularly important in construction procurement, where delays in tender evaluation and award can affect project mobilisation, contractor participation, and overall procurement performance.

Digital innovations in procurement, particularly automated tendering systems, provide an alternative to many of these limitations (Nicoletti, 2018). As part of broader e-procurement systems, automated tendering platforms can digitise and automate activities such as tender advertisement, bid submission, document handling, evaluation, communication, and contract award. Centralising these activities on digital platforms has the potential to reduce administrative overhead, standardise procurement workflows, improve data accuracy, and strengthen auditability through electronic records and traceable processes (Emenogu & Adedokun, 2025).

The potential benefits of automation, however, should not be interpreted as evidence that digital systems are automatically successful once introduced. Studies of e-tendering and e-procurement adoption identify inadequate technological infrastructure, resistance to organisational change, limited digital literacy, and regulatory uncertainty as important implementation

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barriers (Mohungoo, Brown & Kabanda, 2020; Uhaila et al., 2025; Inusah, Kazaz & Ulubeyli, 2025). These factors indicate that procurement digitalisation is both a technological and organisational transformation. A system may offer sophisticated functionality, but its value can be reduced if users cannot access it reliably, lack the skills to use it, or do not operate within a supportive institutional and legal environment.

1.1. Research gap and rationale

Existing literature has contributed substantially to understanding e-procurement adoption and the barriers associated with digital tendering. However, much of the discussion focuses on individual barriers or on the technical benefits of digital procurement. Less attention is given to the way technological, human, organisational, and regulatory conditions interact to determine whether automated tendering can actually resolve the inefficiencies and governance weaknesses of traditional tendering. This is particularly relevant in developing contexts, where infrastructure constraints, skills shortages, institutional capacity, and regulatory uncertainty may influence technology adoption simultaneously.

The gap addressed by this study is therefore not simply the absence of literature on e-tendering, but the limited integrated evaluation of its potential benefits and implementation constraints. The study responds to this gap by synthesising the available literature around the major operational and implementation themes and interpreting their relationships through the Technology Acceptance Model (TAM). This provides a more integrated view of automated tendering in which technology acceptance is considered alongside infrastructure, skills, regulation, and organisational readiness.

1.2. Aim and objective

The aim of the study is to critically evaluate automated tendering systems as a solution to challenges in traditional tendering processes. The specific objective is to evaluate the effectiveness of automated tendering systems in addressing inefficiencies associated with traditional tendering and to identify the key challenges affecting their implementation.

2. Literature Review

The literature review focuses on the main factors that influence the implementation and effectiveness of automated tendering systems. Rather than treating these factors as independent technical problems, the review examines their relationships and considers how they influence the acceptance and actual use of digital tendering.

2.1. Inadequate Technological Infrastructure

Automated tendering depends on reliable internet connectivity, appropriate information and communication technology (ICT) infrastructure, secure digital platforms, and dependable systems for electronic submissions, evaluation, communication, and document storage. In many developing economies, these requirements are not consistently available. Unreliable connectivity, high infrastructure costs, and unstable power supply can therefore limit the practical operation of e-tendering systems (Uhaila et al., 2025).

The literature also indicates that infrastructure is broader than internet access alone. Limited broadband coverage, outdated ICT systems, and incompatibility between legacy systems and newer procurement platforms can prevent organisations from obtaining the full benefits of automation (Inusah, Kazaz & Ulubeyli, 2025). Research on digital government similarly identifies infrastructure gaps and technological incompatibility as constraints on effective digital service delivery (Mangai & Ayodele, 2025).

Critically, these findings suggest that infrastructure should be understood as an enabling condition rather than simply another implementation cost. Where users experience unstable access or system failures, the perceived ease of use of an automated tendering system is likely to decline. Thus, infrastructure can influence technology acceptance as well as the technical availability of the system. Investment in hardware and connectivity without corresponding attention to system usability and organisational capacity may therefore produce limited returns.

2.2. Resistance to Change

Resistance to change represents a significant organisational barrier to the adoption of automated tendering systems. Procurement professionals, contractors, and other stakeholders accustomed to paper-based procedures may perceive digital platforms as complex, risky, or disruptive to established practices. Uncertainty about new technology and concerns about changes to existing responsibilities can contribute to reluctance to adopt new systems (Uhaila et al., 2025).

Literature reviews of public e-procurement also identify organisational culture, leadership attitudes, stakeholder behaviour, and organisational politics as factors that influence implementation (Mohungoo, Brown & Kabanda, 2020). However, the literature does not necessarily support the view that resistance is permanent. Adequate training, awareness, leadership support, and user involvement can reduce resistance and increase acceptance. This distinction is important because it shifts the interpretation of resistance from an inherent weakness of automated tendering to a transitional management issue that can be influenced by implementation strategy.

2.3. Limited Digital Literacy

Limited digital literacy among procurement officials, suppliers, and contractors can restrict the effective use

of automated tendering systems. Users require sufficient ICT skills to navigate procurement portals, upload and retrieve documents, complete electronic submissions, and respond to system requirements. The literature indicates that shortages of skilled personnel can affect system configuration, maintenance, troubleshooting, and secure data management (Inusah, Kazaz & Ulubeyli, 2025).

Digital literacy is therefore closely connected to perceived ease of use. A platform may be technically capable of simplifying procurement, but users with limited digital confidence may experience the same platform as difficult to operate. Research on digital public services similarly shows that insufficient training and limited exposure to digital technologies can reduce user confidence and discourage adoption (Mangai & Ayodele, 2025). Capacity building should consequently be regarded as part of the implementation system rather than as an optional activity after the technology has been procured.

2.4. Regulatory Uncertainties

Regulatory and legal uncertainty is another important challenge. Effective e-tendering requires procurement rules that recognise electronic documentation, digital signatures, electronic communication, online evaluation, and the evidentiary value of digital records. Where procurement regulations were developed primarily around paper-based procedures, uncertainty may arise regarding the legal status of electronic transactions and the management of disputes (Inusah, Kazaz & Ulubeyli, 2025).

The regulatory environment can therefore influence confidence in automated tendering beyond the functionality of the technology itself. Clear policies, standards, and procedures can strengthen trust and institutional readiness, whereas unclear rules may discourage adoption even where appropriate ICT infrastructure exists. Research on public e-procurement similarly identifies the policy and regulatory environment as an important condition for digital procurement adoption (Mohungoo, Brown & Kabanda, 2020; Inusah, Kazaz & Ulubeyli, 2025).

2.5. Critical synthesis of the literature

The four themes identified in the literature are interconnected rather than mutually exclusive. Infrastructure determines whether a system can be accessed reliably; digital literacy influences whether users can operate it effectively; regulation determines whether electronic processes are supported by a legitimate governance framework; and organisational change affects whether users are willing to incorporate the system into routine procurement practice. The literature therefore suggests that implementation success depends on the interaction between technical capability and the environment in which the technology is introduced.

There is also an important distinction between the existence of an automated tendering platform and the realisation of its intended benefits. A digital system may reduce paperwork and create electronic audit trails, but these advantages can be weakened by poor connectivity, low user competence, unclear procedures, or resistance. Conversely, infrastructure investment and training may increase the perceived usefulness and ease of use of the technology, strengthening users' willingness to adopt it. This interrelationship provides the basis for applying TAM as the theoretical lens for the study.

2.6. Theoretical framework: Technology Acceptance Model

This study is underpinned by the Technology Acceptance Model (TAM), which explains technology adoption through constructs including perceived usefulness and perceived ease of use. The model is relevant to automated tendering because procurement officials, contractors, and other users are more likely to accept digital procurement platforms when they perceive them as useful, accessible, and capable of improving their work.

As illustrated in Figure 1 (Appendix 1), perceived ease of use and perceived usefulness influence users' attitudes and behavioural intention to use the system, which in turn supports actual system use. The framework in this study extends the interpretation by positioning inadequate infrastructure, resistance to change, limited digital literacy, and regulatory uncertainty as external conditions that can influence these TAM constructs. For example, limited digital literacy can reduce perceived ease of use, while evidence that automation improves efficiency and transparency can increase perceived usefulness. Regulatory uncertainty and organisational resistance can affect attitudes and behavioural intention, even where the technology itself is functional.

3. Methodology

3.1. Research design

The study adopts a qualitative exploratory research design to evaluate automated tendering systems as a solution to challenges inherent in traditional tendering processes. An exploratory approach is appropriate because automated tendering continues to evolve and its effectiveness is shaped by contextual, organisational, technological, and institutional conditions. The design enables the study to synthesise findings from existing empirical research, conceptual analyses, policy literature, and documented procurement experiences rather than reducing the issue to a purely statistical assessment.

3.2. Data collection and literature selection

The study relies primarily on a systematic literature review of secondary sources. The source base comprised peer-reviewed journal articles, conference papers, policy documents, and practitioner reports relevant to e-procurement, automated tendering, digital transformation in procurement, and public-sector digitalisation. Sources published within the previous 15 years were prioritised to capture contemporary developments in digital procurement, while seminal earlier works were retained where they were conceptually important.

The selection process was guided by relevance to the study objective. Literature was considered when it examined automated tendering, e-tendering, broader e-procurement systems, limitations or inefficiencies in traditional tendering, digital transformation in public or private procurement, or implementation conditions such as infrastructure, regulation, and user readiness.

3.3. Inclusion and exclusion criteria

Inclusion criteria	Exclusion criteria
Studies focusing on automated tendering, e-tendering, or broader e-procurement systems.	Articles unrelated to procurement or digital tendering.
Research examining limitations or inefficiencies in traditional tendering.	Studies focusing exclusively on supply chain management or logistics without a procurement component.
Publications discussing digital transformation in public or private procurement.	Highly technical ICT papers that do not address process-level procurement outcomes.
Studies addressing implementation challenges such as infrastructure, regulation, and user readiness.	

3.4. Data analysis procedure

The selected literature was analysed using thematic content analysis. The analysis proceeded through four interrelated stages. First, relevant literature was reviewed to identify evidence concerning the performance and implementation of automated tendering. Second, recurring statements and findings were coded according to their substantive meaning, including efficiency, transparency, accountability, infrastructure, digital skills, regulation, and organisational readiness. Third, related codes were grouped into broader themes. Finally, the themes were compared across the selected literature to identify dominant patterns, areas of convergence, and relationships between implementation conditions and expected procurement outcomes.

The analysis was interpretive rather than statistical. The purpose was to establish patterns across the literature and explain how the identified factors may interact. The final themes were then interpreted through TAM so that the findings could be connected to perceived ease of use, perceived usefulness, attitude, behavioural intention, and actual system use. This analytical step strengthens the link between the literature review and the theoretical framework.

3.5. Trustworthiness and rigour

Trustworthiness was addressed through the use of multiple categories of secondary sources, including scholarly literature, government and policy material, and conference publications. The use of different source types provided an element of triangulation and reduced reliance on a single perspective. In addition, the inclusion and exclusion criteria provided a consistent basis for determining relevance, while thematic coding was applied systematically to maintain coherence between the literature, the identified themes, and the interpretation of findings.

The study also maintained conceptual consistency by relating the thematic findings to the TAM constructs. Where literature presented different interpretations, these were considered during synthesis rather than assuming that all sources reached the same conclusion. This was particularly relevant to resistance to change, where the literature suggests that resistance may decrease when training and leadership support are provided.

3.6. Ethical considerations

Ethical clearance was not required because the study relied exclusively on secondary information obtained from publicly available scholarly literature and policy documents and did not involve human participants or the collection of personal data. Nevertheless, academic integrity was maintained by acknowledging the original sources and presenting the reviewed literature accurately. The study does not claim to have collected primary participant data.

3.7. Limitations of the methodology

The study is limited by its reliance on secondary literature and therefore does not provide primary empirical evidence from procurement officials, contractors, or clients. The findings should consequently be interpreted as an integrated synthesis of existing knowledge rather than as a direct measurement of the performance of a specific automated tendering platform. In addition, differences in procurement environments across countries may limit the direct transferability of individual findings. These limitations also provide a basis for future research using interviews, surveys, case studies, or

comparative evaluations of operational e-tendering systems.

4. Findings

The thematic analysis identified four major implementation themes: inadequate technological infrastructure, limited digital literacy and skills, regulatory and institutional uncertainty, and resistance to organisational change. At the same time, the reviewed literature indicates that automated tendering can improve procurement efficiency, transparency, accountability, and access to procurement information. The findings therefore show a dual relationship: automation provides potential performance benefits, but those benefits depend on the conditions under which the system is implemented.

4.1. Summary of thematic findings

Theme	Core finding	TAM interpretation	Implication
Inadequate technological infrastructure	Poor connectivity, unreliable power, outdated ICT systems, and system incompatibility can constrain implementation.	Infrastructure can reduce perceived ease of use and limit actual system use.	Infrastructure investment is a foundational requirement for automation.
Limited digital literacy and skills	Insufficient user competence can reduce confidence and effective utilisation of digital tendering platforms.	Limited skills may reduce perceived ease of use and behavioural intention.	Training and continuing support should accompany implementation.
Regulatory and institutional uncertainties	Unclear legal and policy frameworks can create uncertainty around electronic procurement processes.	Uncertainty can weaken confidence, attitudes, and willingness to use the system.	Digital tendering requires supportive and clearly defined governance arrangements.
Resistance to organisational change	Stakeholder reluctance can delay adoption and reduce effective integration into procurement practice.	Resistance can negatively affect attitude and behavioural intention.	Change management, leadership support, and stakeholder engagement are required.

4.2. Procurement benefits of automation

The literature reviewed indicates that automated tendering can address several weaknesses associated with traditional procurement. Digital workflows can reduce manual intervention and administrative handling, shorten processes, and improve the availability of procurement information. Electronic records can also strengthen transparency and accountability by providing traceable information about tender activities and decisions (Nicoletti, 2018; Emenogu & Adedokun, 2025).

These benefits correspond closely with the perceived usefulness construct in TAM. Where users can see that an automated system reduces paperwork, improves access to information, or makes procurement activities more efficient, the perceived value of the technology is strengthened. The benefit is therefore not simply the replacement of paper with electronic documents; it is the potential improvement of procurement processes and governance.

4.3. Implementation barriers and their interrelationship

Technological infrastructure emerged as a dominant implementation concern. However, the analysis indicates that infrastructure cannot be separated from the human and institutional dimensions of adoption. For example, an unstable digital environment can make a system difficult to use, while limited digital skills can make an otherwise functional platform appear complex. Similarly, regulatory uncertainty may reduce confidence in electronic processes, while organisational resistance can prevent users from incorporating the system into routine work.

The findings therefore indicate that implementation barriers operate cumulatively. Addressing one factor in isolation may not be sufficient. This supports an integrated implementation approach in which technology, skills, regulation, and organisational change are planned together.

5. Discussion

The findings reinforce the view that automated tendering can improve procurement performance, but they also show that the introduction of technology does not, by itself, guarantee successful digital transformation. The main value of the findings is

therefore in demonstrating the relationship between procurement benefits and the conditions required to realise them.

5.1. From technological solution to socio-technical transformation

Traditional tendering problems are often framed as process inefficiencies that can be solved through digitisation. The reviewed literature suggests a more complex position. Automation can improve process speed, reduce manual handling, and strengthen transparency, but these outcomes depend on the surrounding socio-technical environment. This means that automated tendering should be treated as an organisational transformation rather than simply an ICT procurement exercise.

This interpretation extends the discussion of infrastructure. While infrastructure emerged as a dominant barrier, its importance is partly derived from its effect on users and processes. A reliable platform can support ease of use and actual use, whereas unreliable access can undermine both. The finding consequently supports the TAM proposition that perceived ease of use matters, while showing that ease of use is also shaped by conditions outside the software itself.

5.2. Human capacity and technology acceptance

The findings on digital literacy demonstrate that human capacity is central to procurement digitalisation. Users who lack confidence in navigating digital platforms may be less likely to perceive the technology as easy to use, regardless of its technical capabilities. This provides a direct connection between the literature on digital skills and TAM. Training is therefore not merely an implementation support activity; it is part of the process through which users develop confidence and willingness to adopt the technology.

The same argument applies to resistance to change. Rather than treating resistance as evidence that users reject technology in principle, the literature indicates that resistance may be influenced by uncertainty, inadequate training, leadership, and organisational culture (Mohungoo, Brown & Kabanda, 2020; Uhaila et al., 2025). This suggests that implementation strategies that involve users, communicate benefits, and provide sustained support may improve attitudes and behavioural intention.

5.3. Regulation, trust and governance

The regulatory findings highlight an additional dimension that is not fully captured when e-tendering is viewed only as a technical system. Procurement decisions operate within legal and governance frameworks. Where rules do not clearly recognise electronic submissions, signatures, records, and evaluation procedures, uncertainty may reduce institutional confidence in automation. Regulatory clarity is therefore a prerequisite for translating technical capability into legitimate procurement practice.

This also connects with the governance benefits associated with automated tendering. Electronic audit trails and standardised processes can strengthen transparency and accountability, but these benefits depend on stakeholders trusting the system and understanding the rules under which it operates. Automated tendering therefore has the potential to strengthen governance, but governance readiness is itself necessary for successful automation.

5.4. Extending existing knowledge through an integrated TAM perspective

The study extends the existing discussion by bringing together factors that are often examined separately. Infrastructure, digital literacy, regulation, and resistance are not simply four independent barriers; they interact with the technology acceptance process. Infrastructure and skills influence perceived ease of use, the efficiency and transparency benefits influence perceived usefulness, organisational resistance influences attitude and behavioural intention, and regulatory conditions influence confidence in actual system use.

This integrated interpretation helps explain why organisations may experience different outcomes from similar automated tendering technologies. The technology may be broadly comparable, while the surrounding conditions of implementation differ. The contribution of the study is therefore the synthesis of technological, human, organisational, and institutional factors into a single interpretation of successful automated tendering adoption.

6. Contribution to Knowledge

The study contributes to procurement and construction management literature in three related ways. First, it provides a consolidated evaluation of automated tendering by considering both its potential benefits and the conditions that constrain implementation. This moves the discussion beyond a simple comparison between manual and digital processes.

Second, the study provides a theoretical contribution by applying TAM to automated tendering while explicitly linking technology acceptance to external implementation conditions. The framework shows how infrastructure, digital literacy, organisational resistance, and regulatory uncertainty can influence perceived ease of use, perceived usefulness, attitudes, behavioural intention, and actual system use.

Third, the study offers a practical and contextual contribution by emphasising that successful digital procurement requires coordinated action across

technology, people, organisations, and institutions. This is particularly relevant to developing procurement environments where infrastructure and institutional constraints may influence adoption alongside the technical characteristics of the system.

7. Conclusion

This study evaluated automated tendering systems as a solution to challenges associated with traditional tendering processes. The review indicates that automation has the potential to improve procurement efficiency, reduce manual intervention, improve access to information, and strengthen transparency and accountability. However, the realisation of these benefits depends on the environment in which the technology is implemented.

Four interconnected barriers were identified: inadequate technological infrastructure, limited digital literacy and skills, regulatory and institutional uncertainties, and resistance to organisational change. The findings show that these barriers should not be considered in isolation. They influence users' perceptions and willingness to adopt the technology and can ultimately determine whether an automated tendering system is used effectively.

Using TAM as an analytical lens, the study demonstrates that successful adoption requires more than technical functionality. Users need to perceive the system as useful and easy to use, while organisations need to provide the infrastructure, skills, leadership, governance arrangements, and regulatory certainty required for sustained use. The study therefore concludes that automated tendering represents a practical opportunity for improving procurement, but its effectiveness depends on an integrated implementation strategy.

8. Recommendations

8.1. Investment in technological infrastructure

Governments and organisations should prioritise reliable digital infrastructure to support automated tendering. This includes improving internet connectivity, upgrading ICT systems, addressing system compatibility, and ensuring dependable power supply. Infrastructure planning should be treated as a prerequisite for reliable system use rather than as an activity undertaken after procurement software has been acquired.

8.2. Capacity building and digital skills development

Training programmes should be implemented for procurement officials, contractors, and suppliers. Continuous professional development should cover platform use, electronic documentation, digital submission procedures, and relevant cybersecurity practices. Training should continue beyond initial implementation so that users can develop confidence and respond to system changes.

8.3. Strengthening legal and regulatory frameworks

Policymakers should review and update procurement regulations to accommodate electronic procurement processes. Legal frameworks should clearly recognise electronic submissions, digital signatures, online tender evaluation, electronic records, and procedures for resolving disputes arising from digital procurement.

8.4. Change management and stakeholder engagement

Organisations should implement structured change-management strategies to address resistance to automated systems. Awareness programmes, stakeholder consultations, leadership support, user participation, and pilot implementation can help users adapt to new procurement processes and increase confidence in the technology.

8.5. Continuous monitoring and system improvement

Organisations adopting automated tendering should establish mechanisms for monitoring system performance and collecting user feedback. Continuous evaluation can identify operational problems, usability issues, training needs, and emerging regulatory requirements, allowing the system to remain responsive to procurement needs.

9. Areas for Future Research

Future studies should complement this literature-based analysis with primary empirical research involving procurement officials, contractors, consultants, and clients. Interviews or surveys could be used to examine how the identified TAM constructs operate in practice. Case studies of implemented e-tendering platforms could also compare procurement outcomes before and after automation. Comparative research across developing and developed procurement environments would further help determine how infrastructure, institutional capacity, and regulatory conditions influence the effectiveness of automated tendering.

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Appendix 1

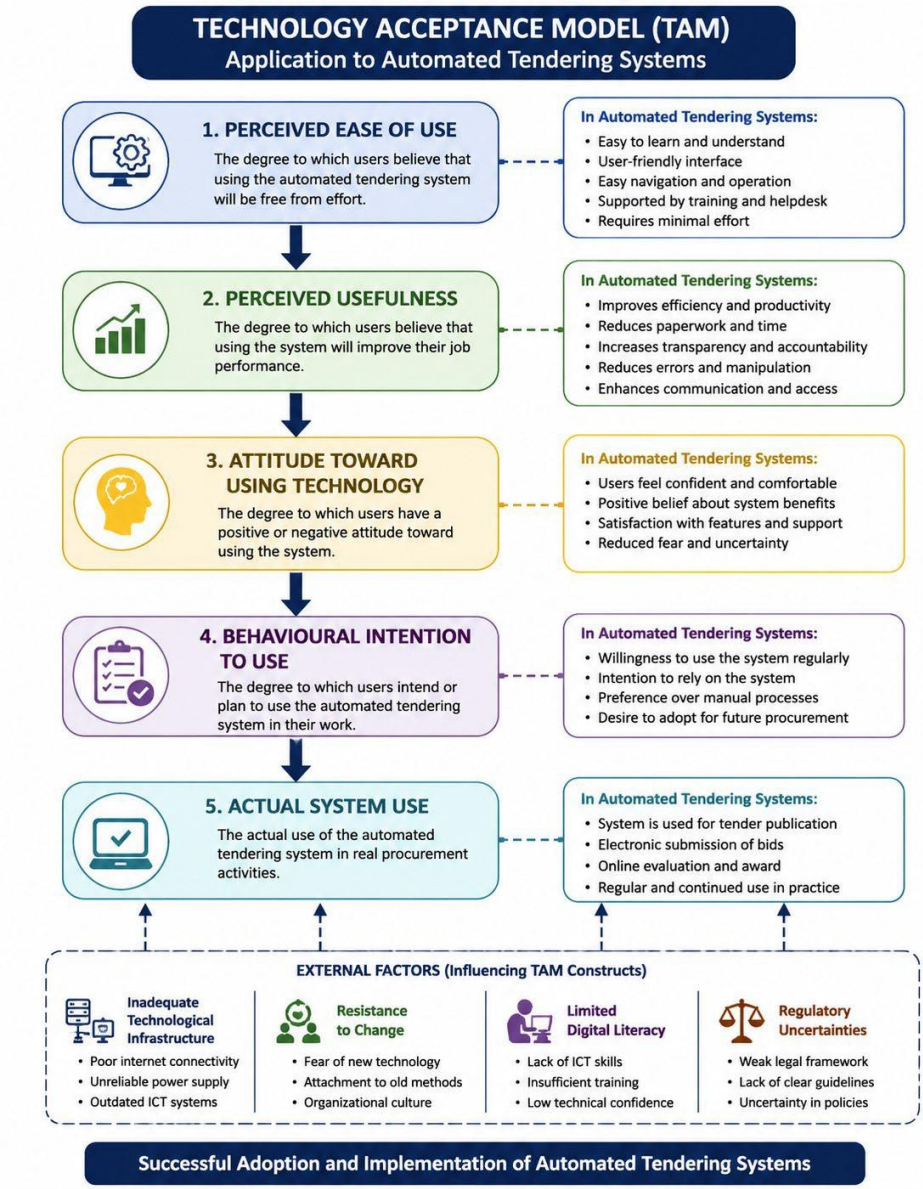

Figure 1: Theoretical Framework – Technology Acceptance Model applied to Automated Tendering Systems

Transforming Construction Education through Artificial Intelligence and Simulation-Based Work Integrated Learning: A Systematic Literature Review

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Abstract

The rapid advancement of Artificial Intelligence (AI) is transforming higher education, particularly in professionally oriented fields such as construction education. At the Central University of Technology, Work Integrated Learning (WIL) plays a vital role in preparing students for industry readiness and digital transformation. However, limited industry placements, assessment integrity, and growing digitalisation have increased interest in simulation-based and AI-enabled WIL models. This systematic literature review (SLR) investigates the integration of AI into simulation-based WIL in construction education. Using PRISMA principles, literature published between 2016 and 2026 was systematically reviewed and analysed. 38 scholarly articles were reviewed. Thematic analysis identified key themes including AI-enabled pedagogy, simulation-based WIL, assessment transformation, governance and ethics, and student readiness. Findings indicate that AI can enhance simulated WIL through reflective learning, technical report writing, problem-solving, adaptive learning, and digital collaboration. AI integration further improves student engagement, workplace preparedness, and access to construction knowledge where traditional placements are limited. Despite these benefits, concerns remain regarding assessment authenticity, overreliance on generative AI, digital literacy inequalities, ethical risks, and weak governance frameworks. The review concludes that effective AI-supported WIL requires a balanced pedagogical approach that combines authentic assessment, educator supervision, simulation-based learning, and responsible AI governance.

Keywords: Artificial Intelligence; Construction Education, Simulation-Based Learning; Work Integrated Learning;

1 Introduction

The Fourth Industrial Revolution (4IR) has transformed industries through digital technologies, automation, artificial intelligence (AI), and data-driven systems (Schwab, 2017). In construction, technologies such as Building Information Modelling (BIM), AI-assisted scheduling, Predictive Analytics (PA), Digital Twins (DT), Robotics, and automated cost estimation are improving productivity, sustainability, collaboration, and project performance (Oesterreich et al., 2016; Sawhney et al., 2020). These developments require higher education institutions to align curricula and experiential learning approaches with evolving industry demands (Hruby, 2025).

Work-Integrated Learning (WIL) remains a critical strategy for preparing students in construction-related disciplines by integrating academic knowledge with workplace experience through placements, internships, apprenticeships, and simulation-based learning (Briant et al., 2023). Simulation-based learning is increasingly adopted in higher education because it enhances conceptual understanding, inquiry, problem-solving, and decision-making while providing opportunities to practise complex professional skills in realistic environments (Tabak et al., 2018; Chernikova et al., 2020). In construction education, simulations can replicate project delivery processes, site management activities, and collaborative workplace interactions.

Traditional WIL models face growing challenges arising from increasing enrolments, limited placement opportunities, economic constraints, health and safety requirements, and disruptions such as the COVID-19 pandemic (Dlamini et al., 2022). Consequently, simulation-based WIL has emerged as a viable alternative for providing authentic experiential learning when workplace placements are unavailable (Mogoale et al., 2025; Laverie et al., 2022). Such approaches support the development of technical and professional competencies, including communication, project coordination, teamwork, problem-solving, contract administration, and ethical decision-making (Prada et al., 2022).

Simultaneously, generative AI tools, including ChatGPT, intelligent tutoring systems, automated assessment platforms, and learning analytics, are reshaping teaching and learning practices (Bakare et al., 2023). These technologies can personalise learning, improve engagement, support technical

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communication, and strengthen reflective learning (Brugliera, 2024; Korke et al., 2023). Despite these benefits, concerns regarding academic integrity, assessment authenticity, ethical governance, data privacy, bias, and educator readiness remain significant (Al-Shamaileh et al., 2025; Chiu et al., 2023). Furthermore, limited research has examined the integration of AI within simulation-based WIL in construction education, particularly in the South African context, highlighting a critical gap for future investigation.

2 Literature Review

2.1 Artificial Intelligence in Higher Education

Artificial Intelligence (AI) has emerged as a transformative technology in higher education, enabling computer systems to perform tasks such as learning, reasoning, problem-solving, and language processing (Walter. 2024). AI technologies in education include intelligent tutoring systems, adaptive learning platforms, chatbots, predictive analytics, automated feedback tools, and generative AI applications (Fatria, 2021; Mogoale et al. 2025). The rapid advancement of generative AI, particularly large language models, has significantly influenced educational practices by supporting writing assistance, personalised learning, assessment feedback, and access to information (Lee et al., 2024). Khoza (2026), mentions that in higher education and construction education specifically, as a result, institutions are developing ethical guidelines, governance frameworks, and responsible AI use policies.

2.2 Work Integrated Learning in Construction Education

Work Integrated Learning (WIL) is a pedagogical approach that integrates academic learning with practical workplace experience through methods such as internships, apprenticeships, cooperative education, project-based learning, and simulation-based learning (Mpofu et al., 2022). In construction education, WIL plays an important role in developing professional competence by exposing students to project environments, organisational structures, site operations, and practical application of theoretical knowledge (Adedoyin et al: 2023). As a result, WIL significantly contributes to graduate employability and industry readiness (Mabungela et al., 2024). The COVID-19 pandemic further highlighted weaknesses in conventional placement systems, encouraging institutions to adopt virtual and simulation-based experiential learning alternatives (Mhlanga et al., 2022).

2.3 Simulation-Based Pedagogy and Experiential Learning

Simulation-based pedagogy uses realistic scenarios to support experiential learning and develop practical decision-making, collaboration, and professional judgment skills (Laverie et al., 2026). In construction education, simulations support training in project management, safety, contract administration, budgeting, communication, stakeholder negotiation, and ethical decision-making (Opesemowo et al., 2025). The integration of AI further improves simulation-based learning through adaptive environments, intelligent feedback, conversational tools, and personalised learning experiences (Kasneci et al., 2023).

2.4 AI-Enabled Pedagogical Benefits and Challenges

Although AI offers significant opportunities in higher education, it also raises important risks related to governance and academic integrity (Cheng et al, 2025. Opesemowo et al, 2025) indicate that a major concern is assessment authenticity, as Gen AI tools can produce essays, reports, and project documentation with minimal human involvement. This creates challenges regarding plagiarism, authorship, and the verification of student competencies (Lee et al., 2025). In construction education, where practical professional competence is essential, excessive reliance on AI-generated outputs may weaken critical thinking and undermine the development of industry-relevant skills (Mogoale et al. 2025).

2.5 Gap in Knowledge

Although existing studies show that AI can enhance personalised learning, feedback quality, and student engagement, concerns remain regarding its effects on critical thinking, independent problem-solving, and academic integrity. The shortage of workplace-based learning opportunities in construction education is also widely recognised as a barrier to competency development and programme completion. While simulation-based WIL offers authentic learning experiences when physical placements are unavailable, current evidence suggests that simulations cannot fully replicate the complexity of real construction sites. Consequently, a significant knowledge gap exists regarding how AI-enabled blended WIL models, combining simulation-based and traditional experiential learning, can effectively develop industry-relevant competencies and workplace readiness among construction students. Furthermore, limited empirical research has evaluated the effectiveness of these approaches within construction education, particularly in resource-constrained contexts where access to workplace placements is restricted. This gap underscores the need for research on the design, implementation, and outcomes of AI-enhanced blended WIL models.

2 Research Methodology

3.1 Research Design

The study adopted a Systematic Literature Review (SLR) approach guided by the Preferred Reporting

Items for Systematic Reviews and Meta-Analyses (PRISMA) framework. PRISMA provides a structured process comprising four stages: identification, screening, eligibility, and inclusion (Page et al., 2021). A search strategy was developed from the research topic, *Transforming Construction Education through Artificial Intelligence and Simulation-Based Work-Integrated Learning*. Key search terms included "Work-Integrated Learning", "Artificial Intelligence", "Digital Technologies", "Simulation-Based Learning", and "Construction Education". Boolean operators ("AND" and "OR"), wildcards (*, ?), and quotation marks (" ") were used to refine and broaden the search. The review employed a rigorous and systematic process to identify, evaluate, and synthesise relevant literature on AI and simulation-based WIL in construction education between 2016 and 2026. Searches were conducted across major academic databases, including, Emerald Insight, ScienceDirect, IEEE Xplore, and SpringerLink. Retrieved publications underwent title, abstract, and full-text screening in accordance with the PRISMA protocol. Following the application of inclusion and exclusion criteria, 38 peer-reviewed publications were selected for critical review. The selected studies were subsequently analysed using thematic analysis to identify recurring themes, research trends, challenges, opportunities, and knowledge gaps relating to AI-enabled simulation-based WIL in construction education. An inductive coding approach was adopted. Figure 1 presents the publication retrieval and selection process.

3 Findings

Based on the literature synthesis, the study proposes various themes seen in Table 1. The themes are

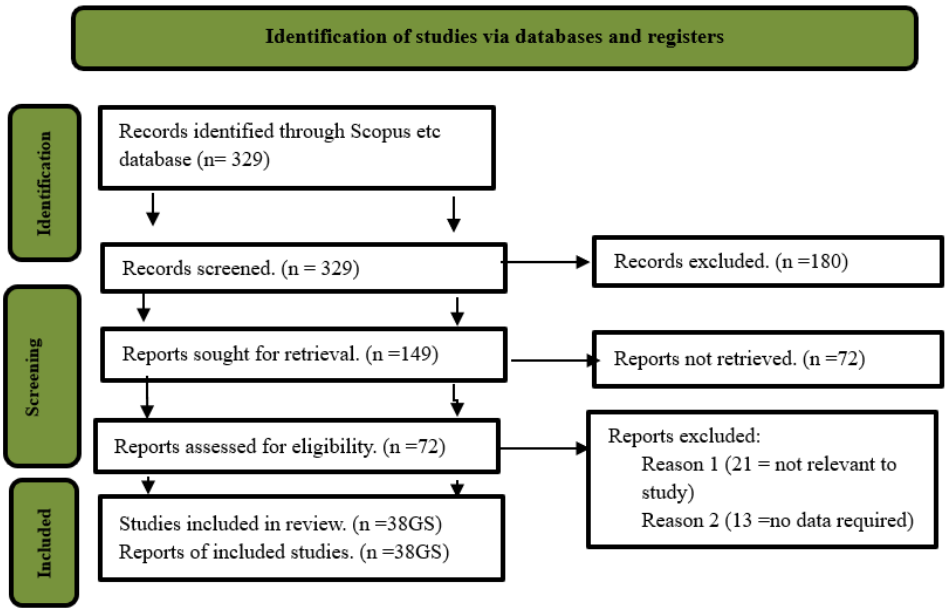

Figure 1: Publication retrieval process

Table 1: Key Themes and Findings from the Literature Review

THEME	KEY FINDINGS	RECENT SUPPORTING CITATIONS
AI-enabled pedagogy	AI tools support personalised learning, technical report writing, adaptive learning, and reflective learning in construction education.	Kizilcec et al., (2025); Khoza et al (2025); Al-Shamaileh et al (2026); Bakare et al (2023). Briant et al, (2023).
Simulation-based WIL	Simulation environments provide alternative experiential learning opportunities where physical placements are limited.	Laverie et al., (2026); Kingston et al, (2025); Dittrich et al, (2025); Chernikova et al, (2020)
Assessment Transformation	AI is forcing institutions to redesign assessments towards authentic, oral, collaborative, and scenario-based evaluations.	Cheng et al, (2025); Mogoale et al. (2025); Lee et al (2025); (Chiu et al., 2023). Tabak et al., (2018);
Student readiness and employability	AI-supported learning improves workplace readiness, digital collaboration, and industry preparedness.	Cheng et al., (2025); Opesemowo et al., (2025); Mogoale et al. (2025).; Briant et al, (2023).

developed into a conceptual framework for responsible AI-supported simulated Work-Integrated Learning (WIL) in construction education. The framework consists of four interconnected dimensions which have been developed into themes: (1) AI-enabled pedagogy; (2) Simulation-based WIL; (3) Assessment Transformation; and (4) Student readiness and employability. The conceptual framework proposes that AI should serve as a supportive educational tool that enhances teaching and learning rather than replacing human instruction, professional judgment, or experiential learning processes. Furthermore, AI is proposed as the link to a digitally simulated learning environment for WIL outcomes, given the challenges within higher education institutions, such as placement challenges due to few active construction sites amid a construction industry recession. This blended WIL model triggers assessment transformation, which as a result will realise more students meeting the necessary exit level outcomes and increasing the employability and work place readiness.

4 Discussion of the findings

4.1 Theme 1: AI-enabled pedagogy

AI-enabled pedagogy is transforming higher education by reshaping teaching, learning, and student engagement. In construction education, AI technologies support personalised learning, adaptive content delivery, intelligent tutoring systems, automated feedback, and simulation-based learning environments that enhance student learning experiences and outcomes (Kizilcec et al., 2025). These technologies enable educators to identify learning gaps, provide timely support, and tailor instructional approaches to diverse learner needs, thereby fostering more effective and inclusive learning environments.

The integration of AI into pedagogy also necessitates curriculum transformation. Al-Shamaileh et al. (2025) argues that construction programmes should incorporate AI literacy, digital competencies, and simulation-based experiential learning to align with evolving industry requirements. Similarly, Mogoale et al. (2025) emphasise that embedding these competencies within teaching and learning processes promotes responsive education while preparing graduates for technologically advanced workplaces. Consequently, future construction professionals will require competencies in AI-assisted problem-solving, digital collaboration, data interpretation, ethical technology use, construction informatics, and effective human–AI interaction, reinforcing the relevance of Construction 5.0 in construction education

4.2 Theme 2: Simulation-based WIL

Simulation-based Work-Integrated Learning (WIL) has increasingly emerged as a transformative pedagogical strategy within higher education, particularly in addressing industry readiness, employability, and experiential learning gaps (Mhlanga et al; 2025). There are notable successful case studies in medicine where simulation-based WIL has addressed the aforementioned (Kizilcec et al, (2025); Brugliera (2024); Chernikova et al. (2020); Cheng et al., 2025). Curriculum transformation through simulation-based WIL aligns with contemporary shifts toward digitally enhanced and practice-oriented learning environments. Recent studies indicate that simulation-based learning fosters student engagement with multiple forms of knowledge and authentic professional decision-making processes (Dittrich, et al., (2025); Mhlanga et al; (2025). Similarly, Kingston et al. (2025) highlight that simulation-based experiences strengthen reflective learning, professional confidence, and collaborative competencies among students. Within technologically advanced learning environments, virtual simulation experiments have further demonstrated positive impacts on student motivation, technology acceptance, and learning outcomes (Cheng et al, (2025). In the broader WIL discourse, Mhlanga (2025) and Walter (2024), argues that simulation-driven WIL models provide strategic opportunities for universities to improve graduate employability while responding to industry demands and placement constraints.

4.3 Theme 3: Assessment Transformation

Walter (2024) argue that AI is reshaping assessment practices by supporting adaptive feedback, learner autonomy, and more personalised learning experiences within professional education. In the context of WIL, both Cheng et al; (2025) and Mhlanga (2025) advocate for assessment designs that prioritise reflective practice, problem-solving, and process-oriented learning over traditional content recall and AI detection methods. Mogoale et al. (2025); further demonstrate that participatory co-design approaches can strengthen AI-integrated assessment by involving both educators and students in developing meaningful and industry-relevant learning activities. This will transform currently how WIL assessments are undertaken which is primarily currently being based physically on a live construction site. This current practice is a major deterrent in graduate throughput due to a limited number of placement opportunities.

4.4 Theme 4: Student readiness and employability

The literature indicates a growing consensus that student readiness and employability are increasingly influenced by Work-Integrated Learning (WIL), digital competence, adaptability, and AI-related capabilities in rapidly evolving labour markets (Briant, 2024; Kizilcec et al., 2025; Brugliera, 2024; Chernikova et al., 2020; Cheng et al., 2025). Cheng et al. (2025) found that employability skills play a significant role in improving employment outcomes within AI-driven economies, particularly when reinforced by academic achievement and learner motivation. Furthermore, Fitria (2021) showed that predictive analytics can be used to identify

employability trends among graduates, enabling institutions to make informed decisions that strengthen student readiness and improve alignment between educational outcomes and labour market demands.

5 Implications for Construction Education

Reviewed scholarship demonstrates that Artificial Intelligence (AI), simulation technologies, and digital pedagogies are transforming construction education and reshaping the delivery of Work-Integrated Learning (WIL). The literature suggests that construction graduates increasingly require competencies beyond traditional technical knowledge, including digital literacy, AI fluency, adaptability, collaboration, and critical problem-solving skills to remain employable within the current construction environment. These developments have significant implications for construction education, particularly in contexts where access to traditional workplace placements is limited. Consequently, higher education institutions should develop simulated WIL environments that incorporate technologies such as Building Information Modelling (BIM), Virtual Construction Simulations which are integrated with AI-assisted decision-making tools. By replicating workplace challenges, collaborative practices, and project decision-making processes, simulated WIL environments can enhance student readiness, strengthen employability skills, and bridge the gap between academic learning and industry expectations.

6 Conclusion and Further Research

This systematic literature review examined the integration of Artificial Intelligence (AI) within simulation-based Work-Integrated Learning (WIL) in construction education. The findings indicate that AI-enabled simulations have significant potential to enhance experiential learning by developing students' reflective learning, technical communication, problem-solving, digital collaboration, and workplace readiness. These competencies are increasingly important for graduate employability in the digitally driven construction industry. The review also highlights a persistent challenge within construction education: limited access to workplace placements. Insufficient opportunities for site-based WIL often constrain student progression and reduce programme throughput. In this context, simulation-based WIL offers a practical alternative by creating authentic virtual construction environments that replicate real-world project activities, stakeholder interactions, and decision-making processes. The integration of AI with other identified technologies can provide students with meaningful experiential learning opportunities when traditional placements are unavailable. Furthermore, the study contributes to simulation-based WIL literature by introducing a Construction 5.0 perspective that emphasises human-centred learning, ethical AI use, and industry-aligned digital competencies. The proposed framework highlights how AI-enhanced simulations can support personalised learning, real-time feedback, and competency development while maintaining the human, ethical, and sustainability principles underpinning Construction 5.0. In doing so, the study provides a foundation for curriculum redesign and future empirical research on AI-driven experiential learning in construction education.

The review therefore supports the development of a conceptual model that integrates AI, simulation-based learning, and authentic assessment to improve student readiness and employability in construction education. Future research should focus on designing and empirically validating such models, while evaluating the effectiveness of AI-enabled simulated construction site environments in developing technical and professional competencies. Further studies should also investigate how these environments can be implemented at scale to address the shortage of workplace placements and improve graduate preparedness for the evolving demands of the construction sector. By doing so, construction education institutions can expand access to experiential learning and better align graduate capabilities with industry expectations

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AN IMPLEMENTATION FRAMEWORK FOR AI-ENHANCED 3D MAPPING

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Abstract

Artificial Intelligence (AI) is revolutionising three-dimensional mapping in the civil infrastructure sector. Terrestrial Laser Scanners, GNSS RTK and Robotic Multi-stations are enhanced by AI technologies that assist with data processing, spatial accuracy, and make it easier to monitor infrastructure development. The infrastructure sector in South Africa faces significant implementation barriers. The theoretical framework underpinning the study focuses on the Diffusion of Innovation Theory, highlighting the implementation of AI-enhanced 3D mapping across the sector. Identified articles on AI integration and implementation in the civil infrastructure sector enables the study to systematically examine existing evidence on the adoption, applications, opportunities, and challenges of AI. This approach facilitates the synthesis of current knowledge, identification of research gaps, and development of insights into factors affecting the successful implementation of AI in civil infrastructure. Atlas.ti facilitated a thematic analysis of 50 papers. While the review identified a significant knowledge gap regarding AI-integrated technology systems in South Africa, the underlying causes of this gap were not explicitly established. One explanation is the recent adoption of AI technologies within the sector, with AI being noted for its automating feature extraction, improving terrain models, helping build digital twins, and enabling predictive maintenance. Resulting in faster operations, less manual work, and stronger decision-making. Implementation barriers hinder the success of the AI-Implementation Strategy for South Africa, which is based on phased rollouts, collaboration, workforce training, and clearer policy standards. The study concludes that AI can enhance civil infrastructure efficiency and decision-making while providing a phased implementation roadmap.

Keywords: Artificial Intelligence, 3D mapping, Civil works, Digital infrastructure, Geomatics, South Africa

1. Introduction

The civil engineering sector has undergone significant technological transformation through the adoption of AI, automation, and digital technologies, enhancing efficiency, infrastructure management, and decision-making processes (Manzoor *et al*.,2021; Xu *et al*.,2022). The integration of geospatial data, Building Information Modelling (BIM), digital twins, and predictive analytics has improved project planning, monitoring, and asset maintenance throughout the infrastructure lifecycle (Nyokum & Tamut, 2025; El-Abbasy, 2025). As infrastructure supports economic growth, urban functionality, and regional connectivity, smart mapping has become increasingly important (National Planning Commission,2020). However, traditional surveying methods remain limited by time and resource requirements when processing large and complex datasets (Aouad *et al*.,2018). AI-enhanced 3D mapping enables civil engineering teams to use laser scanners, drones, robotic total stations, and GNSS platforms to automate feature identification, terrain analysis, defect detection, and infrastructure assessment (Shirowzhan *et al.*, 2020). These advancements have increased the practicality of digital construction approaches, including BIM, digital twins, and smart infrastructure systems (Bolton *et al*., 2018). The global AI construction market is projected to grow from approximately USD3.02 billion in 2026 to USD 9.48 billion by 2030, driven by demand for improved infrastructure monitoring, cost optimisation, and sustainable infrastructure development (The Business Research Company, 2026; Grand View Research, 2025; Adebiyi *et al*., 2024; Lu *et al*., 2020). Despite these developments, South Africa's civil engineering sector continues to face challenges in adopting AI and digital technologies such as BIM. Adoption remains fragmented due to limited skills, high implementation costs, insufficient institutional support, resistance to organizational change, and inadequate digital infrastructure (Tjebane *et al.*, 2022; Calitz & Wium, 2022). Although interest in AI applications is increasing, research on the adoption and implementation of AI-enabled 3D mapping technologies within South African civil infrastructure remains limited (Tjebane *et al.*, 2022; Calitz & Wium, 2022). In this study, integration refers to the embedding and operational combination of AI techniques within 3D mapping systems to enhance spatial data

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acquisition, processing, analysis, and application in civil infrastructure projects.

2. Literature Review

The literature review examines AI-enabled 3D mapping in the civil sector. It is guided by diffusion of innovation theory, which explains how technological innovation influences efficiency, implementation, and digital transformation adoption within South Africa's civil sector (Lu *et al.*, 2020).

2.1 The Role of Artificial Intelligence in 3D Mapping for Civil Infrastructure

AI and machine learning have advanced geomatics and civil engineering by enabling efficient processing of complex spatial datasets for remote sensing, terrain analysis, infrastructure monitoring, point cloud segmentation, feature extraction, and defect detection (Ma *et al.*, 2019; Zhu *et al.*, 2020). AI-enabled 3D mapping supports applications including road corridor mapping, pavement assessment, earthwork estimation, structural monitoring, digital terrain modelling, and asset management (Li *et al.*, 2020; Ma *et al.*, 2019; Zhu *et al.*, 2017). Technologies such as TLS and UAV photogrammetry generate point cloud data that AI classifies to improve maintenance planning, reduce risks, and enhance real-time engineering decision-making (Boje *et al.*, 2020; Li *et al.*, 2020).

2.2 Digital Transformation Enhanced by Artificial Intelligence in Civil Infrastructure

Digital transformation within the construction sector has accelerated through the Fourth Industrial Revolution, with AI operating alongside BIM, IoT, robotics, cloud computing, and geospatial analytics (Oesterreich & Teuteberg, 2019). AI integration with 3D mapping enhances infrastructure projects by automating spatial data collection, processing, and analysis, improving delivery efficiency (Li *et al.*, 2020; Zhu *et al.*, 2017). AI-driven systems improve surveying accuracy through automated feature extraction and high-precision spatial interpretation, reducing human error during planning and execution (Ma *et al.*, 2019; Li *et al.*, 2021). AI-assisted monitoring supports defect detection, safety management, and lifecycle maintenance planning (Adebiyi *et al.*, 2024; Lu *et al.*, 2020; Zhang, 2021). Digital twins further support predictive maintenance through virtual infrastructure representations (Fuller *et al.*, 2020). However, adoption remains constrained by technical capacity, costs, skills shortages, interoperability challenges, and limited implementation strategies (Tjebane *et al.*, 2022; Calitz & Wium, 2022; Lu *et al.*, 2020; Adebiyi *et al.*, 2024).

2.3 Comparative Analysis of AI-Enhanced 3D Mapping Technologies

Different 3D mapping technologies offer varying operational capabilities in the civil sector. Table 1 presents an overview comparison of key technologies and AI applications.

Table 1: Comparative Analysis of AI-Enhanced 3d Mapping Technologies

Technology	AI Application	Main Advantages	Main Limitations	Civil Works
TLS	Point cloud classification	High spatial detail	Expensive processing	Urban roads and bridges
UAV Photogrammetry	Automated terrain modelling	Rapid area coverage	Weather dependent	Earthworks and corridors
GNSS RTK	Position optimization	Fast field deployment	Lower vertical precision	Open terrain surveying
Robotic Total Stations	Automated tracking	High layout precision	Requires line-of-sight	Structural and road layout
Mobile Mapping Systems	Real-time feature extraction	High mobility	Large data storage requirements	Transport infrastructure

Source: Adapted from Kim *et al.*, 2022

The literature indicates that integrated systems comprising multiple interacting components can outperform standalone systems due to complementarity, improved co-ordination, and enhanced system-level functionality. When you use intelligence to bring these systems together, they can share information and work together more easily. This is especially true for surveying platforms, where combining data from sources can yield more accurate results (Kim *et al.*, 2022). AI enables surveying platforms to work together and share data (Zhang, 2021).

2.4 Artificial Intelligence Adoption Challenges in South Africa

The South African civil infrastructure sector faces several barriers limiting AI implementation, including legacy systems, limited interoperability, skills shortages, excessive costs, inadequate digital infrastructure, and resistance to technological change (Tjebane *et al.*, 2022; Adekunle *et al.*, 2022). Training institutions remain focused on traditional surveying and engineering curricula, contributing to gaps in AI and geospatial analytics skills (Calitz & Wium, 2022; Tjebane *et al.*, 2022). Although digital transformation policies recognise the importance of AI, smart

infrastructure, and digital engineering, structured implementation frameworks remain limited (DCDT, 2021; PC4IR, 2020; Calitz & Wium, 2022). Organisations such as SANRAL and Transnet SOC Ltd have incorporated digital monitoring, geospatial technologies, and BIM-related practices into selected operations (SANRAL, 2017; Transnet SOC Ltd, 2020). However, adoption remains fragmented due to institutional capacity constraints, weak policy integration, and limited investment in digital construction and geomatics sectors (Zhang, 2021).

2.5 Diffusion of Innovation Theory

The Diffusion of Innovation Theory provides framework for understanding how technological innovations are adopted and integrated into professional systems through factors such as relative advantage, compatibility, complexity, and observability (Rogers, 2003; Shibeika & Harty, 2015). Within this study, the theory explains the adoption of AI-enhanced geomatics technologies, including TLS, MTS, and GNSS/RTK systems, within the South African road construction sector, where adoption is influenced by institutional readiness, skills availability, and organisational culture (Zhang, 2023; Oesterreich & Teuteberg, 2016). Research on construction digitalisation demonstrated that BIM, digital twins, and AI-enabled systems are being adopted unevenly due to differences in infrastructure capacity, policy support, and organisational maturity (Adebiyi *et al*., 2024; Douglas *et al*., 2021). The theory therefore highlights that perceived benefits of AI-based geomatics solutions alone are insufficient for successful integration, particularly in developing contexts such as South Africa where institutional capacity and technological readiness influence adoption outcomes (Lit *et al*., 2020; Froise & Shakantu, 2014).

3. Research Methodology

3.1 Research Design and Data Collection

This study is grounded in an interpretivist research philosophy, as it seeks to understand how AI is applied and integrated within 3D mapping and civil engineering contexts through interpretation of existing literature, focusing on meanings, practices, and contextual factors influencing its use in real-world settings. An inductive research approach was adopted, allowing themes to emerge from the reviewed studies rather than testing predefined hypotheses. A qualitative methodology was applied, with thematic analysis used to identify, compare and interpret recurring patterns related to AI applications in geomatics and infrastructure development. The research strategy was a systematic literature review focusing on peer-reviewed academic sources, industry reports, and policy documents. The study adopts a cross-sectional time horizon, focusing on literature between 2010 and 2026 to capture developments in AI applications and integration within 3D mapping and civil engineering contexts (Saunders *et al*., 2019). Secondary data were collected from peer-reviewed journal articles, conference papers, government policy documents, industry reports, and academic books relating to geomatics and infrastructure development. Literature was retrieved from academic databases including Scopus, Web of Science, and Google Scholar using search terms such as "Artificial Intelligence," "3D Mapping", "Geomatics", "Civil Engineering", "Digital Construction", "Infrastructure Monitoring", and "South Africa". The review focused primarily on studies published between 2015 and 2026 to capture contemporary developments in AI applications within engineering and geomatics disciplines. Literature selection was guided by relevance to AI applications in surveying, infrastructure monitoring, and civil engineering practice, ensuring a focused and contextually aligned dataset (Page *et al*., 2021).

3.2 Systematic Literature Review

A structured literature review was conducted in accordance with the PRISMA 202 guidelines to ensure a transparent and systematic study process (Page *et al*., 2021). The review (Figure 1) identified 1,200 records, with 200 duplicates removed, leaving 1,000 studies for screening. After title and abstract screening, 190 full-

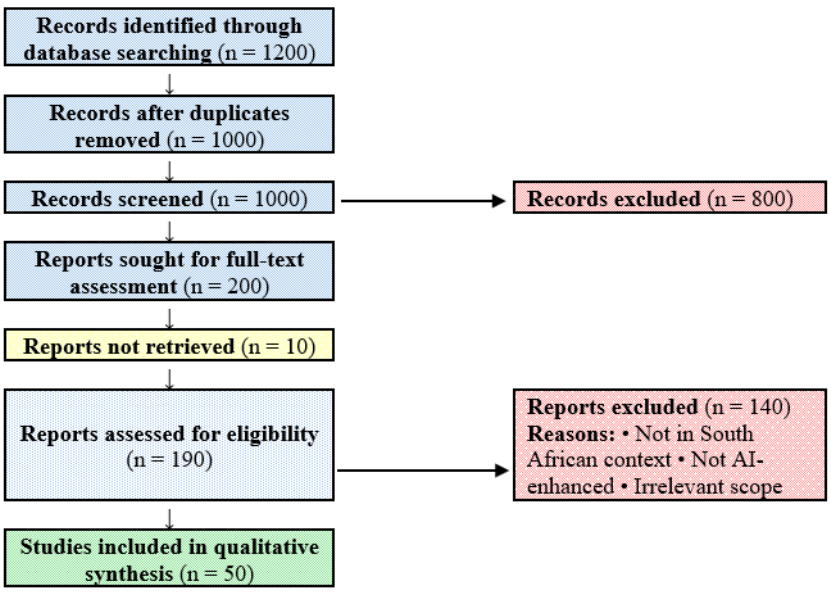

Figure 1: Prisma Flow Diagram

text articles were assessed for eligibility, resulting in the inclusion of 50 studies. Studies were excluded if they did not address AI applications in civil engineering or geomatics, lacked relevance to infrastructure mapping and surveying technologies, or fell outside the study scope. Both researchers independently assessed studies for eligibility, methodological clarity, relevance and reproducibility. The final studies were analysed using thematic analysis (Page *et al*., 2021). Quality assessment also considered contributions to AI-driven surveying and infrastructure monitoring, particularly to use of TLS, MTS, GNSS/RTK systems and digital construction platforms. These criteria improved consistency, reduced selection bias and strengthened the validity of the review findings (Kitchenham *et al*., 2015; Moher et al., 2015).

3.3 Comparative Thematic Analysis

Thematic analysis was employed to systematically analyse, interpret, and identify patterns within the qualitative data using the six-phase framework developed by Braun and Clarke (Braun & Clarke, 2019). The collected literature was analysed to identify recurring patterns, concepts, and trends relating to the application of AI in civil engineering and 3D mapping (Braun & Clarke, 2006). Three themes emerged: (1) AI applications in 3D mapping and geomatics, (2) the benefits and challenges of AI in civil engineering and infrastructure development, and (3) contextual factors influencing AI adoption within the South African construction and geomatics sectors. Atlas.ti software was used to code, categorise, and analyse the selected literature (Table 2). A total of 50 peer-reviewed studies were included, with findings grouped according to the identified themes.

Research primarily focuses on digital construction technologies, while organisational, policy, and adoption-related factors remain less explored. The literature also reveals geographical imbalance, with African contexts underrepresented, highlighting the need for further research on AI-enabled 3D geomatics technologies in developing environments. Although the review focused on 2015-2026 literature, foundational studies before 2015 were retained, including Turkan et al. (2012), Cheng & Teizer (2013), Kim et al. (2013), Volk et al. (2014), and LeCun, Bengio and Hinton (2015).

4. Findings and Discussion

4.1 Role of Artificial Intelligence in 3D Mapping Civil Infrastructure

AI-enabled 3D mapping technologies represent a dominant theme in the literature, with 34 of 50 reviewed studies (68%) examining applications within 3D mapping, geomatics, and digital engineering. AI is primarily applied in point-cloud processing, feature extraction, infrastructure inspection, UAV mapping, and integration with BIM and digital twin systems. AI algorithms process large geospatial datasets from laser scanning, LiDAR, and UAV technologies to support object recognition, classification, and infrastructure planning (Ma *et al*., 2019; Qi *et al*., 2021). Studies further identify AI applications in defect detection, condition assessment, and maintenance planning, supporting data-driven infrastructure management (Omar & Nehdi, 2016; Zhang *et al*., 2020; Chen *et al*., 2021) Integration with BIM and digital twins enhances lifecycle management (Volk *et al*., 2014; Bolton *et al*., 2018), However, research remains focused on

Table 2: Critical Appraisal Skills Programme Analysis – Frequency and Percentage Findings

Theme	Frequency (N=50)	Percentage
AI in 3D mapping Technologies	34	68%
Impact of AI on Civil Engineering	44	88%
AI Implementation Strategies	29	58%

Source: Developed by the author from themes identified in the reviewed literature

The reviewed literature demonstrates extensive application of AI in 3D mapping technologies, including BIM, digital twins, UAV mapping, and point -cloud processing (Bolton *et al*., 2021). AI contributes to infrastructure monitoring, defect detection, predictive analytics, and project management (Omar & Nehdi, 2016; Zhang *et al*., 2020; Chen *et al*., 2021). However, fewer studies address implementation challenges, including organisational resistance, skills shortages, and interoperability issues (Darko *et al*., 2020). The CASP analysis identifies the impact of AI on civil engineering as the dominant theme, appearing in 44 studies (88%), followed by AI in 3D mapping technologies in 34 studies (68%), and AI implementation strategies in 29 studies (58%). technological capabilities, with limited evidence on practical implementation and adoption challenges in developing contexts (Hamledari *et al*., 2018; Sacks *et al*., 2020; Javaid *et al*., 2022).

4.2 impact of artificial intelligence on civil infrastructure delivery

The impact of AI on civil engineering and infrastructure delivery was the most prominent theme, appearing in 44 of the 50 reviewed studies (88%). The reviewed studies indicate that AI supports infrastructure monitoring, condition assessment, defect detection, project management, and predictive infrastructure analytics (Omar & Nehdi, 2016; Ding *et*

al., 2018; Zhang *et al*., 2020). The literature also highlights the integration of AI within BIM, digital twin environments, and digital construction systems, demonstrating their growing role in infrastructure planning, delivery, and lifecycle management (Volk *et al*., 2014; Bolton *et al*., 2018). Overall, the findings associate AI with improved infrastructure monitoring, digital project management, predictive analytics, and integrated digital engineering systems. However, most studies emphasise technological development rather than long-term implementation outcomes and organisational impacts.

4.3 Artificial Intelligence Implementation and Adoption

Most reviewed studies originate from Europe, North America, and East Asia, with few focusing on South Africa of the broader African context. CASP provides a conceptual comparison of AI adoption trends in 3D mapping technologies based on the reviewed literature. The studies indicate that research and implementation of AI-enabled 3D mapping technologies remain concentrated outside Africa (Lu *et al*., 2020). They also identify skills shortages, interoperability challenges, organisational resistance, a broader digital transformation constraint as key barriers to AI adoption within the construction and engineering sectors (Oesterreich & Teuteberg, 2016; Darko *et al*., 2020).

4.4 A Conceptual Framework Developed from Themes Identified in the Reviewed Literature

The reviewed literature identified recurring implementation themes, including digital transformation, organisational readiness, skills development, interoperability, BIM integration, and infrastructure management (Oesterreich & Teuteberg, 2016; Darko *et al*., 2020; Alaloul *et al*., 2020). Based on these themes, Table 3 presents a conceptual implementation strategy for adopting AI-enabled 3D mapping technologies within the South African civil infrastructure sector. The strategy synthesises implementation-related findings from the reviewed literature and serves as a conceptual guide rather than a prescriptive implementation model.

As shown in Table 3, the proposed implementation strategy emphasises organisational readiness and capacity development before large-scale technology deployment. This sequence reflects findings from the reviewed literature, which identify skills shortages, implementation challenges, interoperability constraints, and digital transformation requirements as important considerations for successful AI adoption within the engineering and construction sectors (Oesterreich & Teuteberg, 2016; Darko *et al*., 2020).

5. Conclusion

This study examined the application of AI-enabled 3D mapping technologies in civil engineering based on a review of existing literature. The findings indicate that AI is primarily applied in automated surveying, spatial data processing, infrastructure monitoring, and engineering decision-making within digital construction environments. The reviewed studies also show that AI is increasingly integrated with technologies such as BIM, digital twins, and geospatial systems to support infrastructure management processes. The literature further highlights that AI adoption in civil engineering is influenced by factors such as technical capability, organisational readiness, and the availability of appropriate digital infrastructure. These factors appear consistently across the reviewed studies as important considerations for implementation. Overall, the study synthesised existing research on AI in 3D mapping and civil infrastructure and identified key application areas and implementation considerations. However, the literature remains

Table 3: Conceptual AI Implementation Strategy for South African Civil Infrastructure Development

Phase 1: Institutional Readiness (Digital policy development – Infrastructure assessment – Stakeholder engagement)
↓
Phase 2: Capacity Development (AI and geomatics training – Curriculum modernisation – Professional certification)
↓
Phase 3: Technology Integration (Pilot projects Hybrid – surveying deployment – BIM/GIS interoperability)
↓
Phase 4: Industry Expansion (National implementation standards – Public-private partnerships – Digital infrastructure scaling)
↓
Phase 5: Smart Infrastructure Ecosystem (Digital twins – Predictive maintenance – AI-driven infrastructure management)

Source: Developed by the author from themes identified in the reviewed literature (Oesterreich & Teuteberg, 2016; Alaloul *et al*., 2020; Darko *et al*., 2020)

focused on technological development, with limited empirical evidence on large-scale adoption in practice. Further research is recommended to explore real-world implementation and contextual challenges in developing-country environments.

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ACADEMIC PAPERS: THEME 2 -
Project Governance, Business Strategy, Procurement, Contracting and Financial Performance

Improving Hospital Facilities Management through a Human-Centred Complexity Management Approach in Tehran

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Abstract

Hospital facilities management (FM) operates within a complex socio-technical environment where infrastructure, organisational routines, professional roles and human decision-making continuously interact. In high-density metropolitan contexts such as Tehran, this complexity is intensified by increasing service demand, ageing infrastructure, financial constraints and fragmented governance. This exploratory mixed-methods study investigates human-centred drivers of operational complexity in hospital FM and proposes a Human-Centred Complexity Management Framework. Quantitative data were collected through structured questionnaires completed by 40 hospital FM professionals selected through purposive sampling. The instrument included 18 five-point Likert-scale items measuring communication effectiveness, interdepartmental coordination, leadership engagement, role clarity and cultural adaptability. Data were analysed descriptively in SPSS, and reliability testing produced a Cronbach's alpha of 0.82. Qualitative insights from semi-structured interviews and on-site observations were analysed thematically to contextualise the questionnaire findings. Results indicate that communication gaps recorded the highest perceived influence, followed by coordination failures, role ambiguity and cultural resistance. The proposed framework integrates structured communication, cross-functional coordination, role clarification, adaptive leadership and behavioural governance alignment. The study contributes to complexity-informed FM by showing that hospital resilience depends not only on technical maintenance capacity, but also on the alignment of human, organisational and governance mechanisms.

Keywords: Complexity Management, Facilities Management, Healthcare Infrastructure, Hospital Performance, Socio-Technical Systems

1. Introduction

Hospitals are among the most complex built environments in contemporary cities. They operate continuously, accommodate vulnerable users and depend on highly specialised technical systems, while also requiring coordination among clinical, administrative, maintenance, safety and support-service functions. Facilities management (FM) in hospitals therefore extends beyond routine maintenance; it includes infrastructure reliability, emergency preparedness, environmental performance, compliance governance and operational continuity.

In metropolitan contexts such as Tehran, hospital FM is further challenged by increasing service demand, ageing infrastructure, financial constraints and fragmented administrative oversight. These pressures mean that operational disruptions are rarely purely technical. A delayed maintenance report, unclear responsibility boundary or weak escalation pathway may generate wider disruption across the facility. Consequently, hospital FM should be viewed as a socio-technical coordination function in which technical systems and human-organisational behaviour are interdependent.

Hospitals are increasingly understood as complex adaptive systems because they involve uncertainty, non-linearity, distributed decision-making and emergent behaviour (Plsek & Greenhalgh, 2001; Greenhalgh & Papoutsi, 2018). Socio-technical systems theory similarly suggests that organisational performance depends on the joint optimisation of technical and social subsystems (Trist, 1981; Cherns, 1976). In hospital FM, this means that asset condition, maintenance processes and infrastructure performance are closely connected to communication quality, leadership engagement, role clarity and organisational culture.

Despite growing attention to healthcare complexity and infrastructure resilience, empirical research on human-centred complexity drivers in hospital FM remains limited, particularly in developing metropolitan settings. This study addresses that gap by examining communication effectiveness, interdepartmental coordination, leadership engagement, role clarity and cultural adaptability in Tehran hospitals. The aim is to identify key human-centred drivers of FM complexity and develop a practical framework for improving resilience and sustainable performance. The paper

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contributes by repositioning FM from a reactive maintenance service to a strategic coordination mechanism that supports hospital continuity and governance.

2. Literature Review

2.1. Hospitals as complex socio-technical systems

Complexity theory is relevant to healthcare because hospital outcomes emerge from interactions among clinical processes, technical systems, professional groups, governance structures and contextual pressures. In such environments, minor disruptions may escalate when feedback mechanisms are weak or delayed. Greenhalgh & Papoutsi (2018) argue that health systems research should recognise uncertainty, adaptation, contextual variation and emergent causality rather than relying only on linear explanations.

Socio-technical systems theory provides a complementary lens. The technical subsystem includes buildings, utilities, medical-support infrastructure, maintenance systems and safety technologies. The social subsystem includes communication routines, leadership practices, departmental relationships, role allocation and behavioural responses to change. Misalignment between these subsystems can undermine performance even when technical standards are formally in place. Thus, hospital FM performance depends on both asset reliability and organisational coordination.

2.2. Human-centred complexity drivers in hospital FM

Human-centred complexity drivers are the behavioural, organisational and governance-related factors that influence how FM teams identify, prioritise and resolve operational problems. Communication effectiveness is central because FM teams rely on timely information from clinical units, administrative departments, maintenance staff, technical supervisors and external service providers. Weak communication reduces feedback quality and can delay corrective action.

Interdepartmental coordination is equally important because hospital FM problems often cross functional boundaries. A facilities issue may require cooperation between maintenance, procurement, clinical services, infection control, finance and senior management. If these actors operate in silos, decisions become slow and reactive. Leadership engagement also influences prioritisation, resource allocation and strategic integration of FM. Recent healthcare leadership literature highlights the need for leaders to navigate uncertainty, interdependence and complexity (Spanos et al., 2024).

Role clarity supports accountability and response speed, while cultural adaptability influences whether staff accept new reporting systems, coordination routines and digital FM tools. Implementation research shows that organisational context, readiness for change and individual behaviour affect the success of new practices in healthcare settings (Damschroder et al., 2022). Teamwork and coordination also shape implementation outcomes in healthcare and human-service organisations (McGuier et al., 2024). These studies support the need for a human-centred complexity lens in hospital FM.

2.3. Research gap and conceptual position

The literature indicates that hospitals are complex socio-technical systems, yet FM research often gives greater attention to technical maintenance, asset management, sustainability and compliance than to the human-centred mechanisms that stabilise or destabilise operations. This paper therefore positions communication, coordination, leadership, role clarity and cultural adaptability as interconnected governance mechanisms that influence FM resilience. This conceptual position provides the basis for the empirical analysis and framework development presented below.

3. Research Methodology

3.1. Research design and context

An exploratory mixed-methods design was adopted because the study aimed to identify perceived complexity drivers quantitatively and interpret them through qualitative contextual evidence. Mixed methods are appropriate when quantitative patterns need to be understood alongside professional experience and contextual insight (Creswell & Plano Clark, 2018). The design was triangulation-oriented rather than intended for broad statistical generalisation.

The study was conducted in large hospitals in Tehran, where FM operations are shaped by high service demand, ageing infrastructure, resource constraints and fragmented governance. This context is appropriate for examining how technical FM responsibilities interact with organisational and behavioural factors in complex healthcare environments.

3.2. Sampling, instrument and analysis

Purposive sampling was used because the study required participants with direct familiarity with hospital FM operations, an approach suitable for exploratory studies involving information-rich professional cases (Palinkas et al., 2015; Etikan et al., 2016). The final valid quantitative sample consisted of 40 completed questionnaires from FM professionals involved in maintenance coordination, technical supervision, operational support and facilities-related decision-making. The study did not aim to compare occupational subgroups; instead, it examined shared human-centred complexity drivers across FM-related roles.

To strengthen sample transparency, the 40 valid questionnaires are treated as a purposive professional sample rather than a statistically representative population sample. Participants were drawn from FM management, technical supervision, maintenance coordination and operational support roles. Because the invitation pool was assembled through professional access points and only complete questionnaires were retained for analysis, a conventional population-based response rate is not reported; this is acknowledged as a methodological limitation. The occupational roles were analysed as one FM-professional group because the exploratory aim was to identify shared human-centred complexity drivers rather than compare role subgroups (Table 1).

3.3. Ethical considerations and limitations

Participation was treated as voluntary, and responses are reported in aggregated form to reduce the risk of individual identification. The study is limited to a single metropolitan context and a purposive sample of 40 valid responses. Therefore, the findings should be interpreted as exploratory and context-specific rather than statistically generalisable. A conventional response rate and detailed personal-demographic subgroup counts are not reported because the study used purposive professional access and analysed FM-related roles as one exploratory group. Future research should use larger samples, fuller demographic profiling, clearly disaggregated occupational categories, a defined sampling frame and advanced statistical modelling.

Table 1: Participant profile, role coverage and methodological transparency

Sample reporting issue	Clarification used in this study	Implication for interpretation
Sample size	Forty valid questionnaires from hospital FM professionals were analysed.	Findings represent perceived patterns within an exploratory professional sample.
Role coverage	Participants were drawn from FM management, technical supervision, maintenance coordination and operational support roles.	The study captures cross-functional FM perspectives without claiming occupational subgroup comparison.
Sampling technique	Purposive sampling was used to reach information-rich professional cases.	The sample is suitable for exploratory inquiry but not for statistical generalisation.
Response rate	A conventional population-based response rate was not calculated because access was purposive and only complete questionnaires were retained.	This is treated as a limitation and should be addressed in future studies with a defined sampling frame.
Qualitative saturation	Recurring patterns were observed, but the qualitative component was used for triangulation rather than formal theory generation.	The study avoids making an unsupported claim of theoretical saturation.
Participant profile and demographics	Reporting focuses on professional role coverage relevant to hospital FM. Personal demographic variables are not disaggregated because the study used aggregated, anonymised professional responses and did not test demographic subgroup effects.	This improves participant-profile transparency while avoiding unsupported demographic claims or identifiable subgroup reporting.

The questionnaire consisted of 18 five-point Likert-scale items measuring communication effectiveness, interdepartmental coordination, leadership engagement, role clarity and cultural adaptability. Quantitative data were analysed descriptively in SPSS using mean values and standard deviation, with the results reported as aggregated patterns. Reliability analysis yielded a Cronbach's alpha of 0.82, indicating acceptable internal consistency for exploratory analysis.

Qualitative evidence was collected through semi-structured interviews and on-site observations and analysed thematically following Braun & Clarke (2006). The qualitative component was used to contextualise and triangulate the questionnaire findings rather than to claim broad theoretical saturation. This cautious interpretation is consistent with the exploratory scope of the study.

4. Findings and Discussion

4.1. Descriptive results

The descriptive findings indicate that human-centred organisational factors strongly influence hospital FM complexity. Communication gaps recorded the highest mean score, followed by coordination failures, role ambiguity and cultural resistance. These results suggest that operational disruption is not driven only by technical deficiencies, but also by weaknesses in information flow, interdepartmental alignment, accountability and behavioural adaptation.

Given the exploratory purposive design, the descriptive statistics are used to identify perceived priority drivers rather than to infer population-level causal effects. This analytical scope is consistent with the study aim and supports cautious interpretation of the mean-score ranking (Table 2).

Table 2: Descriptive results of key human-centred complexity drivers

Human-centred complexity driver	Mean score	Interpretation
Communication gaps	4.32	Very high perceived influence
Coordination failures	4.18	High perceived influence
Role ambiguity	3.95	High perceived influence
Cultural resistance	3.88	High perceived influence

4.2. Interpretation of findings

Communication gaps were the strongest driver. In hospital FM, communication functions as an operational feedback system through which problems are detected, prioritised, escalated and resolved. Fragmented reporting channels can delay maintenance response and weaken service continuity. This aligns with complexity-informed healthcare research, which emphasises feedback, adaptation and contextual responsiveness (Greenhalgh & Papoutsi, 2018).

Coordination failures also received a high score. Hospital FM issues frequently require cooperation between technical teams, clinical departments, procurement units, safety officers and senior management. When these actors operate in silos, FM decisions become reactive and infrastructure risks may be addressed late. This finding supports the socio-technical argument that technical performance depends on organisational alignment.

Role ambiguity weakens accountability and response speed. During urgent maintenance events, unclear responsibility for reporting, approval, escalation or resolution can produce delay and duplication. Cultural resistance further limits improvement because new reporting systems, cross-functional routines and digital FM tools require behavioural adaptation. Implementation literature therefore supports treating FM improvement as an organisational change process, not only a technical intervention (Damschroder et al., 2022).

4.3. Qualitative triangulation

The qualitative component helped explain how the main drivers appear in daily FM practice. Interview and observation insights pointed to delayed information flow, fragmented routines, unclear task ownership, resistance to procedural change and limited strategic integration of FM (Table 3).

4.4. Human-Centred Complexity Management Framework

Based on the findings, a Human-Centred Complexity Management Framework is proposed. The framework translates the identified drivers into governance mechanisms for improving FM responsiveness, accountability and resilience. It does not replace technical maintenance systems; rather, it complements them by aligning technical activities with communication, coordination, leadership and behavioural governance (Table 4).

Table 3: Qualitative triangulation of human-centred complexity drivers

Qualitative theme	Related driver	Operational meaning
Delayed information flow	Communication gaps	Maintenance issues may be reported or escalated late
Fragmented departmental routines	Coordination failures	FM decisions become reactive and less integrated
Unclear task ownership	Role ambiguity	Accountability and response speed are weakened
Resistance to procedural change	Cultural resistance	Improvement initiatives become harder to implement
Limited strategic integration of FM	Leadership and governance alignment	Facilities risks may be underrepresented in planning

Table 4: Human-Centred Complexity Management Framework for hospital FM

Component	Problem addressed	Practical FM action	Expected benefit
Structured communication system	Delayed reporting and weak feedback	Standardised reporting channels and escalation protocols	Faster issue identification and clearer prioritisation
Interdepartmental coordination	Departmental silos	Cross-functional FM coordination meetings	Improved collaboration across hospital units
Role clarification	Unclear task ownership	Responsibility matrix for reporting, approval and resolution	Clearer accountability and reduced duplication
Adaptive leadership engagement	Reactive FM decision-making	FM involvement in planning and risk review	Better anticipation of infrastructure risks
Behavioural governance alignment	Resistance to procedural change	Training, participation and feedback routines	Higher acceptance of FM improvements

Figure 1 summarises how the identified human-centred drivers are converted into behavioural governance alignment and, ultimately, improved FM resilience and operational performance. The visual logic clarifies the practical sequence from complexity drivers to governance mechanisms and performance outcomes.

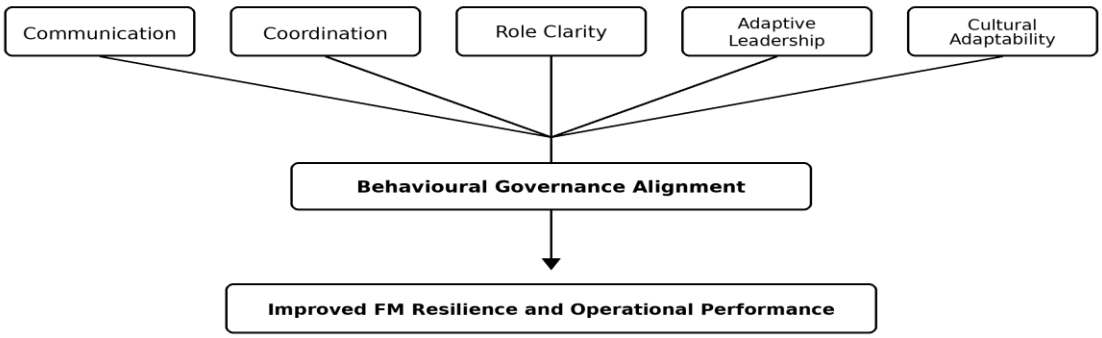

Figure 1: Conceptual logic of the Human-Centred Complexity Management Framework

4.5. Managerial recommendations

The findings can be translated into practical actions for hospital administrators and FM managers. Table 5 summarises concise recommendations that can be implemented without relying solely on major capital investment.

Table 5: Managerial recommendations for improving hospital FM complexity management

Identified problem	Managerial recommendation	Responsible level	Expected benefit
Communication gaps	Introduce a standardised FM reporting channel	FM manager and operations team	Faster reporting and fewer response delays
Coordination failures	Hold regular cross-functional FM coordination meetings	Hospital administration and FM leadership	Better interdepartmental alignment
Role ambiguity	Develop a responsibility matrix for FM issues	FM leadership and department heads	Clearer accountability
Cultural resistance	Use training, feedback and staff participation	FM leadership and HR/training units	Greater acceptance of change
Weak strategic integration	Include FM in risk review and planning discussions	Senior management	More proactive infrastructure governance

5. Conclusion and Further Research

This study examined human-centred drivers of operational complexity in hospital FM in Tehran. The findings indicate that FM complexity is shaped not only by technical infrastructure conditions, but also by communication, coordination, role clarity, leadership engagement and cultural adaptability. Communication gaps were the most influential driver, followed by coordination failures, role ambiguity and cultural resistance.

The theoretical contribution lies in applying complexity-informed and socio-technical thinking to hospital FM. The practical contribution is the Human-Centred Complexity Management Framework, which offers hospital administrators and FM managers a structured way to strengthen feedback, coordination, accountability, adaptive leadership and behavioural alignment. The results suggest that hospital FM should be positioned as a strategic coordination function rather than a purely reactive maintenance service.

The study remains exploratory and context-specific. Future research should involve larger samples, multiple metropolitan regions, fuller demographic data and advanced statistical techniques such as regression analysis or structural equation modelling. Longitudinal research could also test whether the proposed framework improves FM resilience, response speed and operational performance over time

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Appendix A. Questionnaire Structure and Items

The questionnaire consisted of 18 five-point Likert-scale items covering the five dimensions below. The appendix is included to clarify the structure of the instrument without adding unsupported statistical claims.

Table A1. Questionnaire structure

Dimension	Items covered
Communication effectiveness	Clear interdepartmental communication; consistent maintenance reporting; timely escalation of FM issues; clarity of information flow
Interdepartmental coordination	Coordination with clinical, administrative and technical units; cross-functional problem-solving; avoidance of departmental silos; joint prioritisation of FM issues
Leadership engagement	FM involvement in operational decisions; leadership support for infrastructure risk review; proactive resource prioritisation
Role clarity	Clarity of reporting duties; clarity of approval responsibilities; clarity of escalation pathways; avoidance of duplicated responsibilities

Dimension	Items covered
Cultural adaptability	Readiness to accept new FM routines; willingness to use reporting systems; openness to procedural change

Key Determinants of Time-Related Preliminary and General (P&G) Costs in Construction Projects

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Abstract

Time-related Preliminary and General (P&G) costs represent a significant portion of construction project expenditures. This study aims to identify the key determinants influencing time-related P&G costs in construction projects to support better cost control and project management.
This study adopts a qualitative research design using content analysis as the primary methodological approach. The study was conducted across major academic databases using predefined keywords and inclusion criteria. Peer-reviewed journal articles and conference papers addressing construction cost management, site overheads, and project duration were analysed. The literature was categorised to identify recurring determinants and their impact on time-related P&G costs.
Project duration is identified as the primary driver of time-related P&G costs. Other significant determinants include project size and complexity, procurement and contract conditions, planning and scheduling efficiency, and contractor management capability. External factors, such as adverse weather, regulatory compliance, and industrial action, further extend project timelines. Client-related factors, particularly scope changes, also exacerbate cost escalation.
Overall, the study concludes that time-related P&G costs are predominantly shaped by interconnected managerial and organisational factors rather than discrete technical issues. Effective coordination, competent contractor capability, and robust site management practices emerge as critical levers for minimising delays and controlling cost escalation. The findings imply that project stakeholders should prioritise integrated planning, strengthen contractor selection criteria, and adopt collaborative coordination mechanisms to improve time and cost performance. These insights provide a foundation for more proactive and system-oriented approaches to managing time-related construction costs in complex project environments.

Keywords: Time-related costs, Preliminary and General (P&G) costs, Construction project management, Cost determinants, Systematic literature review

1. Introduction

Time-related Preliminary and General (P&G) costs constitute a significant portion of total construction project expenditures, particularly in mega infrastructure projects executed by multiple contractors. In such environments, the project owner appoints multiple contractors, each responsible for specific components of the work. However, the interdependent nature of these activities, for instance, a civil contractor must complete certain works before a mechanical contractor can access the site, introduces a high risk of delays. These delays directly impact project duration, which in turn escalates time-related P&G costs, including site establishment, supervision, security, and temporary services.

Moreover, construction activities must comply with stringent quality assurance and health and safety requirements, further increasing the complexity of coordination among contractors. Inefficiencies in managing contractor interfaces, particularly when multiple contractors operate simultaneously on-site, often lead to poor coordination, duplication of effort, and disruptions to planned schedules. Such challenges contribute to extended project durations, thereby increasing time-related P&G costs and exposing the project to extension-of-time (EoT) claims.

Delays in site handover or access caused by underperformance by preceding contractors have a cascading effect on subsequent contractors, leading to claims for additional time and associated costs. These claims significantly inflate the project's overall cost and impose a financial burden on the project owner. Therefore, understanding the determinants that influence time-related P&G costs is critical in multi-contractor project environments.

This study aims to identify and evaluate the key factors contributing to increased time-related P&G costs in construction projects. Early identification of these determinants will enable project managers to implement proactive mitigation strategies, improve coordination among contractors, and enhance overall cost control and project performance.

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2. Literature Review

There are several key determinants of time-related preliminary and general (P&G) costs in construction projects where the scope of work is executed by multiple contractors. Within the context of this study, these determinants are particularly important in understanding how project complexity and multi-contractor arrangements influence cost escalation and the occurrence of construction claims.

2.1. Procurement preparation

Procurement plays a critical role in construction projects, particularly in the contracting and sourcing of goods and services and has a direct influence on time-related Preliminary and General (P&G) costs. Inadequate procurement planning is a key factor contributing to construction claims (Lal & Mathew, 2022), as it often leads to delays that disrupt project timelines. For instance, delays in procurement processes can postpone contractor access to the site (Amoatey & Ankrah, 2017), thereby affecting the construction schedule and resulting in extension of time (EoT) claims. Such delays prolong project duration and consequently increase time-related P&G costs, including site overheads, supervision, and temporary facilities.

Furthermore, poor procurement planning during the execution phase can significantly hinder construction activities. Contractors frequently experience delays due to the late delivery of construction materials (Ajibike et al., 2022; Namous & Al Battah, 2021; Oluwajana et al., 2022; Tahmasebinia & Vicheth Song, 2022). These delays are often attributed to inadequate consideration of material lead times and market shortages (Enshassi et al., 2009; Habibi & Kermanshachi, 2018). When materials are not delivered as scheduled, construction activities are disrupted across multiple contractors on-site, particularly in multi-contractor environments where tasks are highly interdependent.

The resulting delays have a cascading effect, leading to multiple claims from affected contractors. These claims may arise from restricted access to the site or from extended project durations caused by material shortages experienced by other contractors. Consequently, the accumulation of such delays significantly escalates time-related P&G costs and increases the project owner's financial burden.

Therefore, the development and implementation of a well-defined procurement strategy is essential for effective project delivery. Such a strategy should clearly outline the planning and sourcing of goods and services, with careful consideration of lead times, market conditions, and contractor coordination. By strengthening procurement planning and execution, project managers can mitigate delays, reduce the likelihood of construction claims, and improve control over time-related P&G costs.

2.2. Planning

Inadequate project planning is a critical factor affecting both project cost and schedule performance (Oluwajana et al., 2022; Ammar et al., 2022), with direct implications for time-related Preliminary and General (P&G) costs. Insufficient planning at the early stages of a project often results in poor preparedness for both planning and execution phases (El-Maaty et al., 2017). This lack of preparedness extends to contract planning, where deficiencies may lead to poorly structured contracts and unrealistic project parameters (Asiedu & Adaku, 2020; Arantes & Ferreira, 2020).

One of the key consequences of poor contract planning is the establishment of unrealistic contract durations (Albtoush et al., 2022; Badawy et al., 2022; Shashikanth & Prasad, 2021). When project owners impose impractical timelines, contractors are unable to execute work efficiently, resulting in delays and disruptions to the construction schedule. These delays often lead to cost overruns and give rise to extension-of-time (EoT) claims by affected contractors (Famiyeh et al., 2017; Arantes & Ferreira, 2020). The extension of project duration consequently increases time-related P&G costs, including site overheads, supervision, and temporary facilities.

Furthermore, inadequate planning negatively impacts the timely delivery of construction materials and the effective sourcing of equipment. Delays in material delivery (Ajibike et al., 2022; Namous & Al Battah, 2021; Oluwajana et al., 2022; Tahmasebinia & Song, 2022) and insufficient equipment availability (Oluwajana et al., 2022) disrupt construction activities and reduce productivity on-site. In multi-contractor environments, such disruptions have a cascading effect, delaying dependent activities and further extending the project timeline.

Overall, inadequate planning contributes significantly to prolonged project durations, increased likelihood of construction claims, and escalation of time-related P&G costs. Addressing planning deficiencies in the early stages of a project is therefore essential to enhance schedule reliability, improve coordination, and strengthen cost-control mechanisms.

2.3. Cost estimation

Inaccurate cost estimation is a significant contributor to project inefficiencies and has direct implications for time-related Preliminary and General (P&G) costs. In some instances, contractors deliberately underestimate project costs in order to secure contract awards (Famiyeh et al., 2017). While this strategy may increase the likelihood of winning bids, it often results in unrealistic budgets that do not align with the project's actual scope and complexity.

Inaccurate project cost estimates frequently lead to cost overruns, particularly when adjustments are required during project execution, such as change orders (Ammar, Abdel-Monem & El-Dash, 2022; Fashina et al., 2021; Mekonen, 2025; Oluwajana et al., 2022). These change orders often disrupt planned schedules, resulting in delays that give rise to extension-of-time (EoT) claims. Consequently, prolonged project durations increase time-related P&G costs, including site overheads, supervision, and temporary facilities.

A key underlying factor contributing to inaccurate cost estimation is a poorly defined scope of work. When the project scope is unclear or inadequately specified, estimators cannot accurately quantify resources, durations, or associated costs. This limitation is further exacerbated by the use of inappropriate or outdated estimation techniques (Famiyeh et al., 2017). The combination of scope ambiguity and weak estimation practices increases the likelihood of budget inaccuracies, schedule disruptions, and subsequent construction claims.

Therefore, improving the accuracy of cost estimation through a clearly defined project scope and the adoption of robust estimation techniques is essential for controlling project duration and minimising time-related P&G cost escalation.

2.4. Design changes

Changes in design, change orders, and scope variations are widely recognised as significant factors affecting both project cost and schedule performance (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). These changes often disrupt planned construction activities, leading to rework, resource reallocation, and inefficiencies that extend project duration. As a result, prolonged timelines directly increase time-related Preliminary and General (P&G) costs, including site overheads, supervision, and temporary facilities.

Several studies further emphasise that scope changes substantially escalate project costs and contribute to significant delays in project schedules (Amoatey & Ankrah, 2017; Asiedu & Adaku, 2020; Mahamid, 2017; Prasad et al., 2019). Design changes, often stemming from a poorly defined scope of work (Famiyeh et al., 2017), exacerbate these challenges by introducing uncertainties and requiring adjustments during execution. Such modifications not only affect productivity but also disrupt the coordination of activities, particularly in complex, multi-contractor environments.

Failure to effectively manage scope and design changes can result in substantial delays, ultimately leading to claims for extension of time (EoT) (Rustandi et al., 2022). These claims further increase time-related P&G costs, placing additional financial pressure on the project owner.

Therefore, effective management of design and scope changes—through clear scope definition, robust change control processes, and proactive planning, is essential to minimise disruptions, control project duration, and reduce the escalation of time-related P&G costs.

2.5. Project experience of the contractor

Contractor inexperience represents an important determinant of time-related preliminary and general (P&G) costs, particularly within multi-contractor construction environments. A multi-contractor set-up requires contractors with proven experience in similar construction works to ensure efficient coordination, execution, and scheduling of project activities. However, contractor inexperience has been shown to negatively affect site operations, particularly through disrupted project execution, poor activity sequencing, and scheduling delays (Namous & Al Battah, 2021; Oluwajana et al., 2022; Tahmasebinia & Song, 2022; Alekhya et al., 2021).

Furthermore, inadequate contractor experience has been identified as a contributing factor to increased project costs, including time-related P&G costs, due to inefficiencies and extended project durations (Amoatey & Ankrah, 2017). In addition, poor coordination among project stakeholders, often linked to contractor inexperience, has been associated with ineffective management of construction activities, leading to delays and cost escalations (Mahamid, 2017).

Accordingly, within the scope of this study, contractor experience is considered a key determinant to be systematically reviewed, categorised, and evaluated as part of the broader investigation into the factors influencing time-related P&G costs in the South African construction industry.

2.6. Site management and supervision

Site management and supervision of construction activities are critical determinants of time-related preliminary and general (P&G) costs, as they directly influence project efficiency and the likelihood of cost overruns. Effective site management and supervision have been shown to reduce the probability of project cost escalations by ensuring proper coordination, control, and monitoring of construction activities (Radzi et al., 2022; Tahmasebinia & Song, 2022; Alekhya et al., 2021).

Conversely, poor site management and supervision are frequently attributed to inadequate management skills among project personnel (Vivek & Rao, 2021; Namous & Al Battah, 2021; Tahmasebinia & Song, 2022; Alekhya et al., 2021). Studies further indicate that cost overruns are often linked to deficiencies in managerial

and technical competencies, limited human capacity, and insufficient understanding of the local construction context (Santoso & Gallage, 2019; Durdyev & Hosseini, 2020).

Additional contributing factors include weak supervision and control mechanisms (Asiedu & Adaku, 2020), inadequate inspection and oversight by contractors (Famiyeh et al., 2017; Habibi & Kermanshachi, 2018), and poor project coordination (Mahamid, 2017). Collectively, these deficiencies in site management practices have been widely associated with ineffective project execution and increased project site management challenges, ultimately leading to higher project costs and delays (Famiyeh et al., 2017; Habibi & Kermanshachi, 2018; Durdyev & Hosseini, 2020; Arantes & Ferreira, 2020).

2.7. Project construction complexity

In the context of this study, contractors operating in multi-contractor construction environments must have a clear understanding of project complexity to effectively manage time-related preliminary and general (P&G) costs. Where multiple contractors execute different scopes of work on the same site, adequate planning and coordination of shared activities, such as health and safety management, site logistics, and access arrangements, becomes essential to ensure smooth project execution (Oluwajana et al., 2022; Famiyeh et al., 2017).

A sound understanding of the project environment enables contractors to properly sequence activities, plan work schedules, and manage site access requirements. Conversely, restricted or delayed site access can disrupt planned activities, potentially resulting in claims for time extensions and increased construction planning costs. Such delays may also negatively affect the constructability and productivity of other contractors working on the same site, thereby compounding overall project inefficiencies.

Furthermore, Famiyeh et al. (2017) identify the use of inappropriate construction methods as a contributing factor to construction claims. In addition, claims may arise from rework necessitated by poor workmanship and substandard quality of the completed works, both of which further increase time-related costs and reduce project efficiency.

3. Research Methodology

This study adopts a qualitative research design using content analysis as the primary methodological approach. Content analysis is appropriate for systematically examining and interpreting existing literature to identify patterns, themes, and relationships among variables.

The approach enables the study to synthesise fragmented knowledge from published academic sources and industry reports to develop a comprehensive understanding of the key determinants influencing time-related P&G cost escalation in multi-contractor construction environments.

Data for this study is collected from secondary sources, including:

- Peer-reviewed journal articles

Databases such as Scopus, Google Scholar, Web of Science, and ScienceDirect are used to retrieve relevant literature. Sources range 2000 -2025

Inclusion criteria:

- Studies focusing on construction cost overruns and delays
- Studies addressing P&G costs or related site overhead costs
- Research on multi-contractor or complex construction environments
- Studies discussing causes of Extension of Time (EoT) claims

Exclusion criteria:

- Non-construction-related studies
- Articles without peer review or academic credibility
- Studies not addressing time-related cost implications

To enhance methodological transparency, the study follows a structured literature review process comprising three key stages: identification, screening, and synthesis. A total of 19 peer-reviewed journal articles were systematically reviewed using structured identification, screening, and selection criteria.

In the identification stage, a systematic search strategy is employed using predefined keywords and Boolean combinations (e.g., “construction cost overruns,” “P&G costs,” “site overheads,” “extension of time,” and “multi-contractor projects”).

During the screening stage, retrieved studies were assessed against the predefined inclusion and exclusion criteria. This involves an initial title and abstract review to eliminate irrelevant studies, followed by a full-text assessment of remaining articles to confirm their alignment with the research objectives. Duplicate records were removed, and only peer-reviewed and methodologically sound studies were retained for analysis.

In the synthesis stage, the selected studies were systematically analysed using thematic content

analysis. Relevant data are iteratively extracted and coded, enabling the identification of recurring patterns, relationships, and dominant themes. These themes were then refined and grouped into higher-order categories that explain the key drivers of time-related cost escalation for P&G in multi-contractor construction environments.

This structured approach improves the reliability, replicability, and rigour of the review process, ensuring that the findings are grounded in a transparent and systematic analysis of the literature.

4. Findings and Discussion

The reviewed literature indicates that several interrelated factors significantly influence time-related preliminary and general (P&G) costs in construction projects, particularly within multi-contractor environments. A key finding is that contractor experience plays a critical role in project performance, where inexperience contributes to poor execution, inadequate scheduling, and weak coordination, ultimately leading to delays and increased project costs. Similarly, deficiencies in site management and supervision are a major driver of cost overruns, largely due to inadequate managerial and technical skills, limited human capacity, and weak oversight mechanisms.

The findings further highlight that construction complexity in multi-contractor settings requires effective planning and coordination of shared activities, including health and safety management and site access. Poor understanding of the project environment often results in delayed site access, disruptions to work sequencing, and reduced constructability across contractors, thereby increasing the likelihood of claims for extensions of time. In addition, inappropriate construction methods and poor workmanship contribute to rework, which further escalates both time-related costs and the incidence of construction claims.

Overall, the findings suggest that time-related P&G costs cannot be attributed to isolated variables but rather arise from the interaction among contractor capability, site management effectiveness, coordination quality, and project complexity. This has theoretical implications, as it challenges linear models of cost-overrun causation and instead supports a systems-based perspective on project performance. Practically, it underscores the need for integrated, proactive site management practices, as well as institutional mechanisms that enhance contractor capabilities and coordination in multi-contractor environments. Addressing these interdependencies is critical to improving project efficiency, reducing claims, and controlling time-related cost escalation.

5. Conclusion and Further Research

This study systematically reviewed and synthesised existing literature on the determinants of time-related preliminary and general (P&G) costs in construction projects. The review identified that contractor experience, site management and supervision, project complexity, coordination effectiveness, and construction methods are key interrelated factors influencing time-related P&G costs. Collectively, these factors contribute to project inefficiencies, delays, claims, and cost overruns, demonstrating that effective management and coordination are central to controlling time-related project expenditures.

The study further highlights that time-related P&G costs are largely driven by systemic and organisational issues rather than isolated operational challenges. Weaknesses in contractor capability, inadequate planning of site activities, and poor coordination among multiple contractors significantly increase the risk of project delays and associated cost escalation.

The implications for practice are that: project stakeholders should adopt more rigorous contractor evaluation processes, invest in strengthening site management and supervisory capacity, and implement structured coordination frameworks, particularly in multi-contractor environments. From a theoretical perspective, the study contributes by consolidating dispersed literature into a coherent framework that explains the underlying drivers of time-related P&G costs. However, the reliance on secondary data highlights the need for empirical validation. Future research should focus on quantifying the relative influence of identified determinants, developing predictive models for cost escalation, and evaluating the effectiveness of integrated delivery approaches in diverse project contexts.

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Total Quality Management Awareness and Practice in Digitalising Construction Industry: Insights from Construction Professionals in Imo State, Nigeria

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Abstract

Persistent quality failure remains a defining problem of the Nigerian construction industry, and the sector's migration towards digitally enabled project delivery raises new questions about whether established Total Quality Management (TQM) principles are understood and practiced by the professionals expected to work within such systems. This study established an empirical baseline of TQM awareness and practice among construction professionals in Imo State, Nigeria, and identifies the TQM dimensions on which digitally enabled quality management would deliver the greatest improvement. Adopting a positivist, quantitative survey design, structured questionnaires were administered to professionals in 63 accessible firms drawn from the 172 contracting firms registered with the Imo State Ministry of Works; 106 valid responses were obtained from 159 questionnaires distributed, a response rate of 66.7%. Internal consistency of the ten-item practice scale was confirmed using Cronbach's alpha ($\alpha = 0.913$), and the data were analysed using descriptive statistics and Mean Item Score (MIS) ranking. The results showed that 72.6% of respondents were aware of TQM principles but only 48.1% worked in organisations applying them, an awareness-to-practice conversion rate of 66.2%, while only 12.3% reported high-level application. Procurement quality control through strict adherence to standards ranked highest (MIS = 4.37), whereas the deployment of modern technological facilities (MIS = 3.30) and communication between operational staff and senior management (MIS = 3.28) ranked lowest. The study concluded that the binding constraint on construction quality is organisational and that practice is arrested between the Plan and Do phases of the Deming cycle.

Keywords: Construction 4.0, Construction Quality Management, Deming PDCA Cycle, Nigerian Construction Firms, TQM Awareness-practice gap.

1. Introduction

Quality is a defining attribute of organisational competitiveness, commonly understood as conformity to requirements together with fitness for purpose (Psarommatis et al., 2022). Samsudin et al. (2021) described it as the level of excellence achieved in competition, encompassing reliability, serviceability and maintainability. In construction, its pursuit is inseparable from the management of the sector's resources, since construction management involves the efficient deployment of labour, materials, plant and equipment towards project completion (Jackson, 2025). Construction is a significant contributor to gross domestic product and to socio-economic development in Nigeria and elsewhere (Cucos & Turcan, 2025; Saka, 2022) quality failure carries consequences well beyond the individual project.

Total Quality Management (TQM) emerged as the systematised response to this challenge. Psarommatis et al. (2022) presented it as a management methodology built on customer satisfaction, defect-free output, cost-effectiveness, leadership commitment and continuous employee development, while Bayev et al. (2022) emphasised its dual orientation towards eliminating poor quality during production and rejecting defective output afterwards. Common to these accounts is the treatment of TQM as an organisation-wide philosophy rather than an inspection activity.

Notwithstanding, the Nigerian construction industry continues to contend with persistent quality failure. Structural failures attributable to poor planning, inadequate supervision, non-adherence to specification and substandard materials are repeatedly documented, and each is a defect TQM is designed to prevent (Owolabi et al., 2024). Egwunatum et al. (2022) attributed most building collapses in Nigeria to ineffective quality control, deficient professional competence and poor communication among project participants, while Sofolahan et al. (2024) noted that the resulting losses extend to life and property, public confidence and the financial position of affected clients. Orumwense (2014) documented comparable unevenness in TQM implementation across Nigerian organisations more than a decade ago, and

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construction-specific studies since have reported the same pattern.

The digital transformation of the industry has introduced new conditions for quality management through Building Information Modelling (BIM), digital project management platforms, digital communication tools and the wider family of Construction 4.0 technologies. Digitalisation creates both opportunity and pressure for TQM: digital tools can automate quality monitoring, standardise inspection and accelerate information exchange between site and management, but they deliver these benefits only where an underlying awareness of TQM and the process discipline to sustain it already exist. Awareness among Nigerian construction professionals nevertheless remains uneven and implementation inconsistent (Ajayi et al., 2024; Egwunatum et al., 2022).

Two gaps follow. First, existing Nigerian studies treat TQM awareness and practice as a single undifferentiated condition, so the rate at which awareness converts into practice, and the point at which conversion fails, remains unquantified. Second, no Nigerian study has ranked TQM principles in a manner that allows the weakest dimensions of practice to be matched to the digital tools now entering the sector. Addressing these gaps, the study pursues three objectives: (i) to determine the level of awareness of TQM principles among construction professionals in Imo State, Nigeria; (ii) to assess the extent to which those principles are applied within their organisations; and (iii) to rank the individual TQM principles by level of practice, in order to identify the dimensions on which digitally enabled quality management offers the greatest potential improvement.

2. Literature Review

2.1. Approach to the review of literature

The literature underpinning this study was identified through a structured narrative review rather than an exhaustive systematic review. Searches were conducted in Scopus and Google Scholar using combinations of the terms “total quality management”, “TQM”, “quality management”, “construction industry”, “Nigeria”, “digitalisation” and “Construction 4.0”, restricted to peer-reviewed articles, theses and conference papers published between 2014 and 2025. Sources were retained where they defined or operationalised TQM constructs, reported empirical TQM findings in a developing-economy construction context, or addressed the intersection of digital construction technologies and quality management. Twenty-four sources met these criteria and constitute the evidential basis of the review; the ten TQM principles operationalised in the survey instrument were derived from those most consistently reported across the empirical studies in this set.

2.2. Conceptualising Total Quality Management

TQM is presented in the literature as a continuous process of improving individuals, departments, groups, and organisational processes to meet customer expectations (Zaid et al., 2020). Bahia et al. (2023) framed it as an organisational philosophy directed at performance improvement; Abbas and Kumari (2023) treated it as a multidimensional construct operating through knowledge management; and Olaleye et al. (2024) emphasised its dependence on employee feedback, societal values and regulatory compliance. The philosophy originated in manufacturing and remains most fully developed there; construction differs in its project-based, site-specific and temporary-coalition mode of production, so TQM cannot simply be transplanted into it without adaptation (Samsudin et al., 2021).

Synthesising these accounts, four dimensions recur across every definition consulted: customer focus and satisfaction; employee involvement and continuous learning; top management commitment and leadership; and systematic quality monitoring and process improvement (Abbas & Kumari, 2023; Bahia et al., 2023; Reinaldo et al., 2021; Zaid et al., 2020). The definition shared a normative account of what TQM comprises; what they do not supply is evidence of the extent to which practising professionals in a developing-economy construction market recognise those dimensions and act upon them. That distinction between normative content and empirical uptake is the conceptual space this study occupies, and the four-dimensional structure provides the theoretical support for the ten principal variables evaluated here.

The applicability of TQM to construction rests on its capacity to ensure that organisations do the right things at the right time while progressively reducing waste and rework (Egwunatum et al., 2022). Reinaldo et al. (2021) analysing the Brazilian construction industry, it is established that the critical factors for successful implementation are organisational rather than technical, dominated by leadership commitment, training and communication, a finding of direct relevance to the Nigerian context examined in this study.

2.3. TQM in the Nigerian Construction Context

Empirical work on TQM in the Nigerian construction industry remains limited but consistent. Egwunatum et al. (2022) examined implementation across firms in Delta State and identified deficient communication, inadequate training, unsuitable equipment and weak management commitment as the principal constraints; awareness was fairly high, but conscious application was restricted by organisational culture and resource limitations. Ajayi et al. (2024) found that contractors implementing TQM recorded higher client satisfaction,

lower rework and better use of employee capability than those that did not. INUWA (2021) reached a similar conclusion in Niger State, reporting that quality management practices were applied unevenly and rarely embedded in formal organisational systems. Owolabi et al. (2024) showed that specifications function as quality assurance tools only where firms possess the supervisory discipline to enforce them.

Two features of this body of work are notable. It is concentrated in the South-South, North-Central and South-West, leaving the South-East, and Imo State in particular, largely unexamined. And it treats awareness and practice as a single undifferentiated condition, reporting that awareness is high and practice lower without quantifying the distance between them or locating where the translation from one to the other fails.

The present study departs from Egwunatum et al. (2022) and Ajayi et al. (2024) in three respects. First, it separates awareness from practice as distinct measured constructs and quantifies the conversion rate between them, so the failure point may be located rather than inferred. Second, it extends the geographical coverage of Nigerian TQM research to the South-Eastern geopolitical zone. Third, it ranks the individual principles by level of practice, permitting the weakest dimensions to be matched directly to the digital tools capable of addressing them.

2.4. Digital construction and quality management

The fourth industrial revolution has introduced digital technologies into construction production in ways that bear directly on how quality is managed. BIM, IoT-enabled site monitoring, digital quality inspection applications and cloud-based project management platforms are described collectively as Construction 4.0, defined by the systematic application of digital technologies across construction processes (Aghimien et al., 2022). In manufacturing, the equivalent transition has moved practice away from defect detection towards zero-defect production, in which quality is designed into the process and monitored continuously (Psarommatis et al., 2022). Construction has begun a comparable transition unevenly: Sofolahan et al. (2024) documented substantial barriers to digital adoption in Nigeria, including cost, skills shortages and the absence of enabling organisational structures.

The relationship between digitalisation and TQM is best understood as enabling rather than substitutive. Digital tools do not replace TQM principles; they supply the operational infrastructure through which quality monitoring, site-to-management information exchange and continuous improvement may be applied more consistently than manual systems permit (Aghimien et al., 2022). It follows that the value of digital investment for quality management depends on which TQM dimensions are weakest in a given context. That is an empirical question, and it is the question this study addresses.

The framing of this study within construction digitalisation is substantiated on three grounds. First, the instrument contains an explicit digital variable: the deployment of modern technological facilities to improve construction quality standards is one of the ten principles measured and ranked, it is noted that digital capability is a measured dimension rather than a contextual assertion. Second, the study population operates in a sector undergoing digital transition, where quality management pressures differ from those of a wholly traditional environment. Third, the analysis identifies which dimensions are least practised and therefore which digital interventions would be consequential; as reported in Section 4.3, the two lowest-ranked principles are those that cloud-based communication and digital monitoring platforms are designed to address. The study does not claim to measure the level of digitalisation of the firms surveyed, and this boundary is stated among the limitations in Section 6.1.

2.5. Theoretical Framework: The Deming (PDCA) Continuous Improvement Cycle

The study is grounded in Deming's Plan-Do-Check-Act (PDCA) continuous improvement cycle, the operational backbone of ISO 9001 quality management systems and the most widely applied framework in TQM research (Psarommatis et al., 2022; Reinaldo et al., 2021). The cycle maps onto the awareness-to-practice trajectory examined here: Plan corresponds to awareness and knowledge of TQM; Do to initial application within the organisation; Check to systematic quality monitoring and feedback; and Act to continuous improvement and system refinement. The framework is used in two ways. Analytically, it provides the structure against which the ten measured principles are interpreted, since each can be located within one of the four phases. Diagnostically, it converts a descriptive finding into a positional one: establishing where along the cycle a sector has stalled is more useful to policy than establishing merely that its quality performance is weak. The gap addressed here is therefore analytical as well as empirical, since prior Nigerian studies report the symptoms of incomplete adoption without locating them within an improvement cycle.

3. Research Methodology

3.1. Research design and philosophy

The study adopted a quantitative research design within the positivist paradigm, which privileges objectivity and quantifiable data derived from empirical observation (Ali, 2024). A cross-sectional survey strategy was selected because it permits systematic collection of standardised data from a defined

population within a bounded period, and because the objectives are descriptive and comparative rather than explanatory (Kothari, 2004).

3.2. Justification for the study area

Imo State was selected for three reasons. It is the administrative and commercial centre of Nigeria's South-Eastern geopolitical zone and hosts a concentration of registered contracting firms serving the wider zone. The South-East is the region least represented in existing Nigerian TQM research, which has concentrated on Delta, Niger and Lagos States. Its construction market is intermediate in scale and digital maturity between the highly developed Lagos market and the less industrialised Northern states, making it an informative, if not statistically generalisable, reference point. The consequences of this choice are addressed in Section 6.1.

3.3. Population, sample size determination and sampling technique

The study population comprised the 172 construction firms registered with the Ministry of Works in Imo State, with the firm as the sampling unit and the individual professional as the unit of analysis. A minimum of sixty-three firms were subsequently accessible and were included. The firms were selected on the basis of accessibility: a substantial proportion of registered firms could not be reached because offices were non-operational, addresses had changed, or firms declined to participate within the data collection window. The selection is therefore properly described as convenience-purposive rather than simple random sampling, being convenient in that accessibility governed inclusion and purposive in that only firms with active projects and qualified professionals in the disciplines of interest were retained. Within each participating firm, two to four professionals comprising quantity surveyors, architects, builders and engineers were invited to respond, on the basis of their technical knowledge and direct involvement in construction project management. A total of 159 questionnaires was distributed and 106 valid responses returned, a response rate of 66.7%, which exceeds the threshold generally regarded as satisfactory in construction management survey research (Aghimien et al., 2022). The 63 participating firms represent 36.6% of the registered firm population.

3.4. Research instrument, validity and reliability

Data were collected using a structured, self-administered questionnaire in three sections: respondent and firm characteristics; awareness of TQM and its application within the respondent's organisation; and the extent of practice of ten TQM principles, measured on a five-point Likert scale anchored at 1 (not practised) and 5 (practised to a very great extent). The ten principles were derived from those most consistently reported in the literature reviewed in Section 2 and mapped to the four dimensions synthesised in Section 2.2, which establishes content validity. Face and content validity were further examined by two academics in construction management and two practising professionals, whose comments informed item wording and sequencing, and the instrument was pilot-tested with 10 professionals excluded from the main survey. Internal consistency was assessed using Cronbach's alpha, which returned $\alpha = 0.913$ for the ten-item practice scale, exceeding the 0.70 threshold conventionally regarded as acceptable. The use of a fully labelled five-point scale follows (Hutchinson & Chyung, 2023), which supports interval-like treatment of such data for the computation of mean scores

3.5. Method of data analysis

Returned questionnaires were screened for completeness and analysed using descriptive statistics: frequencies and percentages for categorical variables, and the Mean Item Score (MIS) for ranking the ten principles. The MIS was computed as $MIS = (5n_5 + 4n_4 + 3n_3 + 2n_2 + 1n_1) / N$, where n_1 to n_5 denote the number of respondents selecting each scale point and N is the number of valid responses to that item. Scores were interpreted against the following decision rule, obtained by dividing the scale into equal intervals: 4.50-5.00 = very high practice; 3.50-4.49 = high; 2.50-3.49 = moderate; 1.50-2.49 = low; and 1.00-1.49 = very low. Where two items returned identical means, the item with the smaller dispersion was ranked higher. Consistent with the descriptive purpose of the study, which is to establish a baseline rather than to test hypothesised relationships, inferential analysis was not undertaken; this decision is discussed among the limitations in Section 6.1.

4. Findings and Discussion

4.1. Profile of Respondents

Table 1 (Appendix 1) presents the demographic and professional profile of the 106 respondents. Engineers constitute the largest professional group (35.8%), followed by quantity surveyors (27.4%), architects (18.9%) and builders (17.9%). In terms of academic qualification, 38.7% hold the Higher National Diploma and 34.9% a B.Sc or B.Tech degree, while 26.5% hold postgraduate qualifications at PGD, M.Sc or M.Tech level. Experience is substantial: 71.7% have more than five years of professional experience and 40.6% more than ten, which lends weight to their responses as informed professional judgements. The majority (76.4%) are registered with a professional regulatory body. All percentages are computed on the full sample of 106 and may not sum to exactly 100.0 owing to rounding.

4.2. Awareness and application of TQM principles

Table 2 presents the findings on awareness and application, and Figure 1 illustrates the cascade from

Table 2: Awareness and Application of TQM Principles

Category	Classification	Frequency	Percentage (%)
TQM Awareness	Yes	77	72.60
	No	29	27.40
	Total	**106**	**100.00**
Level of TQM Awareness	High	46	43.40
	Average	20	18.90
	Low	11	10.40
	Sub-total (Aware)	**77**	**72.60**
	Not Applicable (Unaware)	29	27.40
	Total	**106**	**100.00**
TQM Application	Applied	51	48.10
	Not Applied	26	24.50
	Sub-total (Aware)	**77**	**72.60**
	Not Applicable (Unaware)	29	27.40
	Total	**106**	**100.00**
Level of TQM Application	Generally Applied	33	31.10
	Not Applied	26	24.50
	Highly Applied	13	12.30
	Fairly Applied	5	4.70
	Sub-total (Aware)	**77**	**72.60**
	Not Applicable (Unaware)	29	27.40
	Total	**106**	**100.00**

Source: Field Survey (2026)

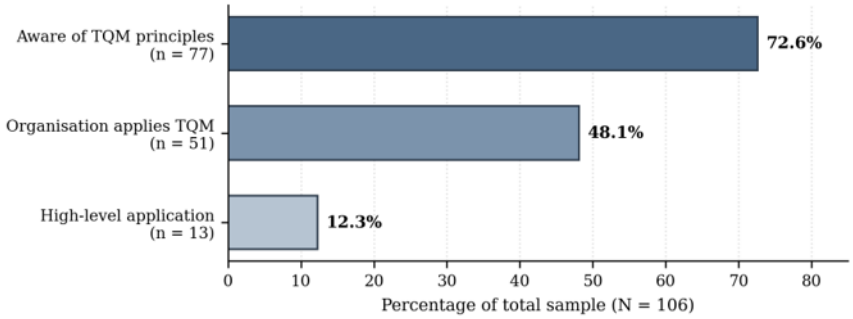

Figure 1: Cascade from TQM awareness to substantive practice among respondents.

Source: Field Survey (2026)

awareness through to substantive practice. Of the 106 respondents, 77 (72.6%) demonstrated awareness of TQM principles while 29 (27.4%) did not. Among the 77 aware respondents, 46 (59.7% of aware respondents and 43.4% of the full sample) reported high awareness, 20 (26.0%; 18.9%) an average level and 11 (14.3%; 10.4%) a low level. On application, 51 respondents (48.1% of the full sample and 66.2% of those aware) reported that their organisations apply TQM principles within their quality improvement policies, while 26 (33.8% of those aware) reported that they do not. Of the 51 applying organisations, 33 (31.1% of the sample) apply TQM generally, 13 (12.3%) highly and 5 (4.7%) only fairly.

These results reveal a substantial awareness-practice gap. Awareness is widespread at 72.6%, but only 48.1% of the sample reports organisational application, so approximately one in three professionals who understand TQM works in an organisation that does not apply it. Expressed as a conversion rate, 66.2% of awareness translates into practice; the remaining 33.8% represents knowledge held by individuals but not institutionalised by their firms. This locates the failure point. The constraint in Imo State is not professional ignorance, which would call for an educational remedy, but organisational non-adoption, which calls for structural and managerial ones. Read through the Deming cycle, the sector is arrested between Plan and Do: the knowledge required to plan quality management exists, but the systems required to execute it, check performance and act on the results do not.

The finding corroborates and extends prior Nigerian evidence. (Egwunatum et al., 2022) each reported high awareness alongside limited conscious application, attributing the shortfall to organisational culture, management commitment and resource constraints. The present study confirms that pattern in a previously unexamined geopolitical zone and, by measuring awareness and practice separately, supplies the quantity those studies did not. The depth measures sharpen the picture further: of the 51 organisations that apply TQM, only 13 (25.5%) do so to a high degree, so the effective rate of substantive practice across the sample is 12.3%. Awareness is therefore not merely imperfectly converted into practice; where conversion occurs, the practice is predominantly shallow.

4.3. Level of Practice of TQM Principles

Table 3 and Figure 2 present the Mean Item Score ranking of the ten TQM principles. All ten means fall between 3.28 and 4.37. Applying the decision rule in Section 3.5, seven principles fall within the high practice band and three within the moderate band; none reached the very high band and none fell into the low bands, indicating a sector in which quality management is neither absent nor systematically embedded.

The highest-ranked principle, procurement quality control through strict adherence to standards (MIS = 4.37), reflects the industry's longstanding concentration on input quality. This is consistent with (Egwunatum et al., 2022; INUWA, 2021), both found material procurement to be the most frequently reported quality management activity among Nigerian construction firms, and with Owolabi et al. (2024), observed that specification compliance is the mechanism most visible to clients and regulators. The prominence of the principle is readily explained: material failure is the defect most directly traceable to a firm, so the incentive

Table 3: Mean Item Score Ranking of TQM Principles

S/N	TQM Principle	Mean	Rank
1	Procurement quality control through strict adherence to standards	**4.37**	1
2	Identification and implementation of improved construction processes	**4.30**	2
3	Site management responsibility through deployment of qualified project managers	**3.95**	3
4	Quality monitoring systems throughout the project lifecycle	**3.84**	4
5	Project Quality Management framework adopted by firms	**3.81**	5
6	Quality assurance practices governing activities on-site	**3.67**	6
7	Promotion of effective teamwork to enhance quality outcomes	**3.54**	7
8	Engagement of skilled workforce to meet organisational policies	**3.48**	8
9	Deployment of modern technological facilities to improve construction quality standards	**3.30**	9
10	Effective communication between operational staff and senior management	**3.28**	10

Source: Field Survey (2026). N = 106 for all items. Scale: 1 = not practised to 5 = practised to a very great extent. Decision rule: 4.50–5.00 = Very high; 3.50–4.49 = High; 2.50–3.49 = Moderate; 1.50–2.49 = Low; 1.00–1.49 = Very low.

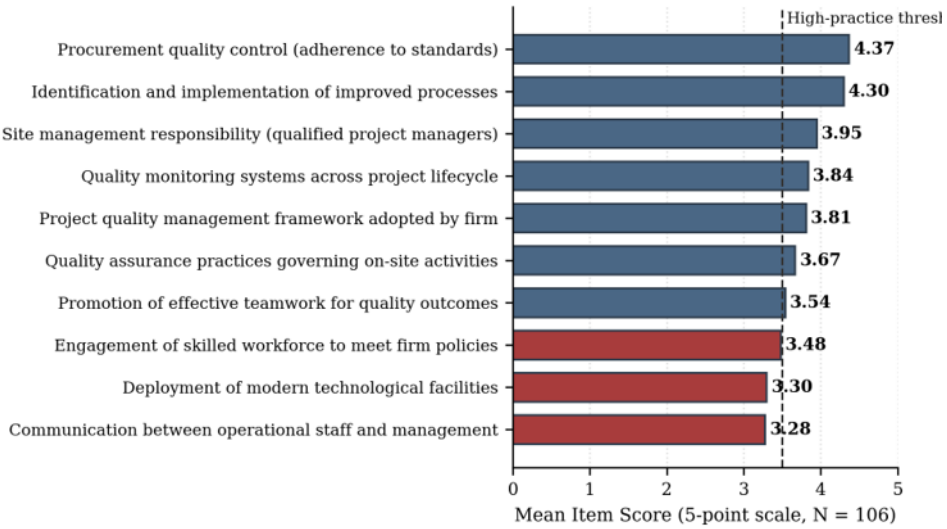

Figure 2: Mean Item Score Ranking of the ten TQM principles.

Source: Field Survey (2026)

to control it is immediate, whereas the benefits of systemic quality management are diffuse and deferred. Within the Deming framework, this is activity concentrated at the input boundary of the Do phase rather than across the full cycle.

The second-ranked principle, identification and implementation of improved construction processes (MIS = 4.30), suggested movement towards process orientation. The middle band, comprising site management responsibility through qualified project managers (3.95), quality monitoring systems across the project lifecycle (3.84), project quality management frameworks (3.81) and quality assurance practices governing site activities (3.67), indicates that oversight is valued and partially institutionalised but not applied consistently across the lifecycle. Notably, principles depending on individual professional competence rank above those depending on organisational systems, which is congruent with the gap identified in Section 4.2: capability resides with individuals more than with the firms employing them.

The two lowest-ranked principles are the most consequential. Effective communication between operational staff and senior management ranks tenth (MIS = 3.28), and the deployment of modern technological facilities ranks ninth (MIS = 3.30). Communication is a precondition of every other principle: without reliable information exchange between site and management, non-conformances cannot be identified, escalated and resolved while remediation remains inexpensive. Samsudin et al. (2021) showed that internal communication patterns are among the strongest determinants of implementation success, and Egwunatum et al. (2022) likewise identified communication as the leading constraint on TQM in Nigeria. The present ranking quantifies that constraint and confirms its persistence in a different geopolitical zone.

That these two principles rank adjacently and lowest constitutes the study's most direct empirical link between quality management and digitalisation. Cloud-based project management systems, digital site reporting applications and mobile communication tools are designed precisely to address the site-to-management information flow that ranks last here, while the low ranking of technological deployment indicates that this remedy remains largely unexploited. The findings are mutually reinforcing: the weakest dimension of practice is the one most amenable to digital remedy, and the digital remedy is itself weakly deployed. This is consistent with the adoption barriers documented by Sofolahan et al. (2024), and indicates that targeted digital investment in communication and quality-monitoring infrastructure would address the binding constraint on TQM practice rather than a peripheral one. In Deming terms, these are the Check and Act capabilities whose absence prevents the cycle from closing.

4.4. Corroboration and triangulation of the findings

Full data triangulation combining quantitative and qualitative evidence was beyond the scope of a single-instrument survey and is acknowledged as a limitation in Section 6.1. Three forms of corroboration were nevertheless applied to test the internal and external consistency of the findings.

The first is internal cross-validation between independent measures within the instrument. Awareness, application and depth of application were captured as separate items, and the ten principal ratings were collected independently of them. These measures converge: the moderate ratings on system-dependent principles are consistent with only 12.3% of the sample reporting high-level application, while the high ratings on input-control principles are consistent with widespread awareness. Had respondents rated the practice items without reference to organisational reality, uniformly high scores would be expected rather than the differentiated pattern observed.

The second is theoretical corroboration. The pattern of results maps coherently onto the Deming cycle, with Plan and Do represented by high awareness and input-oriented practice and Check and Act, represented by monitoring, communication and continuous improvement, ranking consistently lower. The findings are therefore interpretable within an established framework rather than constituting an unstructured set of rankings.

The third is external corroboration against prior empirical work. The awareness-practice disparity replicated Egwunatum et al. (2022) in Delta State and INUWA (2021) in Niger State; the salience of procurement quality control replicates both; the identification of communication as the leading weakness replicates Egwunatum et al. (2022) and is consistent with Samsudin et al. (2021); and weak technological deployment is consistent with Sofolahan et al. (2024).

5. Contribution to Knowledge and Implications for Practice

5.1. Contribution to knowledge

The study advances existing knowledge in four respects. First, it disaggregates awareness from practice and quantifies the conversion between them, establishing that 66.2% of awareness converts into organisational practice and that only 12.3% of the sample reports high-level practice: Egwunatum et al. (2022) and Ajayi et al. (2024) established that a gap exists, whereas this study measures it and identifies where in the chain it opens. Second, it extends the

empirical coverage of Nigerian TQM research to the South-Eastern geopolitical zone, previously unrepresented, providing a baseline for future comparison. Third, it produces a ranked ordering of ten principles by level of practice, converting a general finding of weak implementation into a specific diagnosis of which principles are weak and in what order they should be addressed. Fourth, it establishes an evidence-based correspondence between the weakest dimensions and the digital tools capable of addressing them, moving the discussion of digitalisation and quality management from assertion towards a prioritised, empirically grounded agenda.

5.2. Implication for Practice

The implications below derive from specific findings rather than from the general TQM literature. Because the binding constraint is organisational non-adoption rather than individual ignorance (Section 4.2), professional development alone will not close the gap: the regulatory bodies (NIQS, NIA, NSE and NIOB) should direct continuing professional development towards firm-level implementation, covering the establishment of quality management systems, documentation and internal audit, rather than towards awareness of principles that 72.6% of professionals already possess. Because communication ranks lowest (MIS = 3.28) and technology deployment second lowest (MIS = 3.30), firms in the study area should prioritise cloud-based reporting and quality-monitoring platforms ahead of other digital investment, since this is where the marginal return to digitalisation for quality performance is greatest. Because only 25.5% of applying organisations apply TQM to a high degree, public clients should require verifiable evidence of an operating quality management system, rather than a declaration of quality policy, within procurement evaluation criteria.

6. Conclusion, Limitations and Future Research

This study examined the awareness and practice of Total Quality Management principles among construction professionals in Imo State, Nigeria, within a sector undergoing digital transition. Analysing 106 responses through descriptive statistics and Mean Item Score ranking, and interpreting the results through Deming's PDCA cycle, the study found that 72.6% of professionals are aware of TQM principles while only 48.1% work in organisations that apply them, and that only 12.3% report high-level application. Practice is concentrated in input-oriented principles, namely procurement, quality control and process improvement, while communication between operational staff and senior management and the deployment of modern technological facilities are the least practised. The sector is thus positioned between the Plan and Do phases of the improvement cycle, with Check and Act substantially undeveloped. The principal constraint on construction quality in the study area is therefore organisational rather than educational, and the two weakest dimensions of practice are precisely those for which digital construction tools offer the most direct remedy.

6.1. Limitations of the study

Four limitations are identified in this study. First, the study is geographically confined to Imo State, selected as the commercial centre of the South-Eastern zone and the region least represented in the Nigerian TQM literature. TQM adoption and digital exposure are likely to differ elsewhere: Lagos State, with a larger and more competitive market and higher exposure to digital technology, may exhibit higher conversion of awareness into practice, whereas Northern states, with different institutional arrangements, may exhibit lower. The findings should therefore be read as a zone-specific baseline rather than a national account. Second, firms were selected on the basis of accessibility rather than by probability sampling, so statistical generalisation to the population of 172 registered firms is not claimed. Third, the analysis is descriptive and does not test relationships between firm characteristics and practice levels. Fourth, the study measures reported perceptions of TQM practice and does not measure the digitalisation level of participating firms, so the digital dimension is analytical and contextual rather than a measured firm-level variable.

6.2. Directions for future research

These limitations define the agenda that follows. Future work should employ stratified probability sampling across the six geopolitical zones to permit national generalisation and inter-zonal comparison; incorporate direct measurement of firm-level digital maturity alongside TQM practice, so that the relationship advanced here on analytical grounds may be tested empirically; apply inferential techniques, including regression or structural equation modelling, to identify the determinants of the awareness-to-practice conversion; and combine the survey with qualitative case studies of firms that have closed the awareness-implementation gap, in order to triangulate the survey findings.

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Appendix 1

Table 1: Demographic Profile of Respondents

Category	Classification	Frequency	Percentage (%)
Specialisation	Quantity Surveyors	29	27.4
	Engineers	38	35.8
	Architects	20	18.9
	Builders	19	17.9
	Total	**106**	**100.0**
Academic Qualification	HND	41	38.7
	B.Sc/B.Tech	37	34.9
	PGD	15	14.2
	M.Sc/M.Tech	13	12.3
	Total	**106**	**100.0**
Years of Professional Experience	0–5	30	28.3
	6–10	33	31.1
	11–15	22	20.8
	16–20	13	12.3
	21–25	6	5.7
	26–30	1	0.9
	Above 30	1	0.9
	Total	**106**	**100.0**
Professional Body	NIQS	22	20.8
	NIOB	14	13.2
	NIA	15	14.2
	NSE	30	28.3
	Total Members	**81**	**76.4**
	Non-Members	**25**	**23.6**
	Total	**106**	**100.0**

Source: Field Survey (2026)

An Evaluation of Time and Cost Performance of Construction Projects in Implementing Total Quality Management Principles

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Abstract

Purpose: The study evaluate cost and time overruns in construction projects carried out in Imo State, Nigeria, using Total Quality Management (TQM) principles.
Design: Structured questionnaires were used; the sample comprised 106 respondents, and data from 42 construction projects were included. The analysis used percentile analysis and a paired-samples t-test, which were presented in tables.
Findings: The project duration increased significantly, from an estimated average of 33.83 weeks to the actual completion time of 38.83 weeks ($t = 2.305$, $p = 0.026$). The cost analysis shows no statistically significant difference between estimated and actual cost ($t = -0.516$, $p = 0.608$), indicating that cost performance on TQM-associated projects was stable and broadly within budget. The time analysis reveals a statistically significant mean overrun of 5 weeks (12.3%) ($t = 2.305$, $p = 0.026$). The 12.31% overrun is substantially lower than the 70-188% overruns documented in comparable Nigerian studies.
Research Limitation and Implications: It is limited to construction projects in imo state.
Practical Implications: Regular use of TQM enhances overall project performance and reduces discrepancies between planned and actual performance.

Keywords: Cost Overrun, Iron Triangle, Time Overrun, Time Performance, Total Quality Management.

1. Introduction

One of the most significant factors in competitiveness, customer satisfaction, and profitability is quality, which involves doing things right to achieve excellence and reliability (Alzoubi et al., 2022). It involves consistency, the ability to produce defect-free products or services repeatedly, and fitness for purpose, the guarantee that a product or service fulfils its intended purpose (Gomaa, 2025). Barry & Campbell (2024) define quality as the level of excellence in terms of reliability, maintainability, and performance. In the construction industry, management plays a vital role in ensuring that resources, including labour, materials, machinery, and finance, are used effectively to produce high-quality results (Olurin et al, 2023). According to Shead (2010), management is the process of accomplishing tasks efficiently through coordinated effort, and Adusa-Poku (2014) defined it as the application of knowledge and experience to achieve practical outcomes.

Total Quality Management (TQM) combines the two key concepts of quality and management into a pervasive system of continuous improvement and organisational excellence (Schiavone et al., 2023). According to Lepisto et al. (2024), TQM is a comprehensive process that focuses on customer satisfaction, teamwork, top management commitment, and continuous improvement. Similarly, Deshmukh (2023) viewed TQM as a proactive philosophy that avoids defects during manufacturing rather than fixing them afterwards. Fundamentally, TQM is not a short-term project but a long-term cultural shift, and everyone in an organisation plays a role in improving quality (Putra & Arifin, 2022). TQM in the construction industry focuses on quality planning, quality control, quality assurance, and continuous improvement, thereby contributing to a culture of accountability, efficiency, and client satisfaction. The research problem centres on frequent cost and time overruns in construction projects despite efforts to enhance quality through TQM. Although TQM is a well-established concept in manufacturing and service industries, its application in the construction industry is low and uneven (Egwunatum et al., 2024). As Deshmukh (2023) notes, the implementation of TQM in the construction sector can minimise rework and cost waste and enhance efficiency, yet its potential has not been fully utilised in Nigeria. The industry is still grappling with ineffective communication, undertraining, obsolete tools, and management's lack of commitment, major obstacles to effective TQM implementation (Dilawo & Salimi, 2019).

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This research assessed the time and cost performance of construction projects in Imo State, Nigeria, that apply Total Quality Management (TQM) principles, to determine the extent of time and cost overruns in projects implemented using TQM-grounded practices compared with those implemented using conventional management models. The study compares estimated and actual project performance data from a project that uses TQM principles and performance outcomes and includes a non-comparison group.

2. Literature Review

2.1 Total Quality Management (TQM)

Many researchers have defined Total Quality Management (TQM). According to Deshmukh et al. (2023), TQM is defined as the continuous improvement of individuals, groups, departments, and organisational processes aimed at satisfying customer requirements first time and every time. Permana (2021) defines it as the condition of an organisation in which all activities and functions are designed and executed in a way that satisfies all external customer requirements, with less internal tuning and lower costs, and a better workplace climate. According to Helmond (2023), TQM refers to an organisation's long-term commitment to continuously improving quality through the active involvement of all members at all levels to meet and exceed customer expectations. The Total Quality Management (TQM) concept originated in the manufacturing Industry, leading some to believe it would not be applicable to other industries (Deshmukh et al., 2023). Irrespective of the fact that construction is unlike the manufacturing sector in terms of uniqueness in production. Alawag et al. (2024) affirmed that the merits and applicability of TQM in the Construction Industry help ensure that organisations do the right things correctly in the endless war on waste. TQM thus emphasises continuous improvement in product and service quality. According to Alam et al. (2024), TQM is a management philosophy and set of practices that strive to use an organisation's human and material resources as efficiently as possible to achieve its goals. It is a collection of guiding principles that form the backbone of an organisation in a state of constant improvement. TQM entails applying quality management principles and ideas across all dimensions of business operations (Abbas & Kumari, 2023). Roland (2010) further identified TQM as management practices across the firm geared towards ensuring that the organisation continuously meets or exceeds customer requirements, and highly emphasised process measurement and controls as a means of continuous improvement. Alawag et al. (2024) opined that TQM in the construction business refers to the ability of products and procedures to meet the set requirements and specifications.

2.2 Theoretical Framework: The Iron Triangle of Project Performance

This study is grounded in the Iron Triangle framework, also known as the Triple Constraint Model, which holds that every construction project operates within three interdependent performance constraints: cost, time, and quality (Atkinson, 1999; Kerzner, 2025). A change in one constraint typically affects the others unless scope or resources are adjusted (Fayomi et al., 2023). Total Quality Management is a quality intervention, and the Iron Triangle predicts that quality investment should produce corresponding improvements in cost and time performance by reducing rework and strengthening process discipline (Alawag et al., 2024). This study empirically tests that prediction. The finding that cost performance was statistically stable, while time performance showed a confirmed overrun, suggests that partial alignment with TQM protected the cost constraint but had insufficient reach over the time constraint at this stage of implementation.

3. Research Methodology

A quantitative survey was used to determine the performance of time and cost in construction projects, as applied to Total Quality Management (TQM) principles, in Imo State, Nigeria (Vivek & Rao, 2022). The survey methodology was chosen because it is effective at obtaining structured results from a large sample of construction professionals and, consequently, provides reliable and objective analysis (Dubey & Kothari, 2022). The target population comprises 172 construction firms registered with the Ministry of Works in Imo State. The minimum sample size was calculated using Yamane's (1967) formula: $n = N / (1 + N(e)^2) = 172 / (1 + 172 \times 0.01) \approx 63$ firms. A total of 63 accessible firms were identified using convenience purposive sampling. Within each firm, 2 to 4 professionals were selected as respondents. Of 159 distributed questionnaires, 106 were completed and returned, yielding a response rate of 66.7%. A project was classified as TQM-implementing if the respondent confirmed the application of at least five of the ten TQM principles assessed in the instrument, including procurement quality control, quality monitoring systems, and site management responsibility. The study conformed to a positivist paradigm, focusing on quantifiable facts to determine the relationship between TQM implementation and project performance in terms of time and cost efficiency. A structured questionnaire was used as a data collection instrument (Vincent et al., 2021), a similar approach in their studies. To analyse the data, percentiles and paired-sample t-tests were used to assess the statistical significance of differences in time and cost between estimated and actual project performance. The statistical analysis was performed using SPSS, which provided empirical data on the effectiveness of TQM-based delivery of construction projects (Alawag et al, 2023).

4. Discussion Of Findings

4.1 Characteristics of Questionnaire Respondents

Analysis of the respondents shows that the most represented professionals are Engineers and Quantity Surveyors, with about 38 (36%) and 29 (27%) responses, respectively. This shows that the most dominant construction professionals employed by construction firms are engineers and quantity surveyors, who account for more than 50% of respondents. This is followed by Architects and Builders, with response rates of about 20 (19%) and 19 (18%), respectively. However, most of the respondents sampled possess HND 41 (39%) and B.Sc / B.Tech 37 (35%), while about 15 (14%) and 13 (12%) have PGD and M.Sc / M.Tech degrees, respectively. In terms of years of experience, this research shows that only about 30 (28%) have fewer than 5 years, while a larger share exhibits 6 or more years. Furthermore, the Nigerian Society of Engineers (NSE) 30 (28.3%), followed by the Nigerian Institute of Quantity Surveyors (NIQS; 20.8%), the Nigerian Institute of Architects (NIA; 14.2%), and the Nigerian Institute of Builders (NIOB; 13.2%). This shows that 81 (76.4%) respondents were registered with their professional bodies, and 25 (23.6%) were not.

4.2 Level of Cost and Time Overruns on Construction Projects Executed with the Use of TQM Principles in the Imo State Construction Industry.

4.2.1 Level of Cost Overruns on Construction Projects Executed with TQM

Table 1 presents the results of a paired-samples t-test on cost data from construction projects that used TQM. The result shows a statistically significant decrease in the cost of the identified construction projects, from an average initial estimated cost of ₦99,196,119.05 to an average final cost of ₦98,840,285.71. Statistically, the initial estimated cost exceeds the project's final delivery cost. This is due to the addition of contingencies, which contractors often include to account for unforeseen circumstances. Nevertheless, the result further shows a t-value of -0.516 with a significant p-value of 0.608. This p-value is greater than 0.05, indicating no significant difference in the initial and final construction project costs when using TQM. This means that the difference between the initial estimated cost and the final actual cost is not statistically significant; that is, the cost of TQM-implemented projects lacks deviation from the initial estimate.

4.2.2 Level of Cost Overrun of Construction Project

In Table 2 (Appendix 1), the cost performance of a construction project that applied TQM was analysed using cost data collected from respondents. 42 construction projects were assessed, 6 were completed within the initial estimated cost, 13 were completed below it, and 23 were completed above it. Overall, an average cost savings of N355,833.33 was achieved across all construction projects where TQM was applied. This means that for individual projects carried out by construction firms, cost savings are achieved, and collectively, TQM reduces costs by up to 0.12% across all assessed projects. Thus, applying TQM principles to a project will improve its long-term cost performance by reducing maintenance costs.

'***Note:*** *All figures are rounded off*

4.2.3 Level of Time Overruns on Construction Projects Executed with TQM

Table 3 presents the results of a paired-samples t-test on time data collected from construction projects that

Table 1: Paired Sample T-Test for Initial and Final Cost of Construction Projects Executed with the use of TQM

Paired Differences										
		Mean	**Average Mean**	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**t**	**df**	**Sig. (2-tailed)**
						Lower	**Upper**			
Pair 1	Final cost	**9.8840E7**	-3.55833E5	4.46613E6	6.89139E5	-1.74758E6	1.03591E6	-0.516	41	**0.608**
	Initial Cost	**9.9196E7**								

Table 3: Paired Sample T-Test for Initial and Final Time of Construction Projects Executed with the use of TQM

Paired Differences										
		Mean	**Mean**	**Std. Deviation**	**Std. Error Mean**	**95% Confidence Interval of the Difference**		**t**	**df**	**Sig. (2-tailed)**
						Lower	**Upper**			
Pair 1	Final time -	**38.83**	5.00	14.05911	2.16937	.61887	9.38113	2.305	41	**.026**
	Initial time	**33.83**								

used TQM. The results show a statistically significant increase in the duration of the identified construction projects, from an average initial estimate of 33.83 weeks to 38.83 weeks. Statistically, the final delivery time exceeds the project's initial estimate. This is due to contractors and construction firms tendering jobs on acceptable delivery schedules to win contracts. Nevertheless, the result further shows a t-value of 2.305 with a significant p-value of 0.026. This p-value is less than 0.05, indicating a significant difference between the initial estimated time and the final delivery time of construction projects using TQM.

Furthermore, Table 4 (Appendix 1) below analyses the time performance of a construction project in which TQM was applied, based on time data collected from respondents. Of the 42 construction projects, 23 were completed within the initial estimate, while 19 were completed after the estimated delivery date. Overall, an average time overrun of 12.31% (5 weeks) was observed across all construction projects assessed that applied TQM principles. This is rather encouraging compared with the significant time overrun experienced in past research. The 12.31% mean time overrun observed in this study is substantially lower than the 188% time overrun reported by Omoregie and Radford (2006) for Nigerian construction projects and the 70% overrun documented by Frimpong et al. (2003) in Ghana. Whether this difference is attributable to TQM application or to other project characteristics, such as project type, procurement practices, or client payment patterns, cannot be determined from this dataset alone, as no non-TQM comparison group was assembled.

4.2.4 Level of Time Overruns on TQM Projects

Findings of this research show a percentage deviation of 12.31% on all assessed TQM projects, as indicated in Table 4. This is far below the 188% time deviation reported by Omoregie and Radford (2006) for construction projects in Nigeria, which indicates poor time performance in projects where TQM principles were applied. This result aligns with Onifade et al. (2024), who argue that TQM can reduce costs, increase satisfaction, and save time. Frimpong et al. (2003) observed 70% time overruns in 47 projects assessed in Ghana. Based on these studies, it can be concluded that TQM in construction improves time performance compared with conventional systems. Aghimien & Aigbavboa (2018) also find that educational projects funded by Tetfunds, Capital Project, and IGR exhibit good cost performance, as no significant differences were observed.

5. Conclusion and Further Studies

The study assessed the performance of construction projects implemented in Imo State, Nigeria, in terms of time and cost, using Total Quality Management (TQM). The paired-samples t-test results showed no statistically significant difference in overall project cost, indicating cost stability. However, a statistically significant time overrun was confirmed with a mean overrun. Although TQM helps enhance control and predictability, time and cost overruns were observed. The cost performance data indicated that projects reportedly using TQM principles were generally delivered within their initial budgets across all 42 assessed projects. This study finds that cost performance on TQM-associated projects was statistically stable and that time overruns, while confirmed, were substantially lower than those documented in prior Nigerian and African construction studies. The study is confined to Imo State. Future studies should adopt a matched-comparative design that pairs TQM and non-TQM projects of a similar type and value and should verify TQM classification through independent site audits or client assessments before extending claims about TQM effectiveness.

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Appendix 1

Table 2: Cost Performance of Construction Projects Executed with the Use of TQM

S/N	Project Type	Final cost (₦)	Initial cost (₦)	Variance (₦)	Percentage
1	Office duplex	350200000.00	348000000.00	2200000.00	0.63
2	Plaza building	173500000.00	173000000.00	500000.00	0.29
3	Etf project	160000000.00	160000000.00	0.00	0.00
4	School office	85000000.00	85200000.00	(200000.00)	-0.23
5	Building construction	980000.00	965000.00	15000.00	1.55
6	Commercial building	7500000.00	7400000.00	100000.00	1.35
7	Building project	850000.00	836000.00	14000.00	1.67
8	School project	15000000.00	15000000.00	0.00	0.00
9	State secretariat building	150000000.00	147000000.00	3000000.00	2.04
10	PHCN main office Owerri	82000000.00	85000000.00	(3000000.00)	-3.53
11	Imo river basin office	30000000.00	29600000.00	400000.00	1.35
12	School project	125500000.00	125000000.00	500000.00	0.40
13	School project	78000000.00	78000000.00	0.00	0.00
14	Building project	65200000.00	65000000.00	200000.00	0.31
15	School project	150000000.00	149500000.00	500000.00	0.33
16	School project	135600000.00	135450000.00	150000.00	0.11
17	Road construction	750000000.00	750015000.00	(15000.00)	0.00
18	Construction works	3472000.00	3469000.00	3000.00	0.09
19	Family house	1200000.00	1200000.00	0.00	0.00
20	Church hall	3500000.00	4200000.00	(700000.00)	-16.67
21	Residential building	6630000.00	6615000.00	15000.00	0.23
22	Farm house	2500000.00	2532000.00	(32000.00)	-1.26
23	Church project	2860000.00	2790000.00	70000.00	2.51
24	School project	37000000.00	37300000.00	(300000.00)	-0.80
25	Shopping complex	28000000.00	28000000.00	0.00	0.00
26	Building project	870000.00	890000.00	(20000.00)	-2.25
27	Building works	10500000.00	10000000.00	500000.00	5.00
28	Government project	220000000.00	216000000.00	4000000.00	1.85

S/N	Project Type	Final cost (₦)	Initial cost (₦)	Variance (₦)	Percentage
29	School auditorium	15000000.00	15000000.00	0.00	0.00
30	School office	6500000.00	6700000.00	(200000.00)	-2.99
31	School library (renovation)	3200000.00	3000000.00	200000.00	6.67
32	School gate (renovation)	1780000.00	1700000.00	80000.00	4.71
33	School project	30000000.00	29800000.00	200000.00	0.67
34	Owerri / onitsha road	758600000.00	758300000.00	300000.00	0.04
35	Renovation project	16000000.00	16500000.00	(500000.00)	-3.03
36	New building project	78000000.00	77600000.00	400000.00	0.52
37	Office building	150000000.00	150700000.00	(700000.00)	-0.46
38	Office block	2100000.00	2000000.00	100000.00	5.00
39	Renovation of zonal office	46000000.00	41000000.00	5000000.00	12.20
40	Rotary club office	7600000.00	7800000.00	(200000.00)	-2.56
41	Building	650000.00	675000.00	(25000.00)	-3.70
42	Building renovation	360000000.00	387500000.00	(27500000.00)	-7.10
				(₦ 355833.33)	**0.12**

Table 4: Time Performance of Construction Projects Executed with the Use of TQM

S/N	Project type	Final time (Weeks)	Initial time (Weeks)	Variance (Weeks)	Percentage
1	Office duplex	144	140	4	2.86
2	Plaza building	24	24	0	0.00
3	Etf project	42	42	0	0.00
4	School office	24	24	0	0.00
5	Building construction	32	30	2	6.67
6	Commercial building	128	58	70	120.69
7	Building project	12	12	0	0.00
8	School project	24	24	0	0.00
9	State secretariat building	96	48	48	100.00
10	PHCN main office Owerri	32	32	0	0.00
11	Imo river basin office	24	24	0	0.00
12	School project	56	52	4	7.69
13	School project	24	23	1	4.35
14	Building project	32	32	0	0.00
15	School project	36	35	1	2.86
16	School project	24	24	0	0.00
17	Road construction	64	62	2	3.23
18	Construction works	42	40	2	5.00
19	Family house	36	36	0	0.00
20	Church hall	28	28	0	0.00
21	Residential building	30	29	1	3.45
22	Farm house	24	24	0	0.00
23	Church project	44	24	20	83.33
24	School project	36	30	6	20.00
25	Shopping complex	24	22	2	9.09
26	Building project	24	23	1	4.35
27	Building works	24	24	0	0.00
28	Government project	64	64	0	0.00
29	School auditorium	24	24	0	0.00
30	School office	24	23	1	4.35
31	School library (renovation)	24	22	2	9.09

S/N	Project type	Final time (Weeks)	Initial time (Weeks)	Variance (Weeks)	Percentage
32	School gate (renovation)	24	24	0	0.00
33	School project	24	22	2	9.09
34	Owerri / onitsha road	20	20	0	0.00
35	Renovation project	36	36	0	0.00
36	New building project	35	32	3	9.38
37	Office building	72	34	38	111.76
38	Office block	38	38	0	0.00
39	Renovation of zonal office	48	48	0	0.00
40	Rotary club office	24	24	0	0.00
41	Building	12	12	0	0.00
42	Building renovation	32	32	0	0.00
				5.00 (Weeks)	**12.31**

EVALUATION OF CONTRACTOR PERFORMANCE ON PROJECT EXECUTION AMONG SELECTED INDIGENOUS CONSTRUCTION FIRMS (ICFs) IN NIGERIA.

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Abstract

This study examines contractor performance in project execution among Indigenous Construction Firms (ICFs) operating within the Victoria Island–Ibeju-Lekki corridor of Lagos State, Nigeria. Although contractor performance has received increasing attention in construction management research, there is limited empirical evidence on the factors influencing project execution among indigenous firms in this region. The study therefore investigates the key success factors and constraints affecting contractor performance during project delivery. A quantitative survey design was adopted, and fifty-five (55) structured questionnaires were randomly administered to construction professionals involved in project execution within the study area. Data were analysed using descriptive statistical techniques, including mean score ranking and percentile grading, to determine the relative importance of the identified factors. The findings indicate that the contractor–client relationship is the most significant factor influencing successful project execution, with a mean score of 4.56. This is followed by site management ability (4.22) and project management techniques (4.09). Working within budget recorded the lowest mean score (3.56). The study further identifies inadequate funding, inflation, delayed payments, poor relationships among consultants, changes in government administration, and contractor registration category as the major factors affecting contractor performance during project execution. The study is limited to indigenous construction firms operating in Lagos State and does not compare their performance with that of expatriate firms or firms in other regions. The findings provide practical insights for government agencies, clients, and policymakers seeking to improve project delivery outcomes. Strengthening contractor–client relationships, enhancing site management and project management capabilities, and addressing funding and payment challenges can improve contractor performance and enhance the competitiveness of indigenous construction firms in Nigeria.

Keywords: Construction Firms, Factors, Indigenous Nigeria, Performance, Project

1. Introduction

The construction industry brings a constant and exponential increase to the universe's gross domestic product (GDP), since its finished products are foundational enterprises of the economy, cutting across nearly all aspects of human activity and providing a physical framework necessary for social and economic life (Ackon et al., 2025, Adaji et al., 2023, Horsfall and Akoh, 2025, Ijigah and Olubiyi, 2025). As of 2020, the industry accounted for $10 trillion in global output, nearly 13% of the global economy(Ackon et al., 2025). Bukar and Ibrahim (2021) report that the industry contributed approximately 6%-10% globally. The scale of this contribution varies considerably by level of economic development. Typically, in highly developed economies such as Australia and the United Kingdom (UK), construction values are up to 25% of GDP(Abang, 2025). Iddrisu (2024) asserted that the construction industry contributes an average of 8.5% to Ghana's GDP. Nigeria Bureaucratic report cited in Adaji et al. (2023) corroborates Buba (2023), revealed that the industry contributed 4.45% and 6.83% to Nigeria's GDP between the second quarter of 2019 and 2020, respectively, accounts for up to 50% of domestic fixed capital formation (Buba, 2023, Ijigah and Olubiyi, 2025), and employs approximately 25% of the national workforce across all geopolitical zones (Ijigah and Olubiyi, 2025). Taken together, these figures confirm the sector's centrality to Nigeria's economic infrastructure, despite fluctuations in its precise GDP contribution across reporting periods. Within this sector lie indigenous contracting firms (ICFs). Although various definitions abound for ICFs, they can be simply defined as construction organizations that are wholly owned and managed by Nigerians (Yusuf et al., 2022). In other words, ICFs are registered enterprises operating without most of the foreign equity (Yusuf et

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al., 2022). This ownership and administrative structure is the primary differentiator from expatriate or multinational firms, which remain under the total direction of expatriate staff (Yusuf et al., 2022). Aliyu et al. (2025) state that ICF constitutes approximately 78%-80% of all small and medium-sized construction firms in the country, (Yusuf et al., 2022) opined that they complete a very small percentage of the nation's total project value. Expatriate firms, though fewer, complete "over 90% of the value of all construction projects" in Nigeria (Yusuf et al., 2022)

Lagos State, as Nigeria's foremost commercial and construction hub, presents a particularly important context for examining ICF performance. The Victoria Island and Ibeju-Lekki corridor, encompassing the Lekki Free Trade Zone and a major infrastructure development initiative, represents one of the most active construction activities in this area. Up till now, little importance has been given to assessing ICF performance specifically within this corridor using practitioner-grounded data. Most studies have focused only on project-level analysis in other Nigerian geopolitical zones and have adopted a national perspective, with little or no attention to the specific operational realities facing Lagos-based ICFs (Arijeloye and Oriyomi, 2023). This constitutes a significant empirical gap, as the Lagos construction market presents institutional, financial, and relational conditions distinct from those in other Nigerian regions and that directly shape ICF project outcomes. This study aims to examine contractor performance in project execution among selected indigenous construction firms operating within the Victoria Island–Ibeju-Lekki corridor of Lagos State, with a focus on identifying the key variables contributing to successful project execution and the major factors inhibiting ICFs' performance.

2. Literature Review

2.1. Indigenous Construction Firms (ICFs) in Nigeria

The exact time when Nigeria entered construction contracting is not known. However, scholars have historically categorised Nigerian contracting firms (NCFs) using various frameworks as presented in Figure 1. According to Yusuf et al. (2022), Nigeria's construction firms include both expatriate and indigenous contracting firms (ICFs)**.** The Ministry of Industry grades all Nigerian companies into four (4) main categories based on key financial and workforce size criteria: from micro-scale (capital up to ₦10 million; less than 30 workers) through to large-scale (above ₦300 million; more than 200 workers), with expatriates dominating the large-scale tier (Aliyu et al., 2025). While ICFs constitute the numerical majority of registered contractors, this dominance is largely illusory in terms of market power: large-scale contracts are awarded predominantly to expatriate firms, and Nigeria loses an estimated ₦9 billion annually to foreign capital outflows (Yusuf et al., 2022).

Critically, this exclusion is not simply a function of capability; it reflects institutionally embedded asymmetries in procurement design. Adaji et al. (2023) demonstrate that contractor selection criteria weight financial bonding capacity above demonstrated technical competence, systematically disadvantaging resource-constrained ICFs regardless of competence. This pattern is not unique to Nigeria, for instance: Iddrisu (2024) and Ackon et al. (2025) documented strikingly similar challenges in Ghana: inadequate project management skills, constrained material access, and planning failures, suggesting that post-colonial institutional legacies produce comparable structural constraints across sub-Saharan Africa. Iroha et al.

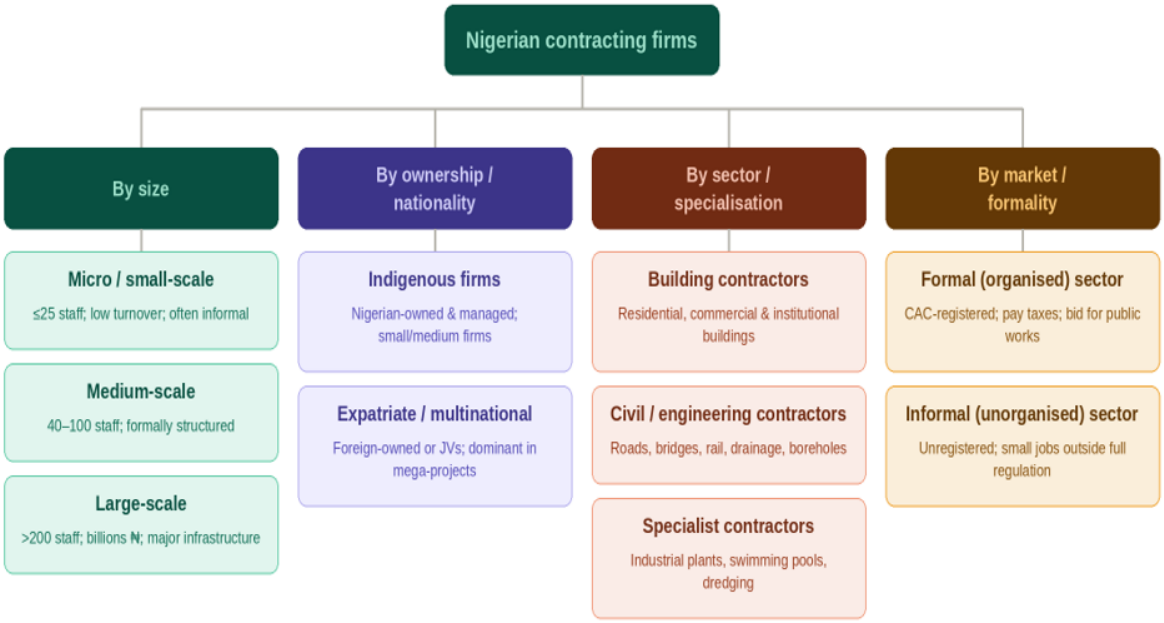

Figure 1: Classification Framework of Nigerian Contracting Firms: Source (Author's compilation, 2026)

(2024) further argue that the underutilisation of trained project managers in Nigeria is a structural failure of organisational design, not merely individual incapacity, reinforcing this continent-wide interpretation.

2.2. Contractor Performance Measurement

Conventionally, a contractor's performance is evaluated using the Iron Triangle framework: cost, time, and quality (Ackon et al., 2025). Accordingly, cost includes all monetary obligations required to complete the project baseline. Time refers to the start and finish schedules of project tasks estimated from resource estimates. Quality is measured as the degree to which a project meets technical specifications and conforms to established requirements. The Iron Triangle remains a valuable tool for quick assessments; however, scholars indicate that these constraints are no longer viewed in isolation. Nuhu et al. (2025) and Olatinwo et al. (2025) argue that it neglects relational, managerial, institutional, and social parameters. A contractor may meet all three output parameters yet still fail on stakeholder management or site security. Its persistent use in Nigerian performance studies reflects a tendency to apply convenient rather than contextually appropriate measurement tools.

Modern evaluation frameworks have consequently expanded to include a broader array of multidimensional indicators: the contractor's relationship with the client is heavily built on openness, trust, and responsive communication. It is identified as a critical performance dimension, particularly where weak contractual enforcement amplifies the role of informal arrangements. Ijigah and Olubiyi (2025) and Ackon et al. (2025) argue that maintaining a responsive working relationship is fundamental to meeting client expectations. However, the literature largely overlooks how asymmetric client power, including unilateral scope changes and delayed public-sector payments, distorts this relationship at ICFs' expense. Site management ability is defined as the proper organisation and management of materials, labour, and other resources on a construction site to reduce waste and improve profitability (Adaji et al., 2023). Security risks encompass physical site enclosure and material protection against theft (Opawole and Kajimo-Shakantu, 2021; Ackon et al., 2025), which represent further performance domains inadequately captured by project-level output metrics. Inadequate material storage compounds these risks, delaying availability, damaging inventory, and increasing operating cost (Aiyetan and Das, 2022, Arijeloye and Oriyomi, 2023).

Quality delivery presents a particular paradox for ICFs. Yusuf et al. (2022) identify high-quality construction as the primary competitive differentiator ICFs can leverage against expatriate firms, making quality a strategic positioning tool. Yet quality failure is most commonly attributed to untrained labour, substandard materials, and inadequate supervision (Iddrisu, 2024). Project Management Techniques, including PERT, Earned Value Management, and a digital tracking tool (Ackon et al., 2025), are theoretically designed to address these gaps. Still, Iroha, Watanabe and Satoshi (2024) show that even qualified project managers are rendered ineffective when organisational structures withhold authority and resources, challenging the assumption that human-capital investment alone resolves performance deficits. Working within budgets is similarly constrained by factors beyond the contractor's control. Ijigah et al. (2023) ranked cost predictability as the most influential factor in Tertiary Educational Trust Fund (TETFund), while Horsfall and Akoh (2025) emphasised the need for lifecycle cost management systems, including variance analysis. Yet Buba (2023) and Akoh et al. (2024) identify inflation, currency instability, and fixed-sum contract designs as the primary budget threats, as well as structural and macroeconomic conditions that transfer financial risk entirely to the contractor. This institutional arrangement disproportionately affects ICFs, whose thin capitalisation leaves them with no buffer against input cost escalation.

2.3. Factors Inhibiting Contractor Performance in Project Execution

The inhibiting factors facing ICFs form an interconnected system rather than discrete variables. At the financial level, funding shortfalls are the single most impactful cause of project delays (Egwim et al., 2021), compounded by inflation, currency instability, and fixed-sum contracts that offer no microeconomic protection (Akoh et al., 2024). Delayed client payments further erode site productivity (Muhammad et al., 2023). At the institutional level, flawed regulatory structures undermine project manager effectiveness (Iroha et al., 2024), while registration processes that ignore technical performance (Adaji et al., 2023) and political contract cancellations following government changes add further layers of risk that well-capitalised expatriate firms can absorb but ICFs typically cannot. Weak stakeholder management practices compound these structural disadvantages by inhibiting goal attainment and consultant coordination (Ola-awo et al., 2021). Viewed through an Institutional Theory lens, these are not random impediments but institutionalised constraints that systematically reproduce ICF disadvantage across project cycles.

Prior studies have examined contractor performance broadly across Nigeria (Akoh et al., 2024, Aliyu et al., 2025, Egwim et al., 2021). However, limited studies have focused specifically on the performance variables and inhibiting factors of ICFs operating within the Lagos South-West commercial corridor. Most performance studies rely on project-level outcome data from northern or south-south states rather than on practitioners' perceptions in Nigeria's highest-value construction market. This study addresses these gaps by assessing ICF performance across eleven execution

parameters through a structured questionnaire administered exclusively to professionals operating in Victoria Island and Ibeju-Lekki LGA, Lagos State.

3. Research Methodology

3.1. Research Design and Study Area

This study uses a survey design to measure construction professionals' opinions and perceptions regarding defined performance variables(Creswell and Creswell, 2017). The study was conducted in Victoria Island and the Ibeju-Lekki Local Government Area (LGA) of Lagos State, Nigeria. The high concentration of active ICFs informed the selection of this study area, the diversity of project types, and the accessibility of qualified construction professionals.

3.2. Population, Sample, and Data Collection

The target population comprised construction professionals, including architects, civil engineers, quantity surveyors, project managers, and contractors, who were actively engaged in ongoing construction projects within the study area. The sampling frame consisted of professionals identified from active construction sites and registered professional offices across Victoria Island and Ibeju-Lekki LGA. Simple random sampling was adopted to ensure equal probability of selection, thereby minimising selection bias (Saunders et al., 2023). Fifty-five (55) structured questionnaires employing a five-point Likert scale (1 = strongly disagree; 5 = strongly agree were administered by the lead researcher during working hours at construction sites and professional offices. Respondents completed the instrument in the researcher's presence, eliminating postal or electronic non-response. Respondents who were unavailable at the initial visit were revisited at a subsequent occasion. Sample size is consistent with comparable Nigerian construction studies (Adaji et al., 2023, Aliyu et al., 2025) and is appropriate for mean score ranking, where the objective is variable prioritisation rather than population generalisation (Fellows and Liu, 2015). Before analysis, the researcher screened all returned questionnaires for completeness and consistency; any item with missing or inconsistent responses was excluded, yielding a 100% usable response rate.

3.3. Validity, Reliability, and Ethics

Content validity was established through a pilot review with three experienced construction professionals and one academic expert, whose feedback refined item wording and clarity. Internal consistency reliability was assessed using Cronbach's alpha; $\alpha = 0.70$ was accepted as indicative of adequate reliability (Tavakol and Dennick, 2011). Participation was entirely voluntary; anonymity and confidentiality of responses were assured; and informed consent was obtained from all respondents prior to questionnaire administration

3.4. Data Analysis Technique

The data collected were analysed using percentile grading and mean score ranking. The mean score for each performance variable was calculated as:

$$\textbf{Mean Score } (\bar{x}) = \Sigma(fi \times xi) / N$$

Where, fi is the frequency of response, xi is the scale value, and N is the total number of respondents (55).

4. Findings and Discussion

4.1. Profile of Respondents

Out of 55 respondents, (72%) were male, reflecting the gender composition typical of the Nigerian construction industry workforce. In terms of professional background, project managers and civil engineers constituted the largest groups at 33% and 22% respectively, followed by quantity surveyors (15%), architects (18%), and contractors (9%). Over 54% of respondents reported more than 10 years of professional experience, lending credibility to the performance assessments. This multidisciplinary composition guards against single-profession bias and strengthens the credibility of performance assessments

4.2. Assessment of Contractor Performance Indicators on Project Execution

Table 1 presents the mean scores and ranks of the 11 project execution performance variables assessed in this study. All eleven variables recorded mean scores above the significance threshold of 3.50, indicating that respondents considered all variables to be relevant performance criteria for ICFs.

Table 1: Contractor Performance Indicators for Project Execution among ICFs

Variables	Response %					Mean Score	Rank
	1	2	3	4	5		
Contractor's Relationship with Client	0	0	2	19	34	4.56	1
Site Management Ability	0	1	5	22	27	4.22	2
Project Management Techniques	0	1	7	23	24	4.09	3
Quality of Work	0	1	6	25	23	4.09	3
Communication	0	2	7	23	23	4.03	5
Level of Security	0	2	8	22	23	4.00	6
Storage Facilities	0	2	8	23	22	4.00	6
Workers Welfare	0	2	8	23	22	4.00	6
Working on Schedule	1	3	9	22	20	3.88	9
Relationship with Site Neighbours	1	4	11	20	19	3.78	10
Working within the Budget	2	5	14	18	16	3.56	11

The Contractor's relationship with the client ranked first, with a mean score of 4.56; 34 of 55 respondents assigned the maximum score, and none assigned the minimum, indicating near-consensus rather than a mere arithmetic outcome. This finding extends Ackon et al. (2025) by showing that, in Lagos, where informal referral networks drive contract awards, the client relationship serves as both a project execution variable and a strategic business asset. This dual role is theoretically absent from Iron Triangle frameworks and represents a significant contextual finding. Site management, project management techniques, and quality of work occupy the second tier (means 4.22–4.09), consistent with Arijeloye and Oriyomi (2023)and (Ijigah and Olubiyi, 2025), who link implementation gaps in these areas to resource constraints rather than awareness deficits, a distinction critical for designing targeted intervention.

A methodological limitation warrants acknowledgement: four variables cluster at a mean of 4.00, making mean ranking alone insufficient to differentiate them. Examination of response distributions reveals greater dispersion for security and storage variables than for workers' welfare, suggesting greater practitioner disagreement, a distinction that inferential testing could clarify in future studies. Working within budget recorded the lowest mean (3.56) and the widest dispersion, with 7 respondents scoring it 1 or 2. Critically, this is not evidence of poor contractor competence. Still, regarding structural financial exposure, ICFs operating on fixed-sum contracts in a high-inflation environment have limited capacity to control input costs, regardless of managerial effort (Akoh et al., 2024). This has direct policy implications, specifically, the need to introduce inflation-adjustment mechanisms in public procurement contracts awarded to ICFs.

4.3. Factors Inhibiting Contractor Performance in Project Execution

Table 2 presents the eight principal factors identified by respondents as negatively influencing contractor performance during project execution.

Lack of proper funding, delayed payments, and inflation are the top three factors that form a compounding financial cycle rather than independent variables. Inflation erodes fixed contract values (Akoh et al., 2024), while delayed payments prevent contractors from managing that erosion through early procurement, and the resulting liquidity gap produces the funding shortfall that Egwim et al. (2021) identify as the primary delay driver. Policy interventions targeting one factor in isolation will deliver only partial relief. At the institutional level, the CORBON registration system ranked 4th, restricting ICF access to higher-value contracts by privileging financial capitalisation over demonstrated competence (Adaji et al., 2023), a regulatory design failure that reproduces the very performance gap it ostensibly seeks to measure. Poor consultant relationships ranked 5th reflect a failure in professional coordination that imposes additional performance costs on contractors (Olatinwo et al., 2025). Governance instability and the absence of enabling legislation rank lowest, yet their impact is likely underreported: practitioners may de-prioritise factors they perceive as beyond their control, suggesting that low index scores here reflect adaptive fatalism rather than minor impact.

5. Conclusion and Further Research

This study assessed the performance of selected indigenous construction firms in the South-West Region of Nigeria. The study identifies eight principal factors negatively influencing ICF performance and concludes that indigenous construction firms should reflect on their performance and change their present attitudes, which most clients regarded as nonchalant and lacking integrity. Therefore, government policy should be improved based on the performance of indigenous construction firms. Finally, Indigenous construction firms should also investigate appropriate capacity-building for their employees, including skilled, unskilled, and semi–skilled workers. This would improve the quality of their work delivery and improve their time management skills. Further research should investigate the performance of firms in other parts of Nigeria.

Table 2: Factors Inhabiting Contractor Performance

CAUSES	Index	Rank
Lack of proper funding	2.63	1
Delay in payment	2.40	2
Inflation	2.40	2
Category of registration	2.31	4
Change of government	1.69	5
Good relationship among consultants	1.69	5
Poor design and supervision	1.63	7
Lack of enabling law to regulate construction practice	1.44	8

Source: Field Survey (Author’s Compilation, 2026)

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Seasonal price variation of building materials and construction project performance in Nigeria

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Abstract

This study investigates the seasonal price variation of building materials and its impact on construction project performance in the Nigerian construction industry. The study specifically evaluates how the prevalence of seasonal price variation of building materials within the construction industry influence construction project performance in Nigeria. A survey research design was adopted, utilizing a structured questionnaire administered to 145 construction contractors across three major Nigerian cities: Lagos, Abuja, and Port Harcourt. Data collected were analysed using descriptive and inferential statistics. The study findings indicate that exchange rate fluctuations emerged as the most dominant factor driving seasonal price variation of building materials, with a mean score (MS) of 4.714. This was followed by inflation and monetary policy (MS = 4.619) and energy and fuel cost dynamics (MS = 4.333), ranked as the second and third factors respectively. Further analysis revealed that seasonal price variations significantly affected project cost and schedule delivery time, while their impact on quality performance was not statistically significant (Spearman *rho correlation coefficient = 0.000, p > 0.05*). The study concludes that seasonal price variation of building materials in Nigeria is less a seasonal anomaly and more a structural economic phenomenon, which undermines cost and in performance in construction project delivery. The study recommends a construction cost stabilization framework that will enhance cost predictability, improve schedule stability, and strengthen resilience against price shocks. Implementing such measures would support more sustainable construction project performance and value delivery in Nigeria.

Keywords: Building materials, Construction project performance, Seasonal price variation, Structural economic phenomenon, and Nigeria.

1. Introduction

The construction industry remains a critical pillar of national development due to its central role in infrastructure provision, employment generation, and economic growth. Globally, the sector contributes significantly to gross domestic product (GDP) and stimulates activities across allied industries such as manufacturing, transportation, and finance. Recent estimates indicate that global construction output was valued at approximately US$9.7 trillion in 2022 and is projected to increase substantially in the coming decades, reflecting the sector's expanding economic relevance (Sweet, 2021; Economic Consulting Team, 2024). These trends underscore the strategic importance of ensuring efficiency and performance in construction project delivery. In Nigeria, the construction industry occupies a central position in socio-economic development, particularly in addressing infrastructure deficits in housing, transportation, energy, and public utilities. The sector consistently ranks among the leading contributors to non-oil GDP and exhibits strong backward and forward linkages with other sectors of the economy (Oke *et al.,* 2019). Despite its significance, project delivery in Nigeria continues to be constrained by persistent challenges, including cost overruns, schedule delays, and quality shortfalls. A major underlying factor contributing to these challenges is the instability in the prices of building materials.

Building materials typically constitute a substantial portion of total construction costs, particularly in developing economies (Adu *et al*., 2020; Nnadi & Najjobyo, 2025). Caldas *et al*. (2015) reported that material inputs may account for up to 80% of overall construction expenditure. Given this high-cost share, material price volatility is a leading contributor to cost overruns, with most projects experiencing budget deviations, particularly in developing countries (Chapman & Quang, 2021). Fluctuations in material prices also directly influence project feasibility, budgeting accuracy, and performance outcomes. Empirical studies from Malaysia, Oman, India, Botswana, and Egypt indicate that material price volatility has led to project delays and cost overruns in both public and private construction projects (Al Amri & Marey-Perez, 2021; Adeyemi *et al.,* 2019). In

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Nigeria, the situation is particularly acute, with material prices experiencing uncontrollable and unprecedented increases, largely due to currency devaluation and liberalization of exchange rates (Olatunde *et al.,* 2025). Major construction materials such as cement, steel, and roofing components recorded price increases exceeding 200% between January 2024 and January 2026.

While construction economics literature has extensively discussed price volatility, most studies emphasize macroeconomic drivers such as inflation, exchange-rate fluctuations, and supply-chain disruptions, with limited attention to seasonality as a distinct and systematic source of variation. Seasonal price variation refers to predictable, cyclical changes in material prices associated with weather conditions, demand fluctuations, production constraints, and transportation challenges (Oginni *et al*., 2014). In Nigeria, construction activity typically intensifies during the dry season, when weather conditions favor material production, transportation, and site operations. Conversely, the rainy season constrains quarrying, timber processing, logistics, and site productivity, resulting in supply shortages and increased distribution costs (Usman *et al*., 2024). These seasonal dynamics exert upward pressure on the prices of key construction materials, including cement, aggregates, timber, and steel.

Unlike general inflationary trends, seasonal price variation is relatively predictable. However, when not anticipated or managed, it can adversely affect project performance. Escalating material costs disrupt cash flows, complicate procurement planning, and increase the likelihood of cost overruns. Delays in material procurement often led to schedule slippages and extended project durations. In some cases, rising material costs necessitate contract renegotiations, claims, or disputes between stakeholders (Anireddy, 2024). Moreover, attempts to mitigate price escalation through material substitution or scope adjustments may compromise construction quality and long-term asset performance. Consequently, seasonal price variation can negatively affect the three core dimensions of project performance in term of cost, time, and quality, thereby undermining value delivery and stakeholder satisfaction (Abdelalim *et al.,* 2025).

In Nigeria, most studies on construction cost overruns and material price instability have focused on inflation and exchange-rate volatility, with limited attention to seasonality as a distinct driver of price variation (Adegbembo & Adeniyi, 2015). There is also a paucity of research linking seasonal price variation to multidimensional project performance outcomes in terms of cost, time, and quality. Against this backdrop, the present study examines seasonal price variation of building materials and its implications for construction project performance in Nigeria. Specifically, it assesses the prevalence of seasonal price variation and evaluates its influence on project performance, providing empirical insights into the interaction between seasonal price dynamics and project outcomes.

2. Literature Review

2.1. Seasonal Price Variation of Building Materials

The construction industry is widely recognized as one of the most cost-sensitive and volatility-prone sectors of the economy, primarily because building materials account for a substantial portion of total project costs (Adu *et al.,* 2020; Malkanthi *et al.,* 2023; Anireddy, 2024). While material price volatility has been extensively studied in construction economics, the explicit and systematic investigation of seasonal price variation remains limited. Emerging evidence, however, suggests that construction material prices exhibit cyclical patterns that cannot be fully explained by inflation or broader macroeconomic volatility alone. Seasonal price variation refers to recurring, time-dependent fluctuations in material prices, driven by periodic changes in construction demand, supply logistics, and environmental conditions. Time-series analyses increasingly reveal seasonal components embedded in construction material price data. For example, Maqsoom *et al*. (2024) demonstrated that material price fluctuations persist even after controlling for inflation and exchange-rate movements, indicating the influence of cyclical forces. Similarly, forecasting studies using decomposition and autoregressive models show that prices of key materials, including cement and steel, fluctuate in alignment with seasonal construction activity (Passek & Nubel, 2025).

Climatic and weather-related conditions are central drivers of seasonal variation in construction activity and material prices. Empirical studies indicate that precipitation, temperature, and humidity significantly affect construction productivity, material handling, and site operations (Oruc *et al.,* 2024). These environmental factors indirectly influence procurement timing, demand intensity, and logistics efficiency, reinforcing cyclical price movements. In climate-dependent construction environments, seasonal constraints on production and transportation often result in temporary supply shortages and price escalations. Econometric evidence from Scopus-indexed studies further confirms that seasonality contributes substantially to short-term construction material price volatility. Time-series decomposition analyses show that seasonal components account for a significant share of observed price fluctuations, particularly in regions with pronounced wet–dry seasonal cycles (Banaś & Kozuch, 2019; Liu *et al*., 2024). These findings challenge the notion that price instability is driven primarily by macroeconomic shocks and highlight the need for season-sensitive cost forecasting models.

In developing economies such as Nigeria, seasonal price effects are amplified by structural supply-side constraints. Fragmented supply chains, inadequate transport infrastructure, limited storage capacity, and heavy reliance on road logistics heighten vulnerability to seasonal disruptions. Empirical studies link rising transportation costs, delivery delays, and reduced material availability to increased procurement costs and negative project performance outcomes (Awaad *et al.,* 2024). During the rainy season, reduced quarry output, poor road conditions, and port congestion constrain supply, whereas dry seasons often coincide with intensified construction demand, reinforcing cyclical price escalation. Market structures and supplier behaviours further exacerbate seasonal price variation. High market concentration, supply scarcity, weak regulatory oversight, and limited price transparency enable suppliers to exploit periods of high demand, limiting effective price stabilization (Gunduz, 2025). Although inflation explains long-term upward price trends, evidence indicates that seasonality drives short-term deviations around inflation-adjusted price paths (Maqsoom *et al.,* 2024). Failure to account for these dynamics in cost estimation is associated with budget underestimation and elevated risk of cost overruns (Musarat *et al*., 2024). Despite growing recognition of these trends, the literature remains fragmented, with few studies treating seasonality as a primary explanatory variable or directly linking it to construction project performance in Nigeria (Gunduz *et al.,* 2025; Timothy, 2025). This gap underscores the need for empirical research that integrates seasonal price dynamics into construction cost management and performance analysis. The seasonal price variation factions considered in this study are summarized in Table 1. These factors were further examined during the pilot survey, resulting in the adoption of 13 variables for the main study.

2.2. Impacts of Seasonal Price Variation of Building Materials on Construction Project Performance

Seasonal price variation of building materials is increasingly recognized as a critical determinant of construction project performance. Among the key performance dimensions, cost performance is particularly vulnerable, as materials typically constitute a substantial portion of total project expenditure. Recent studies in construction economics indicate that material price volatility complicates cost forecasting and contributes to budget deviations. For example, Anireddy (2024) observed that fluctuations in material prices are strongly associated with budget increases and reduced predictability of project costs. Similarly, Xiong *et al*. (2025) argue that material price dynamics go beyond general inflationary trends, as seasonal price spikes introduce additional uncertainty that undermines both budgeting accuracy and project viability. Such volatility complicates procurement planning, often resulting in significant disparities between planned and actual project budgets (Anireddy, 2024).

Time performance is also significantly affected by seasonal price dynamics, particularly where procurement planning is poorly aligned with cyclical market conditions. Empirical evidence from developing construction markets demonstrates that material price volatility poses a major challenge to timely project delivery. Nnadi and Najjobyo (2025) highlight that rising and unstable material prices constrain contractor cash flow, leading to postponed purchasing decisions and delayed material

Table 1: Seasonal Price Variation Influencing Building Materials Prices

Factors	Sources
Exchange Rate Fluctuations	Olatunde *et al*., 2025; Passek and Nubel, 2025
Inflation	Maqsoom *et al*., 2024; Gunduz, 2025
Energy and Fuel Cost	Adu *et al.,* 2020
Logistics Variability	Awaad *et al.,* 2024
Supply Chain Disruptions	Passek and Nubel, 2025; Awaad *et al.,* 2024
Demand-Driven Cycles	Nnadi and Najjobyo, 2025
Raw Material Fluctuations	Maqsoom *et al*., 2024
Industrial Capacity	Nnadi and Najjobyo, 2025
Market Structure	Banaś and Kozuch, 2019
Transportation Cost	Awaad *et al.,* 2024
Procurement Timing	Maqsoom et al., 2024; Timothy, 2025
Weather Conditions	Oruc *et al.,* 2024
Labour Cost	Adu *et al.,* 2020
Global and Geopolitical Events	Anireddy, 2024
Monetary Policy	Adegbembo and Adeniyi, 2015; Anireddy, 2024
Construction Activity Patterns	Maqsoom *et al*., 2024
Production Constraints	Nnadi and Najjobyo, 2025
Fuel Cost	Adegbembo and Adeniyi, 2015
Commodity Market Fluctuations	Maqsoom *et al*., 2024

procurement, which directly affect project schedules. These disruptions reduce material availability and slow site operations, increasing the likelihood of schedule overruns. Similarly, Mekonen *et al.* (2025), in a study of Ethiopian construction projects, report that rapid material price changes and shortages are significant contributors to project delays, particularly in contexts with persistent supply chain and logistical challenges. In Nigeria, Timothy (2025) confirms that material cost fluctuations prolong project delivery timelines, highlighting the adverse effects of unstable pricing and procurement conditions on time performance.

Quality performance is indirectly influenced through the cost and schedule pressures induced by seasonal price variation. Escalating material costs often compel contractors to adopt cost-driven strategies such as material substitutions, deferred procurement, or reduced material specifications. While direct empirical evidence linking seasonal price variation to quality outcomes is limited, existing research demonstrates a strong relationship between procurement and material management practices, often shaped by financial constraints and construction quality. Yıldız *et al.* (2024) confirm that ineffective material management arising from cost pressures adversely affects construction quality outcomes. Consequently, inadequate responses to seasonal price volatility can compromise workmanship, material durability, and long-term asset performance. Based on the forgoing, the literature confirms that seasonal material price variation exerts interconnected effects on cost, time, and quality performance.

3. Research Methodology

This study investigates the seasonal price variation of building materials and its influence on project performance in the Nigerian construction industry. A descriptive survey research design was employed, utilizing a structured questionnaire to collect data from industry professionals. The questionnaire method adopted helps to facilitates the efficient collection of standardized data from a relatively large number of respondents and supports quantitative analysis of the study variables. The study variables were derived from a comprehensive literature review focusing on empirical studies related to seasonal price variation of building materials. To ensure the questionnaire captured relevant insights, a pilot study was conducted involving semi-structured interviews with eight academic and industry experts. Data were collected through structured questionnaires administered to 145 construction companies listed in the Federation of Construction Industry (FCI), Nigeria, domiciled in three strategic cities: Lagos, Abuja, and Port Harcourt. The data collection exercise lasted six weeks, which was considered sufficient to obtain responses from the target population. Targeted respondents included project managers, procurement officers, and registered quantity surveyors directly involved in material procurement, project planning, cost control, and construction execution. The questionnaire employed a five-point Likert scale (1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, 5 = strongly agree) and was structured into three sections: Section A captured respondents' demographic information; Section B assessed the prevalence of seasonal price variation factors; Section C examined the influence of these factors on three key project performance indicators: cost effectiveness, timely project delivery, and quality of completed projects.

Out of 145 administered questionnaires (distributed via face-to-face interactions and email), 122 were returned. Four were deemed invalid due to incomplete responses, leaving 118 valid questionnaires, representing a response rate of 81%, which is sufficient for statistical analysis. For analysis, Mean Score (MS) was employed to determine the extent of the prevalence of seasonal price variation of building materials and its perceived influence on construction project performance by ranking respondents' assessments based on their level of agreement. Significance levels were classified following Kazaz et al. (2008) Furthermore, Spearman's Rank Correlation (Spearman's rho) was adopted to examine the strength and direction of the relationship between the prevalence of seasonal price variation of building materials and the three selected construction project performance indicators in Nigeria. The technique is suitable because the study data were derived from ordinal (Likert-scale) responses and Spearman's rho effectively measures the degree of association between variables without requiring a normal distribution of the data.

4. Findings and Discussion

4.1. Characteristics of Respondents Used for the Study

The demographic characteristics of the respondents were analysed using descriptive statistics. The results indicate that 41% of the participants were based in Lagos, 33% in Abuja, and 26% in Port Harcourt. This distribution reflects a reasonable representation of the three major construction hubs selected for the study. In terms of professional background, quantity surveyors constituted the largest proportion of respondents (48%), followed by project managers (29%) and procurement officers (13%). With respect to professional experience, the findings show that over 61% of the respondents possess more than 20 years of relevant industry experience, and all respondents hold at least a first degree or its equivalent. The data obtained from the respondents can be considered credible and suitable for informed analysis and decision-making.

4.2. Analysis of Prevalence of Seasonal Price Variation Factors of Building Materials

To determine the most prevalent factors influencing seasonal price variation of building materials in the Nigerian construction industry, a ranking analysis based on Mean Scores (MS) was conducted. This involved the evaluation of responses to the 13 factors included in the questionnaire. The results comprising Mean Score (MS), standard deviation (SD), rank, and corresponding remarks are presented in Table 2.

Table 2: Results of analysis of seasonal price variation factors of building materials

Seasonal price variation factors	Mean	SD	Rank	Remarks
Exchange Rate Fluctuations	4.714	0.508	1	VHS
Inflation and Monetary Policy	4.619	0.539	2	VHS
Energy and Fuel Cost Dynamics	4.333	0.612	3	HS
Transportation and Logistics Cost Variability	4.238	0.692	4	HS
Supply Chain Disruptions	4.119	0.670	5	HS
Demand-Driven Cycles and Construction Activity Patterns	4.024	0.604	6	HS
Raw Material and Commodity Market Fluctuations	3.857	0.683	7	HS
Industrial Capacity and Production Constraints	3.738	0.701	8	HS
Market Structure and Industry Competition	3.381	0.731	9	MS
Policy, Regulation, and Procurement Timing	3.238	0.692	10	MS
Climatic and Weather-Related Factors	3.048	0.854	11	MS
Labour Cost and Industrial Workforce Dynamics	2.571	0.630	12	LS
Global Economic and Geopolitical Events	2.405	0.734	13	LS

Note: LS = Low Significance, MS = Moderate Significance, HS = High Significance, VHS = Very High Significance

The findings indicate that among all factors, exchange rate fluctuations ranked highest (MS = 4.714, SD = 0.508). This prominence can be attributed to its extensive and immediate impact on a wide range of construction inputs, particularly in an import-dependent industry. Its influence is more pervasive compared to other factors, thereby positioning it as the most dominant driver of seasonal price variation. Conversely, the least ranked factors are labour cost and industrial workforce dynamics (MS = 2.571, SD = 0.630) and global economic and geopolitical events (MS = 2.405, SD = 0.734). The top five most significant factors identified in the analysis are: exchange rate fluctuations (MS = 4.714, SD = 0.508), inflation and monetary policy (MS = 4.619, SD = 0.539), energy and fuel cost dynamics (MS = 4.333, SD = 0.612), transportation and logistics cost variability (MS = 4.238, SD = 0.692), and supply chain disruptions (MS = 4.119, SD = 0.670).

These findings highlight the dominant role of both macroeconomic variables and supply-chain-related factors in shaping seasonal price behaviour in Nigerian construction industry.

4.3. Analysis of Influence of Seasonal Price Variation of Building Materials on Project Performance

This subsection examines the influence of seasonal price variation of building materials on project performance. To achieve this, a null hypothesis was formulated, which states that there is no significant correlation between seasonal price variation of building materials and project performance. The decision rule adopted for the analysis is to reject the null hypothesis when the p-value is less than 0.05 and to accept it when the p-value is greater than 0.05. The top five ranked factors were correlated with three key project performance indicators: cost, time, and quality, using Spearman's rank correlation, as presented in Table 3.

Table 3: Results of correlation analysis between prevalence of seasonal price variation of building materials and project performance

Variables	R-value	P-value	Decision
Exchange rate fluctuations			
Budget increases and inaccurate cost prediction	-0.149	0.348	Reject
Schedule delay and overruns	-0.164	0.301	Reject
Compromise to workmanship and material durability	0.636	0	Accept
Inflationary and monetary policy			
Budget increases and inaccurate cost prediction	0.04	0.799	Reject
Schedule delay and overruns)	0.194	0.217	Reject
Compromise to workmanship and material durability	-0.35	0.023	Accept
Energy and fuel cost dynamics			
Budget increases and inaccurate cost prediction	-0.023	0.886	Reject
Schedule delay and overruns	0.111	0.484	Reject
Compromise to workmanship and material durability	0.409	0.007	Accept
Note: R-value = correlation coefficient; p-value is significant @ $p \geq 0.05$			

The results in Table 3, indicate that the p-values associated with cost and time performance are below the 0.05 significance level. Consequently, the null hypothesis is rejected for these two indicators. This finding suggests that seasonal price variation of building materials has a statistically significant influence on both project cost and schedule performance. For example, exchange rate fluctuations show a positive association with budget increases and inaccurate cost prediction (p-value = 0.348) and schedule delay and overruns (p-value = 0.301). Although these relationships indicate a degree of association, they are not statistically significant at the 5% level. In contrast, the relationship between seasonal price variation and project quality is not statistically significant at the 5% level (p-value = 0.000). Therefore, the null hypothesis is accepted for quality performance. Similar trends were observed for the remaining factors examined in the study. This suggests that, despite cost pressures, construction stakeholders maintain adherence to required technical standards and specifications.

4.4. Discussion of Findings

4.4.1. Prevalence of Seasonal Price Variation of Building Materials in the Nigerian Construction Industry

The findings of this study indicate that exchange rate fluctuations, inflation and monetary policy, energy and fuel cost dynamics, transportation and logistics cost variability, and supply chain disruptions are the most prevalent drivers of seasonal price variation in the Nigerian construction industry. These results underscore the combined influence of macroeconomic conditions and operational supply-chain factors on the price behaviour of construction inputs. Exchange rate fluctuations emerged as a dominant determinant of seasonal price variation. This reflects the Nigerian construction industry's heavy reliance on imported materials, including steel products, finishing materials, and mechanical equipment. Depreciation of the domestic currency increases import costs, which in turn leads to periodic spikes in material prices. Empirical evidence further suggests that exchange rate volatility disrupts supply chain stability and increases procurement costs, particularly in import-dependent developing economies. Inflation and monetary policy were also identified as critical drivers. Inflation raises the general price level of goods and services, including construction materials, thereby contributing to persistent price fluctuations. The findings of Musarat *et al.* (2020) demonstrate a statistically significant relationship between inflation and construction material price behaviour, identifying inflation as a major contributor to project cost overruns. This implies that inflationary pressures directly increase procurement costs, especially during periods of macroeconomic instability.

Energy and fuel cost dynamics constitute another key factor influencing seasonal price fluctuations. The construction industry depends heavily on energy-intensive processes, such as cement manufacturing, steel production, and material transportation. Consequently, increases in diesel and petrol prices often translate into higher material costs. Prior studies show that energy price volatility significantly affects the prices of key materials, including steel, bitumen, and cement (Gunduz *et al*., 2025). Recent increases in fuel pump prices have further exacerbated cost pressures within the Nigerian construction sector. Transportation and logistics cost variability also plays a significant role. Inadequate transport infrastructure, combined with seasonal challenges such as heavy rainfall, flooding, and road deterioration, increases logistics costs and disrupts material distribution. These disruptions often result in temporary supply shortages and consequent price increases. Empirical evidence identifies transportation costs as one of the highest-ranked contributors to construction material price volatility in Nigeria (Nnadi & Najjobyo, 2025).

The findings of this study are consistent with existing literature on construction material price volatility in developing economies. Ikechukwu (2021) identified inflation, exchange rates, and demand–supply dynamics as key determinants of material price fluctuations in Nigeria. Similarly, Adegbembo and Adeniyi (2015) reported a positive correlation between macroeconomic indicators—such as inflation, exchange rates, and interest rates and building material prices. Further evidence from Musarat *et al*. (2020) and Samsir *et al*. (2023) confirms a strong relationship between inflation and construction material price volatility, particularly for cement and steel, in Pakistan and the Johor construction industry, respectively. In addition, studies from Qatar highlight the role of energy costs, transportation expenses, and supply chain disruptions in driving material price volatility and project delays (Gunduz *et al.,* 2025). These parallels suggest that the drivers of seasonal price variation in Nigeria align with global trends. However, their effects are often more pronounced in developing economies due to structural challenges, including infrastructural deficits and macroeconomic instability.

4.4.2. Influence of Seasonal Price Variation of Building Materials on Project Performance

The significant influence of seasonal price variation on project cost can be attributed to the fact that building materials constitute a substantial proportion of total construction expenditure (Caldas *et al*., 2015; Nnadi & Najjobyo, 2025). Fluctuations in the prices of essential materials such as cement, steel, and aggregates often driven by macroeconomic conditions, result in unexpected increases in procurement costs for contractors. This finding aligns with previous studies, which identify inflation, exchange rates, and transportation costs as key drivers of material price

volatility and major contributors to poor cost performance and budget overruns (Nnadi & Najjobyo, 2025; Musarat *et al.,* 2020; Musarat *et al.,* 2021). The observed impact on project time (schedule performance) is largely linked to disruptions in material availability and procurement delays arising from supply chain constraints and logistical challenges. Rapid price increases or material shortages often compel contractors to delay procurement, renegotiate contracts, or seek alternative suppliers. These responses disrupt planned workflows and ultimately lead to schedule overruns and extended project durations. In contrast, seasonal price variation does not appear to significantly influence project quality. This suggests that, despite cost pressures, construction stakeholders maintain adherence to required technical standards and specifications. This finding differs from some studies that associate cost constraints with reduced quality performance. A plausible explanation is that projects represented in this study were subject to strict contractual requirements and effective professional supervision, which limited the likelihood of quality compromise. Consequently, rather than reducing quality, contractors tend to absorb additional costs, renegotiate budgets, or adjust project timelines to ensure compliance with established standards.

5. Conclusion and Further Research

This study establishes that seasonal price variation of building materials in Nigeria is largely driven by the interaction of macroeconomic forces and supply-chain inefficiencies. Key drivers include exchange rate volatility, inflationary pressures, energy cost dynamics, logistics variability, and supply disruptions. These factors operate in a mutually reinforcing manner, producing cyclical and often unpredictable price movements. The findings further suggest that such instability extends beyond mere seasonality and reflects deeper structural weaknesses within the construction economy, particularly its reliance on imported inputs and inadequate logistical systems. The study also reveals that the effects of price variation are most evident in project cost and time performance. In contrast, project quality appears largely unaffected. This outcome indicates that regulatory frameworks, professional standards, and contractual provisions effectively safeguard quality. It is concluded that construction price volatility is not merely a seasonal occurrence in the climatic sense, but a structurally embedded economic phenomenon that undermines cost predictability and schedule reliability. The study therefore recommends that, firstly, there is a need to institutionalize a comprehensive construction cost stabilization framework. This should include the adoption of fluctuation clauses and real-time price indexation in construction contracts through collaboration among government, industry stakeholders, and professional bodies such as the Nigerian Institute of Quantity Surveyors. Secondly, government intervention is required to address underlying structural challenges. Efforts should focus on stabilizing key macroeconomic variables, promoting local production of construction materials, and improving transport infrastructure

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Strengthening Financial Accountability in Project Management Units of Eastern Cape Metropolitan Municipalities

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Abstract

Project management Units play a crucial role in infrastructure development. However, their performance has been inefficient due to structural challenges. Therefore, this study explored the challenges affecting and practical strategies to address the financial accountability inadequacies within Project Management Units (PMUs) of metropolitan municipalities in the Eastern Cape. The study used a qualitative case study approach, focusing on two metropolitan municipalities in the Eastern Cape. Data were collected through semi-structured interviews. Purposively selected senior municipal officials responsible for project and financial management with expertise and insight into the research topic including PMU management, project managers, and finance-related personnel. Interviews were recorded, transcribed, and analysed thematically using ATLAS.ti to identify key patterns and themes. Revealed challenges were Capacity and communication, Documentation and tracking, and Knowledge and Training Gaps. Several strategies to address these accountability challenges were Enhanced professional development and policy training for PMU officials, Implementation of effective internal controls, inclusive stakeholder engagement and transparency, and Resource allocation and project tracking. Strengthening internal controls, improving skills through continuous training, introducing integrated financial systems, and enforcing consequence management are supported as practical resolutions to address financial accountability inadequacies within PMUs. While the study's limited sample size restricts broad generalisability, the results offer a preliminary understanding of systemic challenges and interventions relevant to municipal contexts**.** The study contributes to public sector project management by providing practical governance, financial oversight and technological strategies that can strengthen financial accountability and improve infrastructure delivery within metropolitan municipalities.

Keywords: Eastern Cape, Financial Accountability, Metropolitan municipalities, Municipal Finance Management Act, Project Management Unit

1. Introduction

Effective financial management techniques are essential for the long-term viability of municipalities in South Africa (Botlhoko, 2017). Such practices underpin the process of democratic financial accountability and good governance. According to Khanyile (2016), financial accountability entails the public promotion and disclosure of performance information. Financial accountability, according to Botlhoko (2017), necessitates prudent financial management and the integration of financial and non-financial reporting by governments. His position is that the government ought to provide exhaustive reports detailing the results of its financial expenditures, and that stakeholders ought to conduct themselves in an ethical manner

Municipalities play a crucial role in delivering infrastructure and essential services to communities. Consequently, effective financial management is crucial for achieving long-term developmental objectives. The Constitution of the Republic of South Africa requires municipalities to handle financial resources judiciously while ensuring transparency and accountability in governance processes (Ntshangase & Msosa, 2022). The Municipal Finance Management Act (MFMA) was enacted to enhance financial governance by establishing uniform criteria for budgeting, reporting, and accountability across all local government entities (Botlhoko, 2017).

Local governments face numerous issues, one of which is the deterioration of municipal infrastructure (Botlhoko, 2017). The infrastructure of cities is in desperate need of replacement, restoration, or repair right now. As a result, the cities are now unable to meet the growing demand for their services due to the necessary infrastructure deteriorating more quickly than anyone had predicted (Ntjatsane, 2017). Maluleke (2023) reported that Nelson Mandela Bay Municipality (NMBM) achieved only 53% of its basic service delivery program targets for the financial year 2021/2022. Further, these difficulties highlight the substantial efforts still required to enhance service delivery and reinforce accountability within the Municipality. Maluleke (2023) also stated that Eastern Cape municipalities recorded irregular expenditure of

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R10.6 billion during the 2021/2022 financial year due to their failure to adhere to prescribed procurement procedures. Notably, Buffalo City Metropolitan Municipality (BCMM) was the primary contributor, being responsible for R6.5 billion, which constituted 61% of the total irregular expenditure.

Despite the implementation of these regulations, numerous towns continue to experience issues with erratic expenditure, inadequate supervision, and declining financial performance. Research indicates that Project Management Units (PMUs), responsible for infrastructure development, significantly contribute to these issues due to their inefficiency and institutional constraints (Ngumbela, 2021). The study identified that challenges such as weak internal controls, inadequate financial management practices, and insufficient administrative oversight have been identified as significant factors affecting compliance with financial regulations within the PMUs.

Although previous studies have examined financial accountability and municipal financial management in South Africa, limited research has specifically explored the financial accountability challenges experienced within Project Management Units (PMUs) of metropolitan municipalities in the Eastern Cape Province. Furthermore, little empirical evidence exists on practical strategies that can strengthen accountability within PMUs responsible for infrastructure delivery. This study addresses this gap by providing context-specific insights into the challenges and interventions required to improve financial accountability in metropolitan municipal PMUs.

Therefore, the study aims to explore ways of how the PMUs of Metropolitan Municipalities within the Eastern Cape Province can foster financial accountability. The objectives of the study are to explore the challenges affecting and practical strategies to address the financial accountability inadequacies within Project Management Units (PMUs) of metropolitan municipalities.

2. Literature Review

This section reviews the literature on financial accountability, the legal framework, challenges, and strategies within Project Management Units (PMUs).

2.1. Financial Accountability in PMUs

Financial accountability within PMUs demands adherence to stringent budgetary controls, transparent financial reporting, and prudent fiscal management (Makgato, 2019). PMUs are expected to operate within allocated budgets, optimise resource utilisation and mitigate financial risks to ensure project viability and sustainability (Nkosi & Mamba, 2021). Additionally, stakeholders and funding bodies require PMUs to demonstrate cost-effectiveness, value for money, and compliance with financial regulations (Smith, 2018).

Achieving financial accountability in PMUs requires a multi-faceted approach encompassing transparency, integrity, and stakeholder engagement (Makgato, 2019). PMUs implement internal control mechanisms, conduct regular audits and publish financial statements to enhance transparency and accountability (Smith, 2018). Moreover, fostering a culture of ethical conduct, zero-tolerance for corruption, and promoting stakeholder participation in financial oversight processes contributes to strengthening the financial accountability of PMUs (Nkosi & Mamba, 2021).

2.2. Legislative Framework for Municipal Financial Accountability

Recent studies highlight that legislation, and regulations provide a statutory framework within which officials and managers can carry out their duties and responsibilities (Smith & Adams, 2018). Some of these policies specifically relate to the implementation and maintenance of institutional internal controls (Nkosi & Mamba, 2021). Therefore, public policies legally require officials to perform these duties, knowing that if they do not adhere to legislative policies, corrective measures will be taken against them (Smith, 2018). Government legislation, policy objectives, and administrative functions are intended to regulate government institutions regarding financial management (Makgato, 2019). Financial regulations refer to the legislation and policies designed to govern public sector financial management. “The aim of such legislation is to establish common norms, standards, and procedures across all public agencies and departments to ensure continuity and accountability” (Jones & Kettle, 2019).

Policy, as defined by Nkosi (2017), is a statement of intent that lays out the fundamental principles to achieve specific goals. It interprets the values of society and is usually part of the management of relevant projects and programs. Therefore, PMUs should maintain the regulations provided by the statutory framework to meet their financial management obligations

The Municipal Finance Management Act (MFMA) of South Africa provides a legislative framework governing financial management practices within PMUs (Ndlovu et al., 2020). PMUs are mandated to comply with MFMA regulations, including budget preparation, expenditure control, procurement processes, and financial reporting (Nkosi & Mamba, 2021). Non-compliance with MFMA guidelines can result in financial irregularities, mismanagement of funds, and compromised project outcomes (Makgato, 2019).

2.3. Challenges Affecting Financial Accountability

As indicated before, Local governments face numerous issues, one of which is the deterioration of municipal infrastructure (Botlhoko, 2017). The infrastructure of cities is in desperate need of replacement, restoration, or repair right now. As a result, the cities are now unable to meet the growing demand for their services due to the necessary infrastructure deteriorating more quickly than anyone had predicted (Ntjatsane, 2017). Ntshangase and Msosa (2022) also emphasise that addressing municipal issues effectively leads to improved service delivery and efficiency within the municipalities.

PMUs encounter various financial challenges, such as budget overruns, inadequate funding, and delayed disbursements (Smith, 2018). To address these inadequacies, PMUs employ strategies such as rigorous financial planning, continuous monitoring of expenditures, and proactive risk management (Nkosi & Mamba, 2021). Furthermore, capacity building initiatives, staff training programs, and the adoption of technology-enhanced financial systems contribute to improving financial efficiency and accountability (Ndlovu et al., 2020).

2.4. Strategies for Strengthening Financial Accountability

As public institutions increasingly embrace project management principles and practices to implement strategic objectives and service delivery initiatives, the importance of coordinating the use of organisational resources and aligning core activities becomes more crucial (Van der Waldt, 2009). Creating PMUs is an effective strategy for fostering a project management culture within an organisation and managing the ongoing need for new initiatives (Van der Waldt, 2009). One may see that strategies aimed at enhancing the financial management capabilities of PMUs:

I. Can aid in establishing explicit expectations and goals for financial management.
II. Should offer training and development opportunities to the financial management workforce.
III. Should be included in the implementation of efficient finance management systems.
IV. Should involve the consistent monitoring and evaluation of the financial performance of PMUs.

2.5. Research Gap

Although existing literature extensively discusses financial accountability, legislative compliance and financial management within public institutions, limited studies have specifically examined the financial accountability challenges experienced by Project Management Units (PMUs) in metropolitan municipalities within the Eastern Cape Province. Furthermore, there is limited empirical evidence on practical strategies that integrate governance, internal controls, stakeholder engagement and technology to strengthen financial accountability in municipal PMUs. This study seeks to address this gap by exploring the challenges affecting financial accountability and identifying practical strategies to improve financial accountability within PMUs of Eastern Cape metropolitan municipalities.

3. Research Methodology

The study adopted an interpretivist paradigm and qualitative research method based on a case study approach. This methodology was chosen to gain an in-depth understanding of the financial management practices and challenges within PMUs in selected metropolitan municipalities of the Eastern Cape Province. The two metropolitan municipalities were selected for this study due to their status as the highest contributors to irregular expenditure in the Eastern Cape Province, collectively accounting for over 70% of the province's total irregular expenditure during the 2021/2022 financial year (Maluleke, 2023). Qualitative methods were particularly effective for understanding the nuances and complexities of financial management practices within PMUs.

The qualitative approach was suitable for exploring complex issues where detailed, rich data was needed to provide insights into the context and processes involved (Merriam & Tisdell, 2016; Yin, 2018).

The decision to use a qualitative approach was based on several factors. Qualitative methods were particularly effective for understanding the nuances and complexities of financial management practices within PMUs. They allowed the researcher to capture the experiences, perceptions, and insights of the participants in their own words, providing a deeper understanding of the phenomena under study (Creswell & Poth, 2017).

Purposive sampling was used to select key participants with expertise and insight into the research topic. The researcher aimed to draw conclusions specifically for a particular group. The target population consisted of employees from the PMUs of Nelson Mandela Bay Metropolitan Municipality and Buffalo City Metropolitan Municipality. According to Saunders et al. (2016), a sample size between four and twelve participants is generally sufficient to achieve saturation in qualitative research. Six municipal officials were purposively selected based on their expertise in project and financial management: these included two PMU directors, two project managers, and two accountants from each metropolitan municipality. To ensure the relevance and robustness of the findings, participants were selected based on their extensive experience in municipal financial management, as shown in Table 1. All participants occupied senior roles within their

respective PMUs, with professional expertise spanning project management and financial accountability in public administration.

Semi-structured face-to-face interviews were conducted, and data saturation was achieved after the fifth interview as no new themes or concepts emerged during subsequent interviews. The sixth interview confirmed the consistency and completeness of the identified themes. The researcher visited both municipalities to meet with the participants. Each participant was interviewed individually at the municipality offices to ensure manageable data collection and to effectively gather qualitative data from all members of the population. This process spanned two months. The interviews were transcribed and thematically analysed using ATLAS.ti v25 software

The data were examined inductively by thematic analysis conducted with ATLAS.ti version 25 software, allowing systematic coding and identification of recurring themes explaining the challenges affecting and practical strategies to address the financial accountability inadequacies within Project Management Units (PMUs) of metropolitan municipalities. Reliability in this study referred to the consistency and stability of the research findings, ensuring that they could be replicated under similar conditions (Saunders et al., 2016). To enhance reliability, the researcher employed standardised procedures for conducting interviews to minimise variation in data collection (Bryman, 2016; Creswell & Poth, 2017). On the other hand, validity refers to the accuracy and truthfulness of research findings, ensuring that the study measured what it intended to measure. Saunders et al. (2016) suggested that validity could be improved by using appropriate research methods, ensuring that the data collection instruments were suitable for the research questions, and conducting thorough data analysis.

Ethical guidelines, as outlined by various scholars, emphasise the importance of integrity, honesty, and respect for participants' rights and privacy (Creswell & Poth, 2017). Researchers ensured that participants provided informed consent, understood the purpose of the study, and had the right to withdraw at any stage without repercussions. Furthermore, the research was rigorously complied with the Code of Ethics governing research at Nelson Mandela University and conveyed the findings with integrity, accountability, and professionalism. Ethical approval was secured from the institution before data collection.

4. Findings And Discussion

To ensure the relevance and robustness of the findings, participants were selected based on their extensive experience in municipal financial management, as shown in Table 1. All participants occupied senior roles within their respective PMUs, with professional expertise spanning project management and financial accountability in public administration.

Table 1: Profile of respondents

Interviewees	Designation	Mandatory criteria		Experience
		C1	C2	
I1	Director	✓	✓	12 Years
I2	Project Manager	✓	✓	9 Years
I3	Accountant	✓	✓	11 Years
I4	Director	✓	✓	13 Years
I5	Project Manager	✓	✓	8 Years
I6	Accountant	✓	✓	10 Years

Where:
- C1 – are participants working for NMBM/BCM
- C2- are participants having expertise in financial management within PMUs

The participants were asked the following four questions during the interviews

- From your experience, what are the major challenges that hinder the implementation of financial accountability measures within the PMU?
- From your perspective, what role do PMUs play in enhancing financial accountability and project delivery specifically within the two metropolitan municipalities in the Eastern Cape.?
- Can you describe any successful strategies or initiatives that have been implemented within the PMUs of the two metropolitan municipalities in the Eastern Cape.to address financial accountability challenges?
- How do you envision the future of financial management and accountability within the PMUs of the two metropolitan municipalities in the Eastern Cape., and what improvements or changes would you recommend?

The findings revealed the challenges affecting and practical strategies to address the financial accountability inadequacies within Project Management Units (PMUs) of metropolitan municipalities by five overarching themes that explain the underlying issues contributing to the financial accountability inadequacies: Governance Failures and Ethical Leadership, Weak Financial Oversight and Reporting, Technological and Systemic Improvements, Inclusive Stakeholder Engagement and Transparency Resource Allocation and Project Tracking. The theme and categories are discussed hereafter.

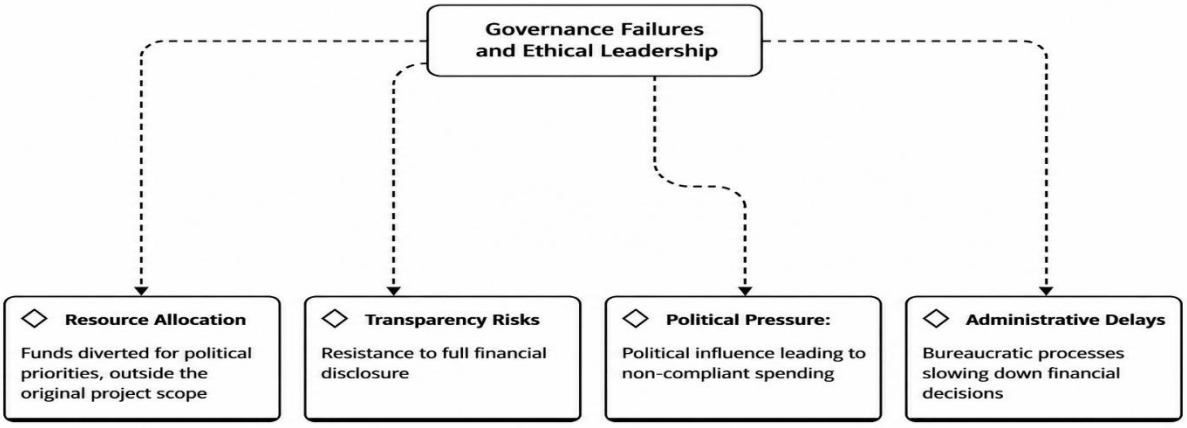

Figure 1: Governance Failures and Ethical Leadership

The findings demonstrate that governance failures, weak financial oversight and technological limitations are interrelated and collectively undermine financial accountability within PMUs. The proposed strategies directly respond to these identified challenges by strengthening governance structures, improving transparency and enhancing financial monitoring systems.

4.1. The challenges that affect the implementation of financial accountability within PMUs

This section presents the findings related to the challenges that hinder the effective implementation of financial accountability within PMUs in the selected municipalities. Thematic analysis of the interview data revealed three overarching themes that illustrate the root causes of these challenges: Governance Failures and Ethical Leadership, Weak Financial Oversight and Reporting, and Technological and Systemic Improvements. Each theme is explored in detail below, supported by direct participant accounts and relevant literature to provide a comprehensive understanding of the systemic and operational barriers to accountability.

4.1.1. Theme 1: Governance Failures and Ethical Leadership

The theme of Governance Failures and Ethical Leadership included four key categories, as shown in Figure 1: Resource Allocation, Transparency Risks, Political Pressure, and Administrative Delays. The category Resource Allocation was assigned the code "funds diverted for political priorities, outside the original project scope." The category Transparency Risks was assigned the code "resistance to full financial disclosure." The category Political Pressure was assigned the code "political influence leading to non-compliant spending." The category Administrative Delays was assigned the code "bureaucratic processes slowing down financial decisions."

Governance Failures and Ethical Leadership, revealed that weak leadership, political interference, and bureaucratic inefficiencies significantly undermine financial accountability. Participants frequently highlighted leadership deficiencies and governance enforcement failures.

Interviewee I3 indicated that *"Poor leadership is one of the biggest stumbling blocks. Many leaders lack the technical understanding to guide project teams effectively and fail to enforce compliance with governance frameworks."*

I6 echoed this, noting that

"Political interference often complicates decision-making processes, delaying critical actions."

Participants also reported the diversion of project funds towards politically visible priorities.

As I1 explained, *"during election seasons, they demand visible projects, disregarding environmental and legislative obligations,"* while

I3 noted that *"resources are often redirected to politically visible projects rather than those aligned with long-term development plans."* Transparency challenges were also evident,

with I3 stating that *"there is always resistance to submitting everything the auditors ask for,"* and I1 indicating that *"leadership avoids presenting full financial statements to the public unless pressured by council."*

These findings align with Masango (2020), who associates weak governance with financial mismanagement, and McKenzie and Marx (2024) and Reddy (2018), who describe the politicisation of municipal spending as a key driver of fiscal mismanagement. Administrative inefficiencies further compounded these governance challenges, as I3 observed that *"simple requests take weeks because they must go through five different departments,"* reflecting what Van der Waldt (2010) describes as procedural paralysis in municipal administration.

4.1.2. Theme 2: Weak Financial Oversight and Reporting

The theme of Weak Financial Oversight and Reporting included four key categories, as shown in Figure 2: Accountability Gaps, Approval Lags, Internal Audits, and Variance Analysis. The category Accountability Gaps was assigned the code "unclear accountability for financial irregularities." The category Approval Lags was assigned the code "delays in approving expenditure or change requests." The category Internal Audits was assigned the code "lack of regular financial reviews." The category Variance Analysis was assigned the code "no routine checks for budget vs. actual expenditure."

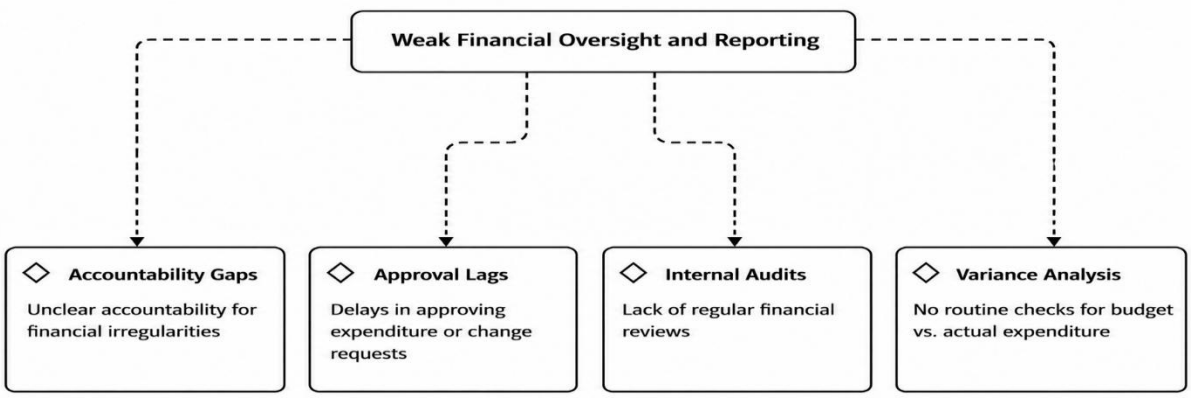

Figure 2: Weak Financial Oversight and Reporting

Weak Financial Oversight and Reporting, demonstrated that accountability structures and financial monitoring systems within PMUs remain inadequate. Participants highlighted unclear accountability structures, delays in financial approvals, ineffective internal audits, and the absence of routine budget monitoring.

Interviewee I4 stated that *"when things go wrong, nobody owns up,"* while I3 emphasised that *"without accountability, financial discipline becomes almost impossible to enforce."*

PMU officials also expressed frustration at being blamed for irregularities despite limited authority, with I6 explaining that *"there's no clear chain of accountability – PMUs are blamed, but they don't have full control."*

Excessive approval delays were another concern, as I1 reported that *"we sometimes wait weeks for approvals even for routine expenses,"* while I5 noted that *"the system doesn't allow for emergency approvals."* Participants further indicated that internal audits were irregular or ineffective. For example, I2 stated that *"internal audits are supposed to be routine, but we go months without a single review,"* and I4 added that *"some municipalities don't even have a functioning internal audit unit."* In addition, routine variance analysis was largely absent, with I3 remarking that *"no one's checking whether what was budgeted actually matches what was spent."*

These findings align with Chigwata and Maziwisa (2023) and Dzagah et al. (2025), who emphasise the importance of clearly defined accountability structures. They also correspond with findings by Visser and Erasmus (2020) and Mbogella et al. (2024), who highlight weaknesses in internal audit functions and financial monitoring within municipalities.

4.1.3. Theme 3: Technological and Systemic Improvements

The theme of Technological and Systemic Improvements included four key categories, as shown in Figure 3: Automation, Data Synchronisation, Digital Training, and System Efficiency. The category Automation was assigned the code "limited use of automation for recurring financial tasks." The category Data Synchronisation was assigned the code "financial data not updated in real time." The category Digital Training was assigned the code "staff untrained on

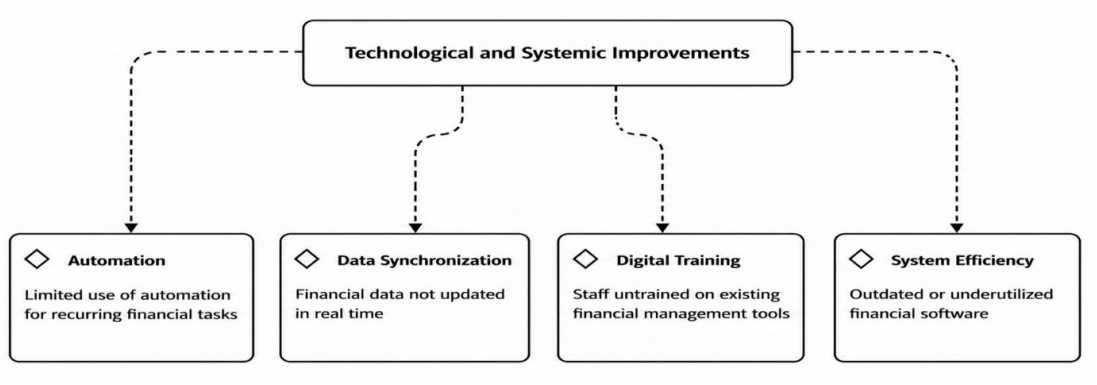

Figure 3: Technological and Systemic Improvements

existing financial management tools." The category System Efficiency was assigned the code "outdated or underutilised financial software."

Technological and Systemic Improvements, highlighted the role of technology in strengthening financial accountability but also revealed major limitations in its implementation. Participants reported limited automation, poor data synchronisation, insufficient digital training, and outdated financial systems.

Interviewee I5 emphasised the need for automation, stating that *"we need to move away from manual systems and implement automated tools that can manage documentation and provide accurate financial reports."* Similarly, I3 noted that *"if something as routine as invoice capturing is still manual, then we're always behind."*

Participants also identified delays in financial information updates across departments. I1 stated that *"with real-time tools, we could see where the money is going and act faster,"* while I6 explained that *"by the time finance updates their records, the projects have already moved on."*

Digital capacity constraints were another concern. I5 explained that *"most of our staff haven't been trained properly on the system,"* while I2 indicated that *"we have new systems but no proper onboarding."* In addition, outdated or underutilised financial software limited operational efficiency.

I3 remarked that *"our systems are old and can't talk to each other,"* while I4 noted that *"some modules have never been configured since installation."*

These findings support Ntshwene and van Wyk (2019) and Naidoo and Mathiba (2021), who emphasise the importance of automation and integrated systems such as mSCOA in improving financial governance. They also align with findings by South African Local Government Association (2018) and AGSA (2022), which identify digital capacity and system integration as critical components of municipal financial accountability.

4.2. Ways to address finance accountability inadequacies within PMUs

This section presents the findings related to the strategies for addressing financial accountability inadequacies within PMUs in the selected municipalities. Thematic analysis of the interview data revealed two overarching themes that reflect the key approaches needed to improve financial oversight and compliance: Inclusive Stakeholder Engagement and Transparency, and Resource Allocation and Project Tracking. Each theme is discussed in detail below, supported by participant insights and relevant literature.

4.2.1. Theme 1: Inclusive stakeholder engagement and transparency

The theme of Inclusive Stakeholder Engagement and Transparency included three key categories, as shown in Figure 4: Escalation Protocols, Regular Meetings, and Financial Committees. The category Escalation

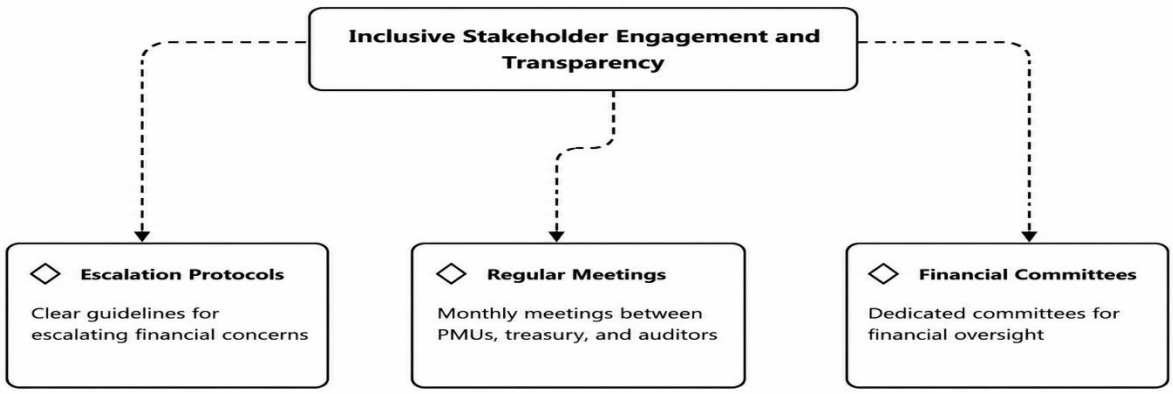

Figure 4: Inclusive stakeholder engagement and transparency

Protocols was assigned the code "clear guidelines for escalating financial concerns." The category Regular Meetings was assigned the code "monthly meetings between PMUs, treasury, and auditors." The category Financial Committees was assigned the code "dedicated committees for financial oversight."

Inclusive Stakeholder Engagement and Transparency, emphasised the importance of structured communication, clear escalation procedures, and strengthened oversight structures. Participants highlighted the need for formal escalation protocols to report financial irregularities.

Interviewee I6 explained that *"when we try to escalate issues like suspicious spending, there's no standard process,"* while I3 stated that *"financial anomalies go unreported because staff don't know where or how to escalate the concern."*

They also correspond with Matsiliza (2012) and Kraai, Ndevu and Matsiliza (2023), who highlight the role of interdepartmental coordination and inclusive oversight committees in improving municipal accountability.

4.2.2. Theme 2: Resource Allocation and Project Tracking

The theme of Resource Allocation and Project Tracking included four key categories, as shown in Figure 5: Audit Trail Features, Cloud-Based Storage, Data Analytics, and Live Dashboards System. The category Audit Trail Features was assigned the code "automated logging of financial transactions." The category Cloud-Based Storage was assigned the code "centralised, accessible record storage for all project data." The category Data Analytics was assigned the code "tools for identifying spending patterns and anomalies." The category Live Dashboards System was assigned the code "real-time budget tracking and alerts."

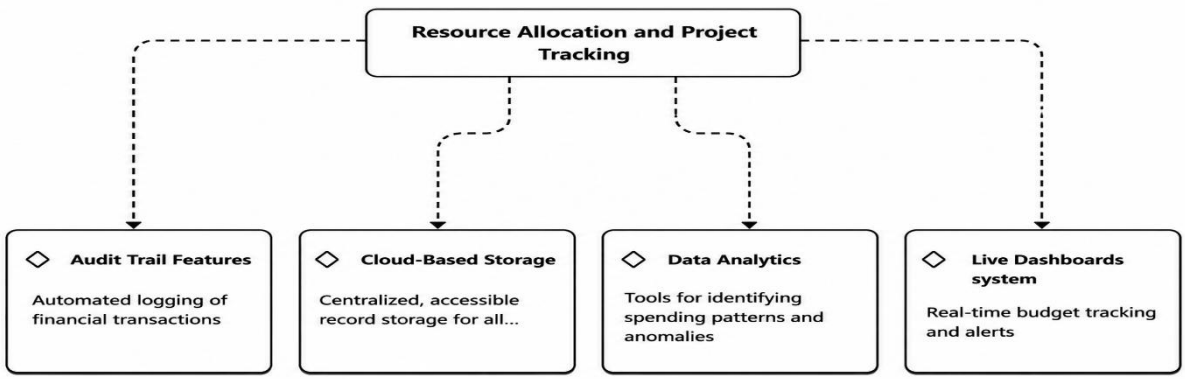

Figure 5: Resource Allocation and Project Tracking

Participants also emphasised the importance of regular coordination meetings between PMUs, treasury, and auditors to identify financial problems early.

I1 explained that *"if we had regular sit-downs with treasury and the auditors, we could pick up issues much earlier,"* while I4 noted that *"monthly meetings would give us a chance to explain variances and fix misalignments before the audit."*

In addition, participants highlighted the importance of strengthening financial oversight committees. I6 suggested that *"establishing independent oversight committees that include members from civil society could enhance budget transparency,"* while I3 stated that *"financial committees often meet just to tick a box."*

These findings align with Maropo (2018) and Mhlongo (2014), who emphasise the importance of formal reporting structures and whistle-blower protection mechanisms in strengthening financial governance.

Resource Allocation and Project Tracking, highlighted the importance of technological tools for improving financial monitoring and compliance. Participants emphasised the need for automated audit trails to ensure transparency and traceability of financial transactions.

Interviewee I1 explained that *"we need to automate audit trails so we can see exactly who made changes to financial records and when,"* while I4 noted that *"without an audit trail, it's hard to hold anyone accountable."*

Participants also emphasised the benefits of cloud-based storage systems to improve access to financial documentation.

I6 shared that *"we've lost project files before because someone's laptop crashed,"* while I1 explained that *"cloud-based platforms would allow auditors and managers to work off the same data."*

Furthermore, participants highlighted the importance of data analytics and real-time financial monitoring systems.

I2 noted that *"we're not analysing data to catch trends or overspending,"* while I3 suggested that *"predictive analytics could help us forecast project overruns and prevent waste."*

These findings align with Ngoepe (2012) and Shozi (2023), who highlight the importance of automated audit trails for financial transparency. They also correspond with Nel et al. (2023) and Mathane (2024), who demonstrate how digital dashboards and analytics tools improve financial monitoring and reduce irregular expenditure in municipalities.

5. Conclusion

Despite the existence of the Municipal Finance Management Act (MFMA), metropolitan municipalities in the Eastern Cape continue to experience irregular expenditure and weak financial accountability within Project Management Units (PMUs). These challenges undermine effective financial management, governance processes, and ultimately affect infrastructure delivery and service provision within municipalities.

The aim of this study was to explore the challenges affecting financial accountability and identify practical strategies to address financial accountability inadequacies within PMUs of metropolitan municipalities in the Eastern Cape Province. A qualitative case study approach was adopted, and data were collected through semi-structured interviews with six municipal officials from Nelson Mandela Bay Metropolitan Municipality and Buffalo City Metropolitan Municipality.

The findings revealed three major challenges affecting financial accountability within PMUs: governance failures and ethical leadership issues, weak financial oversight and reporting mechanisms, and technological and systemic limitations. These challenges manifest through political interference in project funding decisions, unclear accountability structures, delays in financial approvals, ineffective internal audits, and limited integration of financial management systems.

The study further identified strategies that could strengthen financial accountability within PMUs. These include promoting inclusive stakeholder engagement and transparency through improved coordination between PMUs, treasury departments, and oversight committees. Additionally, improving resource allocation and project tracking through the implementation of automated audit trails, cloud-based data storage, data analytics tools, and real-time financial dashboards can significantly enhance financial monitoring and compliance.

The study recommends strengthening internal governance structures, improving coordination between PMUs and financial management units, investing in continuous professional development and MFMA training for municipal officials, and implementing integrated financial management systems such as mSCOA to enhance financial oversight and accountability. Future research should expand the scope of the study to include additional metropolitan municipalities and other categories of municipalities in South Africa to provide broader insights into improving financial accountability within municipal PMUs.

The study is expected to benefit municipal practitioners, policymakers, and project management professionals, particularly those involved in infrastructure delivery and financial management within local government. By aligning the identified challenges and strategies with the research objectives, the study provides a foundation for improving financial governance, enhancing service delivery, and promoting accountability within municipal Project Management Units

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Understanding Root Causes of Cost and Time Overruns in South African Mega Infrastructure Projects

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Abstract

This study investigates the root causes of cost overruns and schedule delays in South African mega infrastructure projects. Mega infrastructure projects are defined as large-scale developments valued at approximately US$1 billion or more, characterised by high complexity, multiple stakeholders, and significant socio-economic impact. A qualitative research approach was adopted, using semi-structured interviews with six purposively selected industry experts possessing extensive experience in the planning, management, and delivery of South African megaprojects. Data were analysed using thematic analysis. The findings reveal that corruption, poor front-end planning, optimism bias, incomplete design and contract documentation, and inadequate project management capacity are the primary causes of cost overruns and project delays. Although these factors have been identified in international studies, the findings suggest that governance weaknesses, institutional constraints, and accountability challenges are particularly influential within the South African construction sector. The study is theoretically grounded in Agency Theory and Optimism Bias Theory, providing insight into how governance failures and unrealistic planning assumptions contribute to project underperformance. The research contributes to the limited body of knowledge on megaproject delivery in developing countries. It offers practical recommendations for policymakers, infrastructure clients, consultants, and project managers to improve project performance and infrastructure delivery outcomes in South Africa.

Keywords: MegaProjects, Cost overruns, Project Delay, Infrastructure Projects, Infrastructure Delivery

1. Introduction

Megaprojects are large-scale, complex infrastructure developments typically valued at US$1 billion or more and characterised by significant technical complexity, long implementation periods, multiple stakeholders, and substantial socio-economic impacts (Flyvbjerg, 2014). Governments and policymakers often promote megaprojects as catalysts for economic growth, employment creation, regional development, and improved infrastructure provision. Beyond addressing infrastructure deficits, these projects are expected to generate long-term economic and social benefits through enhanced connectivity, increased productivity, and improved quality of life (Ansar et al., 2016). Despite their anticipated benefits, megaprojects have a well-documented history of cost overruns and schedule delays. Flyvbjerg (2014) argues that cost overruns and delays are not exceptional occurrences but rather common characteristics of megaproject delivery worldwide. Similarly, Plotch (2015) identifies schedule delays and budget overruns as among the most significant risks affecting the successful delivery of megaprojects. Given their scale and complexity, megaprojects require substantial financial, technical, and managerial resources, making them particularly vulnerable to planning failures, stakeholder conflicts, design changes, and governance challenges.

The financing of megaprojects presents an additional layer of complexity. Due to their enormous capital requirements, megaprojects frequently rely on multiple funding sources, including government allocations, development finance institutions, public-private partnerships, and international lenders (Sergeeva and Ninan, 2023). Such arrangements often increase project complexity and expose projects to financial, institutional, and political risks. These challenges may be more pronounced in developing countries, where institutional capacity constraints, governance weaknesses, and funding limitations can adversely affect project performance (Othman, 2013). Existing literature has extensively examined the causes of cost overruns and schedule delays in developed economies, identifying factors such as optimism bias, strategic misrepresentation, inadequate risk assessment, scope changes, and poor project governance as key contributors (Flyvbjerg, 2009; Cantarelli et al., 2012). However, the extent to which these factors apply to developing-country contexts remains insufficiently understood. Scholars have argued that contextual

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factors such as corruption, political interference, procurement inefficiencies, skills shortages, and institutional weaknesses may play a more significant role in developing countries than in developed economies (Mahamid, 2017; Amoatey and Ankrah, 2017).

South Africa presents a particularly important context for investigating megaproject performance. As one of Africa's largest economies, the country has invested heavily in large-scale infrastructure programmes aimed at supporting economic growth, improving service delivery, and addressing historical infrastructure backlogs. However, several major infrastructure projects have experienced substantial cost overruns and schedule delays, raising concerns regarding project governance, planning effectiveness, and implementation capacity. Despite the growing importance of megaprojects in South Africa, empirical studies focusing specifically on the causes of cost overruns and delays in South African megaprojects remain limited.

This study addresses this gap by investigating the factors contributing to cost overruns and schedule delays in South African megaprojects. The study seeks to identify the underlying causes of project underperformance and examine whether these factors differ from those commonly reported in developed-country contexts. By providing empirical evidence from South Africa, the study contributes to the broader megaproject management literature and offers practical insights for policymakers, government departments, state-owned entities, consultants, and contractors. Understanding the factors that drive cost overruns and delays is essential for developing effective mitigation strategies and improving the planning, delivery, and governance of future megaprojects.

2. Literature Review

2.1. Infrastructure Projects

Infrastructure development is widely recognised as a key driver of economic growth, productivity, employment creation, and improved quality of life (Ncube et al., 2017). In South Africa, infrastructure investment has been identified as a strategic priority to address historical backlogs, improve service delivery, and stimulate economic growth. The South African government has committed significant resources to infrastructure development through initiatives such as the National Infrastructure Plan 2050 and the Strategic Integrated Projects (SIPs), which focus on transport, energy, water, sanitation, and social infrastructure.

South Africa's infrastructure investment programme comprises projects worth several trillion rand. According to Infrastructure South Africa (2023), more than R3 trillion in infrastructure projects have been identified for implementation over the next decade. Large-scale projects such as the Medupi and Kusile Power Stations, the Gautrain Rapid Rail Link, the Ingula Pumped Storage Scheme, and major water transfer projects represent some of the country's most significant infrastructure investments. These projects were expected to improve energy security, transportation efficiency, water availability, and overall economic competitiveness.

Despite these investments, South Africa continues to face infrastructure delivery challenges. Several major projects have experienced substantial delays and cost overruns, raising concerns about planning effectiveness, governance systems, procurement processes, and project management capacity (Mabelo, 2020). These challenges have affected the ability of infrastructure projects to deliver their intended economic and social benefits.

2.2. Project delays and cost overruns

Cost overruns and schedule delays are among the most persistent challenges affecting infrastructure projects worldwide. Flyvbjerg (2014) argues that large infrastructure projects frequently exceed their budgets and planned completion dates because of optimism bias, strategic misrepresentation, inadequate planning, and weak governance structures. Cost overruns occur when actual project costs exceed the approved budget, while schedule delays arise when projects take longer than initially planned to complete.

Research has identified several causes of cost overruns and delays, including scope changes, inadequate front-end planning, design modifications, poor risk management, procurement inefficiencies, contractual disputes, inflation, and market volatility (Park, 2021; Gachie, 2019). In developing countries, additional factors such as corruption, political interference, skills shortages, and institutional weaknesses further exacerbate project performance challenges.

The South African construction industry has experienced many of these challenges. For example, the Medupi and Kusile Power Station projects recorded significant cost escalations and schedule delays. Originally budgeted at approximately R80 billion and R81 billion respectively, the projects experienced substantial increases in final costs and completion periods due to design changes, contractor performance issues, labour unrest, governance challenges, and technical failures (Mahlobo, 2022). Similar challenges have been reported in major transport and water infrastructure projects across the country.

The consequences of cost overruns and delays extend beyond financial losses. Delayed projects postpone the delivery of essential services, reduce expected economic benefits, increase financing costs, and can undermine public confidence in infrastructure investment programmes (Flyvbjerg, 2014).

2.3. Megaprojects in South Africa

Megaprojects are generally defined as infrastructure projects valued at approximately US$1 billion or more that involve substantial complexity, long implementation periods, multiple stakeholders, and significant socio-economic impacts (Flyvbjerg, 2014). South Africa has undertaken numerous megaprojects across the energy, transportation, water, and industrial sectors. Notable examples include the Gautrain Rapid Rail Link, Medupi and Kusile Power Stations, the Ingula Pumped Storage Scheme, the Lesotho Highlands Water Project, and the Port of Durban expansion programme.

While these projects have contributed to infrastructure development and economic growth, many have experienced significant cost overruns and delays. The Gautrain project, initially estimated at approximately R25 billion, ultimately exceeded its original budget. Similarly, Medupi and Kusile became internationally recognised examples of megaproject underperformance due to escalating costs and delayed completion schedules (Mabelo, 2020).

Although international literature has extensively examined the causes of megaproject overruns, most studies have focused on projects in Europe, North America, and Asia. Limited empirical research has specifically investigated the factors contributing to cost overruns and schedule delays in South African megaprojects. Given the country's unique socio-economic, institutional, and governance context, there is a need to better understand the factors driving megaproject performance in South Africa. This study addresses this gap by examining the causes of cost overruns and schedule delays from the perspectives of industry experts involved in South African megaproject delivery.

2.4. Theoretical Underpinning

This study is underpinned by Agency Theory and Optimism Bias Theory. Agency Theory explains how conflicts of interest arise between principals (government clients and funders) and agents (contractors, consultants, and project managers), resulting in opportunistic behaviour, information asymmetry, corruption, and poor project outcomes. The theory is particularly relevant to megaprojects because their scale, complexity, and multiple stakeholder arrangements create opportunities for self-interested decision-making that may undermine project performance.

Optimism Bias Theory, advanced by Flyvbjerg (2014), explains the systematic tendency of planners and decision-makers to underestimate costs, completion times, and risks while overestimating project benefits. The theory provides a useful lens for understanding why megaprojects frequently experience cost overruns and schedule delays despite extensive planning efforts. Together, these theories provide a framework for understanding how governance failures, strategic misrepresentation, and unrealistic planning assumptions contribute to cost overruns and delays in South African megaprojects

3. Research Methodology

This study adopted a qualitative research approach to investigate the causes of cost overruns and schedule delays in South African megaprojects. A qualitative design was considered appropriate because it facilitates an in-depth exploration of complex issues and captures participants' experiences, perceptions, and interpretations regarding project delivery challenges (Creswell and Creswell, 2018). Given the exploratory nature of the study, semi-structured interviews were used as the primary data collection method.

For this study, megaprojects were defined as large-scale infrastructure projects valued at approximately US$1 billion or more and characterised by significant complexity, multiple stakeholders, extended implementation periods, and substantial socio-economic impacts (Flyvbjerg, 2014). Relevant South African megaprojects were identified through government infrastructure reports, public investment programmes, and industry publications. These included major transport, energy, water, and public infrastructure projects that met the established criteria. A purposive sampling strategy was employed to select participants with direct involvement in the planning, design, procurement, management, or execution of megaprojects. Purposive sampling is appropriate in qualitative studies where participants are selected based on their ability to provide rich and relevant information on the phenomenon being investigated (Leedy and Ormrod, 2016). The sample comprised six experienced professionals, including project managers, engineers, quantity surveyors, construction managers, and infrastructure specialists who had worked on South African megaprojects.

Although the sample size was relatively small, qualitative research prioritises depth of insight rather than statistical representation. The selected participants possessed extensive knowledge and experience of megaproject delivery, enabling the collection of rich and detailed data. The sample size was considered sufficient because thematic saturation was achieved. Following the sixth interview, no substantially new themes emerged, and recurring patterns were consistently observed, indicating that additional interviews were unlikely to generate new insights (Guest et al., 2006). Data were collected through semi-structured interviews guided by questions developed from the literature on megaproject performance, cost overruns, and schedule delays. The interviews focused on identifying the causes of delays and cost overruns and examining the role of project governance and

management practices in influencing project outcomes. All participants provided informed consent and granted permission for the interviews to be recorded. The recordings were subsequently transcribed verbatim for analysis.

Ethical clearance was obtained from the relevant university research ethics committee before data collection commenced. Participants were informed about the purpose of the study, confidentiality measures, voluntary participation, and their right to withdraw at any stage. All collected data were securely stored and used exclusively for research purposes.

The interview data were analysed using thematic analysis following the approach proposed by Braun and Clarke (2006). The process involved familiarisation with the data, coding, theme identification, theme review, theme definition, and reporting. Elements of qualitative content analysis were used during the coding stage to organise and categorise the data before broader themes were developed. Thus, content analysis served as a data reduction technique, while thematic analysis provided the overarching analytical framework. To enhance the trustworthiness of the findings, several measures were implemented. Participants were selected based on their expertise and direct involvement in megaproject delivery, interview data were transcribed verbatim, and an audit trail was maintained throughout the analysis process. Furthermore, findings were continuously compared across interviews to verify consistency and minimise researcher bias. These procedures enhanced the credibility, dependability, and overall trustworthiness of the study.

4. Findings and Discussion

This section shows the study results and discusses them to bring meaning. Data from this study were recorded and then transcribed. Thematic analysis was used to develop main themes and to code data. Thematic coding was used for the study. Table 1 below lists participants, their experience, and their positions.

Table 1: Profile of Respondents

Participants	Position	Years of experience
P1	Associate Professor/ Quantity Surveyor	25
P2	Quantity Surveyor	10
P3	Civil Engineer	35
P4	Quantity Surveyor	30
P5	Mechanical Engineer	20
P6	Quantity Surveyor	15

4.1. Corruption

The findings demonstrate that corruption remains a dominant factor affecting South African megaproject performance. While studies in developed countries often emphasise technical complexity and optimism bias (Flyvbjerg, 2014), participants in this study identified corruption and governance failures as more significant challenges. This finding suggests that institutional weaknesses may play a more prominent role in developing-country contexts such as South Africa than in mature infrastructure markets. These findings support the arguments of Altshuler and Luberoff (2003), who contend that misinformation and hidden interests frequently influence infrastructure project decision-making. Participant responses further revealed that some professionals intentionally prolong projects to secure continued financial benefits, thereby increasing project duration and costs. This undermines investor confidence and discourages future investment in the South African construction industry. The findings therefore confirm the literature that ineffective governance, weak accountability, and misrepresentation of project realities significantly contribute to megaproject underperformance.

4.2. Poor Planning

Poor planning emerged as another significant factor contributing to delays and cost overruns. Participants highlighted inadequate front-end planning, insufficient stakeholder consultation, incomplete project scoping, and inadequate risk assessment during the conceptual and design stages. These findings align with Park (2021) and Gachie (2019), who identify poor planning, weak risk management, and inadequate project preparation as major drivers of project overruns. Participants emphasised that unclear project scopes, insufficient technical investigations, and failure to account for disruptions such as weather conditions, strikes, and community requirements often result in unrealistic budgets and schedules. The findings further support the view that effective planning and comprehensive stakeholder engagement are essential for improving megaproject performance.

4.3. Optimism bias

The study also identified optimism bias as a major contributor to project overruns and delays. Participants noted that project budgets, schedules, and expected outcomes are often unrealistically estimated due to excessive confidence among planners, contractors, and decision-makers. These findings strongly support the work of Bent Flyvbjerg (2014), who argues that megaprojects are frequently characterised by underestimated costs and overestimated benefits. Political pressure and the desire to secure project approval were identified as factors that contribute to

unrealistic planning assumptions. Participants further highlighted that optimism bias leads to poor resource allocation and inadequate contingency planning. However, the successful implementation of the Gautrain was cited as evidence that realistic budgeting, proper planning, and effective governance can improve megaprojects.

4.4. Incomplete designs and contract documentation

Incomplete design and contract documentation were identified as additional causes of delays and cost overruns. Participants indicated that projects are sometimes approved before designs are fully developed, resulting in design changes, contractual disputes, and additional costs during implementation. These findings are consistent with the literature by Park (2021), which identifies contractual issues, scope changes, and poor project preparation as significant contributors to overruns. Participants also emphasised the importance of selecting appropriate contract strategies and allocating risks to parties best positioned to manage them. Weak documentation management and incomplete contractual information were found to increase the likelihood of disputes, delayed payments, and claims, ultimately affecting project delivery performance.

4.5. Inadequate Project Management Skills

The findings further revealed that inadequate project management skills and weak institutional capacity contribute significantly to project delays and cost overruns. Participants highlighted challenges relating to leadership, contractor management, stakeholder coordination, and the shortage of experienced professionals capable of managing complex megaprojects. These findings support the views of Mabelo (2020), who emphasises that successful infrastructure delivery depends on effective project management and coordination. Participants further noted that weak project oversight allows contractors to prioritise profit over project quality, cost, and schedule performance. Strong project management teams were therefore considered essential for ensuring accountability, maintaining quality standards, and minimising delays and cost escalations in South African megaprojects.

5. Conclusion and Further Research

This study examined the causes of cost overruns and schedule delays in South African megaprojects. The findings identified corruption, inadequate front-end planning, optimism bias, incomplete design and contract documentation, and weak project management practices as the primary drivers of project overruns and delays. These challenges adversely affect project delivery and reduce the socio-economic benefits expected from megaproject investments.

The study contributes to the advancement of Agency Theory and Optimism Bias Theory by demonstrating how governance failures and unrealistic planning assumptions interact to influence project performance in developing-country contexts. It further provides empirical evidence from South Africa, a setting that remains underrepresented in megaproject research, which has predominantly focused on Europe, North America, and Asia. The findings offer practical insights for government departments, state-owned entities, consultants, and contractors on strengthening governance mechanisms, enhancing planning processes, combating corruption, and improving project management capacity.

Despite these contributions, the study is limited by its focus on South African megaprojects and its reliance on interview-based data, which may affect the generalisability of the findings. The study recommends strengthening anti-corruption measures, improving front-end planning, enhancing governance of design and contract documentation, and building project management capabilities to minimise cost overruns and schedule delays. Future research should develop and validate a conceptual framework that integrates these factors to improve megaproject performance and delivery outcomes

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Project Governance under Economic Turbulence: Adaptive Decision Routines of Micro-Scale AEC Firms

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Abstract

Micro-scale architecture, engineering, and construction (AEC) firms are particularly exposed to economic turbulence due to limited financial buffers and high dependency on project-based cash flow. Existing studies largely document the survival strategies adopted by such firms under uncertain economic conditions; however, less attention has been paid to how these strategies are translated into project-level governance routines. This study addresses this gap by proposing a conceptual approach that explains how micro-scale AEC firms embed adaptive decision-making practices into their project governance structures. The study adopts a conceptual research design based on the synthesis and reinterpretation of findings derived from the authors' previously published empirical and review-based studies, including systematic literature reviews, qualitative interviews with micro-scale AEC firms in Türkiye, and analyses of crisis and post-crisis construction contexts. Through a secondary qualitative synthesis, firm-level strategies are reframed as adaptive project governance routines operating across key decision domains, including contracts, cash flow management, procurement timing, stakeholder relations, and project portfolio configuration. The findings suggest that micro-scale AEC firms do not rely on formalized management systems to cope with economic turbulence; instead, they develop repeatable governance routines that enable flexibility, rapid decision-making, and risk redistribution at the project level.

Keywords:

Adaptive decision routines, Economic turbulence, Micro-scale AEC firms, Organisational Resilience, Project governance.

1. Introduction

The construction sector plays a key role in national economies, but it is highly sensitive to economic fluctuations (Olatunji, 2010; Adabre *et al*., 2022). Periods of economic turbulence—such as inflation, exchange-rate volatility, financing constraints, and payment delays—pose significant challenges for construction projects. These conditions increase uncertainty in decision-making and affect whether projects are initiated, continued, or delayed. Micro-scale architecture, engineering, and construction (AEC) firms are vulnerable in such environments. These firms operate with limited financial resources, small client networks, and a strong dependence on project-based cash flow. Despite these constraints, they form a large portion of the construction sector and play an important role in maintaining housing production. Previous studies show that micro-scale firms adopt various survival strategies, such as diversifying services, strengthening stakeholder relationships, reducing costs, and selecting projects more carefully. However, these strategies are often discussed as isolated actions. There is limited understanding of how they are systematically embedded into project-level decision-making processes. This gap highlights the need to examine how strategies are translated into governance practices. In response, this study aims to explain how survival and adaptation strategies are transformed into adaptive project governance routines in micro-scale AEC firms operating under economic turbulence. The main research question guiding this study is: How are these strategies translated into adaptive project governance routines? To address this question, the study adopts a conceptual research design. It is based on the synthesis and reinterpretation of findings from the authors' previous studies, including systematic literature reviews, qualitative interviews with micro-scale AEC firms in Türkiye, and analyses of crisis and post-crisis construction contexts. A secondary qualitative synthesis is used to map firm-level strategies to project-level governance routines across key decision areas such as contracts, cashflow, procurement, and stakeholder relations.

2. Economic Uncertainty, Resilience and Project Governance in Construction

The construction sector is highly sensitive to macroeconomic conditions. Fluctuations in inflation, exchange rates, interest rates, and material costs directly affect project feasibility, cost estimation, and

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investment decisions (Nguyen & Nguyen, 2020; Adabre *et al*., 2022). In periods of economic instability, construction demand often decreases, while financial risks increase (Olatunji, 2010; Nguyen & Nguyen, 2020). Studies show that cost escalation, exchange rate volatility, and financing constraints are among the main factors influencing project performance in uncertain environments (Adabre *et al.,* 2022; Oteng-Abayie & Dramani, 2019). Economic uncertainty refers to unpredictable changes in macroeconomic conditions that affect project planning, investment decisions, and construction project execution. Uncertainty also affects key project decisions such as bid/no-bid and build/not-build choices (Li *et al*., 2020). In addition, payment delays and non-payment are widely reported as major risks that disrupt cashflow and weaken contractor performance (Abdul-Rahman *et al.,* 2013). These conditions create a complex environment in which firms must continuously adapt their decisions to changing economic signals. Small and micro-scale construction firms are particularly vulnerable to economic turbulence due to their limited financial capacity and restricted access to formal financing. However, their small size also provides flexibility, allowing them to respond quickly to changing market conditions (Ulubeyli *et al.*, 2018). Previous studies identify several strategies used by construction SMEs during economic crises. These include cost reduction, diversification, selective market focus, and strengthening relationships with clients and suppliers (Tansey *et al.,* 2013; Lim *et al.,* 2010). Other studies highlight the importance of informal networks and alternative financing mechanisms, especially in highly uncertain environments (Gür *et al*., 2023). In addition, firms often adjust their project portfolios by prioritising smaller and faster projects to maintain cashflow continuity. Although these strategies are widely documented, they are mostly presented as individual responses rather than structured organisational practices.

The concept of resilience has gained increasing attention in construction and management literature. Organisational resilience has been conceptualised as a meta-capability that enables organisations to anticipate potential threats, cope effectively with disruptions, and adapt to changing conditions through organisational capabilities, routines, and practices (Lengnick-Hall *et al*., 2011; Duchek, 2020). Duchek (2020) further explains resilience as a dynamic process consisting of anticipation, coping, and adaptation phases, through which organisations continuously develop and renew these capabilities. In the construction sector, resilience has been linked to capabilities such as risk management, resource flexibility, and stakeholder coordination (Chih *et al.,* 2022). Studies on SMEs suggest that resilience is supported by flexibility, collaboration, and learning from previous crises (Duchek, 2020; Chih *et al.,* 2022). However, despite the growing literature, most studies focus on organisational capabilities and outcomes, while giving limited attention to how resilience is operationalised at the project level. Organisational capabilities refer to the ability of firms to coordinate resources, knowledge, and routines to adapt to changing market conditions and sustain project performance (Duchek, 2020; Chih *et al.,* 2022).

Previous studies indicate that micro-scale AEC firms respond to economic uncertainty through a combination of financial, organisational, and market-oriented strategies. One of the most frequently reported approaches is the expansion of stakeholder networks, which enables firms to access new business opportunities, mobilise resources, and strengthen organisational resilience (Lengnick-Hall *et al*., 2011; Duchek, 2020). Long-term collaboration with suppliers and subcontractors has also been identified as an important mechanism for reducing transaction costs and increasing operational flexibility under uncertain conditions (Chih *et al.,* 2022; Lim *et al.,* 2010). In addition, firms frequently diversify their services and target markets to reduce dependence on a single source of income, while prioritising smaller and shorter projects to maintain liquidity and minimise financial exposure during periods of economic instability (Ulubeyli *et al.,* 2018; Tansey *et al.,* 2013). The literature further highlights the growing role of digital communication and marketing tools in expanding market access and strengthening business continuity for small firms (Gür *et al.,* 2023).

While previous studies identify a range of survival strategies, they provide limited explanation of how these strategies are embedded in project execution and day-to-day decision-making. From a project governance perspective, governance concerns the way project decisions are structured, coordinated, and implemented throughout the project lifecycle. In large organisations, project governance is typically supported by formal contractual arrangements, predefined procedures, and clearly assigned decision-making responsibilities. However, such formal governance mechanisms are often difficult to implement in micro-scale firms because of their limited organisational structures, resource constraints, and high dependence on owner-managers. Consequently, project decisions are frequently guided by experience, trust, informal coordination, and repeated managerial practices rather than formal governance systems (Too & Weaver, 2014).

The reviewed literature shows that economic uncertainty significantly affects construction activities and that micro-scale firms adopt various strategies to survive under such conditions. It also highlights that resilience is a key concept in explaining how firms cope with disruptions. However, an important gap remains. Existing studies do not clearly explain how survival strategies are translated into project-level decision-

making practices. There is limited understanding of how these strategies become repeatable and structured governance routines within projects. This gap suggests the need to shift the focus from identifying strategies to understanding the mechanisms through which these strategies are implemented. In this context, project governance provides a useful lens, as it focuses on how decisions are structured, coordinated, and repeated within project environments.

3. Research Methodology

This study adopts a conceptual research design based on the synthesis and reinterpretation of findings from the authors' previously published empirical and review-based studies. The aim is to understand how micro-scale architectural firms respond to economic uncertainty. The study focuses on both theoretical knowledge and real-life practices. These include literature reviews, empirical studies, and a master's thesis. It aims to synthesize them and develop a conceptual understanding of adaptive decision-making (Table 1). Previous studies conducted within this research project show that research on micro-scale firms is limited, especially in the Turkish context. This gap highlights the need for empirical data. In the second stage, semi-structured in-depth interviews were conducted. This method allows the researcher to understand real-life experiences and decision-making processes. The interviews were carried out with micro-scale architectural firms operating in Istanbul. The firms were selected using a purposive sampling technique. The main criterion was firm size. All firms have fewer than ten employees, which fits the definition of micro-scale firms (European Commission, 2003). The interviews were conducted with firm owners or managers. This ensures that the data reflects strategic decisions. The interview questions were developed based on both the literature and previous studies conducted within the project. Participants were asked about their experiences during economic crises. They were also asked about the strategies they used and the lessons they learned. The analysis was conducted using qualitative content analysis (Arıcı Üstüner & Balaban Ökten, 2016; Toprak *et al*., 2024a). The data were coded and grouped into themes. An inductive approach was used.. The analysis focused on identifying patterns in firm behavior and strategy use. Finally, the findings obtained from different studies were brought together. Literature findings, interview data, and thesis results were compared and integrated. This process allows the study to move beyond individual findings and to develop a conceptual framework that explains how firm-level strategies are transformed into adaptive project governance routines (Table 1).

Table 1: Project Based Methodological Structure and Data Sources

Research Stage	Method	Data Source	Study / Project Output
Literature Base	Systematic literature review	Academic databases	Arıcı Üstüner & Balaban Ökten (2022); Toprak *et al*. (2024)b
Early Empirical Insight	Qualitative interviews	Micro-scale architectural offices	Arıcı Üstüner & Balaban Ökten (2016)
Expanded Empirical Study	Semi-structured interviews	Micro-scale AEC firms	Toprak *et al*. (2024)a
Deepened Analysis	Mixed-method (SLR + interviews)	Master's thesis dataset	Toprak (2025)
Integrated Analysis	Cross-study synthesis	All datasets combined	This manuscript

Source: Developed by the authors.

4. Findings

The analysis shows that micro-scale architectural firms develop a set of repeated and experience-based practices when operating under economic uncertainty. These practices go beyond individual strategies. They function as routines that guide decision-making at the project level. The table below summarises the data sources used in this study, together with the research methods, sample characteristics, and key findings reported in each publication (Table 2 in Appendix 1).

4.1. Survival Strategies Identified in Micro-Scale Firms

The findings show that firms adopt several key strategies to survive under economic pressure. These strategies are consistent across different studies and datasets. First, firms expand their stakeholder networks. New clients and projects are mostly obtained through personal connections and previous work. This creates a network-based business model. Second, firms strengthen their relationships with suppliers and subcontractors. These relationships help reduce costs and improve quality. In many cases, trust plays a more important role than formal contracts. Third, firms diversify their services and markets. Some firms start offering new services such as furniture design, visualization, or consultancy. Others try to enter new regions or countries. Fourth, firms use flexible production strategies. Small and fast projects are preferred because they provide quick cash flow. This

helps firms manage financial uncertainty. Fifth, firms increase their visibility through digital platforms. Social media, websites, and online portfolios are used to attract new clients. These findings are consistent with previous studies conducted within the project. They confirm that micro-scale firms rely on flexibility, adaptability, and informal structures (Table 3).

4.2. From Strategies to Decision Practices

Although these strategies appear as separate actions, the synthesis of the empirical studies shows that firms consistently adopt similar responses when facing comparable economic challenges. For example, when confronted with cash-flow constraints, firms repeatedly prioritise smaller and shorter projects, request advance payments, or adjust procurement timing. When project pipelines weaken, they expand stakeholder networks and diversify their services to secure new business opportunities. Over time, these recurring responses become structured decision practices rather than isolated actions. These practices are not formally documented or standardised. However, they are applied consistently across projects and over time. As shown in Table 4, firms repeatedly rely on existing client networks to secure new projects, maintain long-term relationships with trusted suppliers, prioritise short-term projects to preserve cash flow, and shift between service types according to market demand. The repeated use of these practices suggests that firms develop implicit decision-making routines that guide project-level decisions under economic uncertainty.

4.3. Emergence of Adaptive Project Governance Routines

Drawing on the project governance perspective introduced in the literature review, the repeated practices identified across the empirical studies can be understood as adaptive project governance routines. Unlike formal project governance systems, where decisions are guided by predefined rules, contractual arrangements, and standardised procedures, micro-scale firms rely on flexible, experience-based routines that evolve through repeated project experience.-These routines enable firms to govern projects through recurring practices across several governance domains (Table 5). In contract management, firms apply

Table 3: Survival Strategies and Supporting Evidence

Strategy	Evidence from Previous Studies	Interpretation
Stakeholder network expansion	Interviews show firms obtain projects through personal networks (Toprak *et al*., 2024a; Toprak, 2025)	Networks function as a primary project acquisition mechanism
Strengthening supplier relationships	Trust-based collaboration reduces cost and risk (Toprak *et al*., 2024a; Toprak, 2025)	Supplier relations act as informal risk management tools
Market and service diversification	Firms expand into new services and markets (Toprak *et al*., 2024a; Toprak, 2025)	Diversification increases adaptability under uncertainty
Flexible production strategies	Preference for small and fast projects (Toprak *et al*., 2024a)	Cash flow management becomes a key survival driver
Digital visibility and marketing	Use of social media and digital tools (Toprak, 2025)	Digital tools support resilience and continuity

Source: Developed by the authors

Table 4: From Strategies to Repeated Decision Practices

Strategy	Observed Practice	Supporting Study	Interpretation
Network-based work acquisition	Repeated reliance on existing contacts	Toprak *et al*. (2024)a; Toprak (2025)	Strategy becomes a routine behavior
Supplier selection based on trust	Continuous collaboration with same actors	Arıcı Üstüner & Balaban Ökten (2016)	Trust replaces formal control mechanisms
Small project preference	Continuous selection of short-term projects	Toprak *et al*. (2024)a	Financial uncertainty shapes decision patterns
Flexible service production	Shifting between service types	Toprak (2025)	Firms adapt through iterative decisions

Source: Developed by the authors

Table 5: Emergence of Adaptive Governance Routines

Governance Domain	Observed Behaviour	Supporting Study	Governance Interpretation
Contract management	Contracts are flexible and often not strictly enforced	Arıcı Üstüner & Balaban Ökten (2016)	Informal governance dominates
Risk management	Decisions based on past experience	Arıcı Üstüner & Balaban Ökten (2016); Toprak (2025)	Learning-based governance
Stakeholder relations	Trust-based collaboration	Toprak *et al*. (2024)a; Toprak *et al*. (2024)b; Toprak (2025)	Relational governance structure
Decision-making	Rapid and situational decisions	All studies	Adaptive governance mechanism
Dispute resolution	Negotiation instead of legal process	Arıcı Üstüner & Balaban Ökten (2016)	Informal conflict management

Source: Developed by the authors

contracts flexibly rather than relying on strict contractual enforcement. In risk management, project decisions are guided by previous experience and lessons learned from earlier projects. Stakeholder relations are maintained through long-term, trust-based collaboration with clients, suppliers, and subcontractors. Decision-making is rapid and situational, allowing firms to respond quickly to changing economic conditions. Finally, disputes are typically resolved through negotiation rather than formal legal procedures. Together, these recurring practices indicate that project governance in micro-scale firms is shaped by practical experience and relational coordination rather than formal governance structures.

The analysis shows that micro-scale architectural firms develop a set of repeated and experience-based practices when operating under economic uncertainty. These practices go beyond individual strategies. They function as routines that guide decision-making at the project level.

5. Discussion

This study examines how micro-scale construction firms respond to economic uncertainty. The findings show that firms use flexible, informal, and adaptive strategies. These findings are consistent with previous studies reporting that SMEs and construction firms rely on flexibility, organisational resilience, adaptive capabilities, and network-based responses to cope with uncertain environments (Lim *et al.,* 2010; Ulubeyli *et al.,* 2018; Chih *et al.,* 2022; Duchek, 2020). Organisational resilience has been conceptualised as a meta-capability developed through organisational capabilities, routines, and practices that enable firms to anticipate, cope with, and adapt to uncertainty (Lengnick-Hall *et al.,* 2011; Duchek, 2020). Consistent with this perspective, the present study shows that micro-scale construction firms operationalise resilience through adaptive project governance routines, including trust-based coordination, flexible contracting, network-based project acquisition, and experience-driven decision-making. Firms do not remain passive during crises. Instead, they actively adapt their behaviors. They change project types, adjust financial decisions, and rely on alternative resources. In addition, the study shows that resilience is not a single action but a process. This is in line with Duchek's (2020) model, which defines resilience as a process including anticipation, coping, and adaptation. The firms observed in this study demonstrate similar stages. First, they recognize uncertainty. Then, they respond through short-term solutions. Finally, they develop more stable practices over time. Another important finding is the role of flexibility and collaboration. The findings of this study strongly support this argument. Firms prefer to work with known actors. They rely on trust-based relationships. They avoid rigid contractual structures. This behavior helps them reduce risk under uncertain conditions. Similarly, the importance of informal financial strategies is confirmed. Gür *et al.* (2023) show that micro and small firms have limited access to formal finance and therefore rely on informal borrowing mechanisms. The findings of this study align with this result. Firms prefer flexible payment systems and informal agreements instead of formal financial structures. The findings also highlight the importance of networks. In this study, networks are not only important but essential. Firms continuously rely on their existing networks to secure projects and resources. This indicates that networks function as a survival mechanism. Another important discussion point is the role of economic conditions. The literature shows that inflation, exchange rates, and financial instability strongly affect SMEs (Yarba & Güner, 2020) . The findings of this study confirm this. Firms constantly adjust their decisions according to economic fluctuations. This creates a highly dynamic decision-making environment. However, this study goes beyond existing literature in one key aspect. Most previous studies identify the strategies that firms adopt in response to economic uncertainty. However, they primarily describe these strategies as isolated responses rather than explaining how they evolve into recurring project-level decision-making practices. In contrast, this study shows that these strategies become repetitive practices over time. Firms tend to use the same solutions in similar situations. For example, they repeatedly rely on the same networks or financial approaches. This repetition leads to the formation of routines. These routines shape how firms make decisions. They are not formally defined, but they are consistently applied. This finding adds a new perspective to the literature. It suggests that micro-scale firms should be understood through their everyday practices, not only through their strategies. For example, strategies such as stakeholder network expansion, service diversification, and flexible contracting become everyday practices when firms repeatedly rely on trusted client networks to secure projects, request advance payments, prioritise short-term projects to maintain cash flow, and negotiate contractual changes according to project conditions. These recurring practices ultimately evolve into adaptive project governance routines. Finally, the study also contributes to the understanding of governance in micro-scale firms. The findings also extend the discussion on project governance by showing that, in micro-scale firms, project governance operates primarily through informal and adaptive mechanisms rather than standardised organisational procedures. Consistent with the literature reviewed, project decisions are guided by experience, trust-based relationships, flexible contractual arrangements, and negotiation. These findings suggest that adaptive project governance in micro-scale firms emerges through recurring project practices instead of formalised organisational processes. Based on the

synthesis of empirical findings and previous studies conducted within this research project, this section proposes a practice-oriented framework. Rather than prescribing universal rules, the framework provides a reference framework for micro-scale firms operating under conditions of economic turbulence. It is structured around the recurring challenges identified in the empirical studies and the corresponding practices adopted to address them (Table 6).

Table 6: A Practice-Oriented Framework for Micro-scale Firm Resilience

Challenge	Observed Practice	Supporting Studies	Interpretation
Limited access to new projects	Expanding stakeholder networks and relying on existing contacts	Toprak *et al*. (2024)a; Toprak (2025)	Networks function as primary project acquisition tools
Financial instability and cashflow problems	Preference for small and fast projects; staged payments	Toprak *et al*. (2024)a; Toprak *et al*. (2024)b; Gür et al. (2023)	Cashflow becomes a central decision parameter
Rising material and production costs	Strengthening relationships with suppliers and subcontractors	Toprak *et al*. (2024)a; Kökçü (2020)	Trust-based collaboration reduces cost uncertainty
Market contraction and demand fluctuation	Diversifying services and entering new markets	Toprak (2025)	Flexibility increases adaptability
Difficulty in formal contract enforcement	Relying on informal agreements and trust-based relations	Arıcı Üstüner & Balaban Ökten (2016)	Informal governance replaces rigid structures
High uncertainty in decision-making	Using experience-based and rapid decision processes	All studies	Decision-making becomes situational and adaptive
Limited visibility in competitive markets	Using digital tools and social media for client acquisition	Toprak (2025)	Digitalization supports resilience

(Source: Developed by the authors.)

These responses are shaped by experience, constraints, and immediate needs. One important point is that these practices are context-dependent. Not all firms apply all practices. The selection of practices depends on the firm's capacity, network, and market position. Therefore, the framework should not be understood as a universal model. It should be seen as a set of possible responses. Another important point is that these practices are interconnected. For example, network expansion is linked to project acquisition. Supplier relationships are linked to cost control. Small project preference is linked to cash flow management. This shows that firm behaviour is not composed of isolated decisions. Instead, decisions regarding project acquisition, cash-flow management, procurement, stakeholder relationships, and service diversification are interconnected. For example, expanding stakeholder networks supports project acquisition, which in turn improves cash-flow continuity, while long-term supplier relationships contribute to cost control and procurement flexibility. These interdependencies indicate that firms make decisions across linked project domains rather than addressing each challenge independently. The framework also shows that many practices rely on informal mechanisms. Trust, experience, and personal relations play a central role. Formal governance mechanisms, such as standardised procedures, detailed contractual controls, and predefined decision-making processes, are limited in micro-scale firms because of their small organisational structures and resource constraints. Instead, firms develop flexible and adaptive ways of working.-Across the empirical studies, similar practices were repeatedly observed among different micro-scale firms operating under economic uncertainty.–Finally, these practices can be understood as the building blocks of adaptive project governance routines. Across the empirical studies synthesised in this research, similar practices—including trust-based collaboration, flexible contracting, network-based project acquisition, and experience-driven decision-making—were repeatedly observed among micro-scale firms operating under economic uncertainty. The recurrence of these practices across different firms and studies suggests that they function as recurring project-level decision-making routines rather than isolated strategic responses. In this sense, the findings suggest that project governance in micro-scale firms is enacted through recurring project practices rather than exclusively through formal organisational mechanisms.

6. Conclusion and Further Research

This study was developed within a TÜBİTAK-supported research project and is based on a conceptual

synthesis of systematic literature reviews, empirical interview-based studies, and a master's thesis. By integrating these complementary sources of evidence, the study provides a broader and more comprehensive understanding of how micro-scale AEC firms respond to economic uncertainty.-The findings show that micro-scale firms rely on flexible, experience-based, and often informal practices when operating under economic turbulence. These practices are not isolated actions. Across the empirical studies synthesised in this research, similar practices were consistently observed among micro-scale firms facing comparable economic conditions. These recurring practices suggest the emergence of adaptive project governance routines that support project-level decision-making. Over time, these patterns shape how firms make decisions at the project level. One of the key insights of this study is that firm behavior can be better understood through routines rather than individual strategies. While previous studies often focus on what firms do, this study explains how these actions are repeated and structured. This leads to the concept of adaptive project governance routines. These routines allow firms to respond quickly to uncertainty without relying on formal systems. The findings of this study can be useful for several groups. Practitioners can use the framework to better understand possible responses to economic uncertainty. Policy makers can benefit from understanding how micro-scale firms actually operate, rather than how they are assumed to operate. Researchers can use the study as a basis for further conceptual and empirical work on micro-scale firms and project governance. Despite these contributions, the study has some limitations. The empirical evidence synthesised in this study is derived from qualitative studies conducted with micro-scale AEC firms operating in Türkiye, primarily in Istanbul, complemented by two systematic literature reviews. Across the empirical studies, data were collected from 28 micro-scale AEC firms, while the master's thesis contributed findings from an additional 10 architecture firms. Therefore, the proposed framework reflects the economic and institutional context of Türkiye and should be interpreted accordingly. Therefore, the findings reflect a specific economic and institutional context. In addition, the study focuses on micro-scale firms and does not directly compare them with larger organizations. Future research can build on this study in several ways. First, the proposed framework can be tested in different geographical contexts to examine its applicability. Second, comparative studies can be conducted between micro, small, and large firms to understand differences in governance structures. Finally, the concept of adaptive project governance routines can be further developed and operationalized in quantitative or mixed-method research designs.

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Appendix 1

Table 2: Data Sources and Key Findings

Study	Research Method	Sample	Key Findings
Arıcı Üstüner & Balaban Ökten (2016)	Qualitative research using semi-structured interviews and qualitative content analysis	9 micro-scale architectural firms operating in Istanbul. All firms employed 10 or fewer permanent employees. Interviews were conducted with firm owners or managers through face-to-face or telephone interviews. Audio recordings were transcribed and analysed.	The study found that project acquisition largely depended on client referrals and trust-based relationships. Contracts varied according to client type, while formal legal protection was used selectively because of cost and time constraints. Firms frequently encountered additional work requests, delayed payments, and contractual disputes, but preferred negotiation rather than legal action. Decision-making relied heavily on previous experience, informal trust, and flexible project management practices rather than formal contractual mechanisms.
Arıcı Üstüner & Balaban Ökten (2022)	Systematic Literature Review (SLR)	168 studies were initially identified through Google Scholar. Following the application of inclusion and exclusion criteria, 19 studies were selected for detailed review.The selected publications addressed construction under uncertain economic conditions.	The review found that existing studies could be grouped into five major research themes: (1) affordable housing, (2) cost estimation, (3) late payment and non-payment, (4) challenges associated with international construction markets and risk factors, and (5) critical success factors. Across these themes, the literature consistently demonstrated that economic uncertainty—including inflation, exchange rate volatility, interest rate fluctuations, and financing constraints—directly affects construction project performance, investment decisions, and project continuity. The review also highlighted that various decision-support models and risk management approaches have been proposed to reduce the impact of economic uncertainty on construction projects.
Toprak et al. (2024a)	Qualitative empirical study using semi-structured, in-depth interviews	Nine micro-scale AEC firms selected through convenience sampling. All firms employed fewer than ten people and represented architecture, interior design, urban design, restoration, visualization, and construction services. Interviews were conducted face-to-face with company owners in January 2024.	The study identified the initial survival strategies adopted by micro-scale AEC firms under economic uncertainty. Firms primarily relied on stakeholder networks to obtain new projects, strengthened supplier and subcontractor relationships, diversified their services and markets, shared office spaces to reduce overhead costs, preferred short-term projects to maintain cash flow, revised contracts according to inflation, purchased materials in advance to reduce price volatility, and increased marketing through digital platforms. The study concluded that the flexibility and adaptability of micro-scale firms constitute important competitive advantages during periods of economic uncertainty and that these findings provide the empirical foundation for a larger ongoing research project.
Toprak et al. (2024b)	Systematic Literature Review (SLR) following a structured	126 peer-reviewed publications selected after screening records retrieved from Scopus, Web of Science, Emerald, ASCE, and Google Scholar.	The review demonstrated that research on the resilience of micro-sized AEC firms has increased considerably in recent years, particularly following the COVID-19 pandemic. Among the reviewed studies, 48 focused on COVID-19, 7 on natural disasters, 6 on war, and 3 on earthquakes. Only 17 studies specifically addressed the

Study	Research Method	Sample	Key Findings
	review protocol	Publications unrelated to the research objectives, duplicates, and non-English/Turkish studies were excluded. Bibliometric relationship and density maps were generated using Mendeleyand VOS viewer.	construction sector, and only one focused on Türkiye, revealing a significant research gap. The review concluded that flexibility, organisational resilience, business networks, financing strategies, and adaptive capabilities are the dominant mechanisms supporting firm survival, while empirical evidence from the construction sector—particularly for micro-sized firms in Türkiye—remains limited, highlighting the need for further field-based research.
Toprak (2025)	Qualitative research using semi-structured interviews a nd inductive content analysis. Interview transcripts were coded and analysed to identify recurring survival strategies, which were subsequently grouped into broader conceptual themes.	10 micro-sized architecture firms operating in Istanbul. Participants were founders or senior managers selected through purposive sampling based on firm size, continued operation during economic crises, and sectoral experience.	The study identified eight recurring survival strategiesadopted by micro-sized architecture firms during economic crises: (1) liquidity and value preservation, (2) cash-flow-oriented contracting, (3) supply chain and inventory flexibility, (4) market and service diversification, (5) outsourcing and work-sharing, (6) operational downsizing, (7) digital marketing and network expansion, and (8) customer and stakeholder relationship resilience. These strategies were further synthesised into three higher-order resilience dimensions: financial flexibility, activity and market diversification, and cost reduction. The findings demonstrate that micro-sized firms rely on multiple complementary strategies simultaneously, highlighting organisational adaptability as a key determinant of survival under uncertain economic conditions.

Source: Developed by the authors

Project Success and Professional Perceptions of Public Value in Small-Scale Urban Infrastructure: A Case Study of Green Point Dome Project, South Africa

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Abstract

Small-scale urban infrastructure projects are under-represented in project management research, particularly regarding how success and long-term public value are understood beyond traditional time, cost, and quality metrics. Existing studies largely emphasise operational performance, offering limited insight into practitioner perceptions of value in complex, publicly oriented contexts. This study addresses this gap by examining how technical, managerial, and planning mechanisms shape professional perceptions of project success and sustained public value. A mixed-methods single-case study was conducted on the Green Point Dome (Cape Town, South Africa), a 3D mass timber structure with educational gardens, selected for its innovation and stakeholder complexity. Data were collected using a structured self-administered survey (Likert-scale and open-ended items) from 17 professionals involved in project delivery. Quantitative data were analysed using descriptive statistics, while qualitative responses underwent thematic analysis. Findings show that perceived success is more strongly linked to collaboration, stakeholder engagement, and adaptive planning than to traditional metrics (on-time: 11.8%; on-budget: 23.5%). Long-term public value especially educational use (88.2%), accessibility (82.4%), and cultural relevance (82.4%) emerged as the dominant dimension. Despite its small sample (n=17) and single-case scope, the study highlights the central role of governance and collaborative processes in shaping perceived success and value.

Keyword: project success; public value; urban infrastructure; collaborative governance; infrastructure planning; stakeholder engagement

1. Introduction

Urban small- to medium-scale infrastructure projects remain underexamined in project management research (Jacobsson & Jąlocha, 2021; Lundin et al., 2015). Here, small-scale denotes projects under ZAR 10 million (USD 410 000), single-site, and of limited organisational complexity though such projects can still involve technical innovation and complex stakeholder interdependence (Van Marrewijk et al., 2008). The study adopted City of Cape Town stage guide review, complexity matrix that define small (less than 10 million), medium m and large projects (City of Cape Town, 2025). While large-scale infrastructure dominates scholarship on governance, finance, and

delivery (Denicol et al., 2020; Flyvbjerg, 2014), smaller public projects community, educational, and cultural facilities operate in distinct contexts requiring closer study (Cheruiyot, 2024; Companie, 2023). Despite their size, they often entail intricate stakeholder environments (Aaltonen & Kujala, 2016), tight budgets, and ambitions for enduring community impact.

The Green Point Dome in Cape Town exemplifies this category (See Figure 1). Delivered at ZAR 7.8 million, it is a timber dome with integrated educational gardens and represents a world-first three-dimensional mass-timber configuration. The project combined engineering innovation, multidisciplinary collaboration, community engagement, and public funding, and received multiple awards for engineering, sustainability, and project management excellence (HHO Consulting Engineers, 2025; Klaaren & Watermeyer, 2022).

Traditional project success metrics emphasise the "iron triangle" of time, cost, and quality (Atkinson, 1999). Contemporary research, however, argues that this is insufficient for public infrastructure, where long-term social, environmental, and cultural outcomes matter (Silvius & Schipper, 2020). The concept of public value extends evaluation beyond outputs to broader societal benefits (Moore, 1995, 2013), though it is criticised for ambiguous operationalisation and for masking contestation over what constitutes value (Rhodes & Wanna, 2007; Dahl & Soss, 2014).

This study addresses the gap between project success evaluation and long-term public value in small-scale

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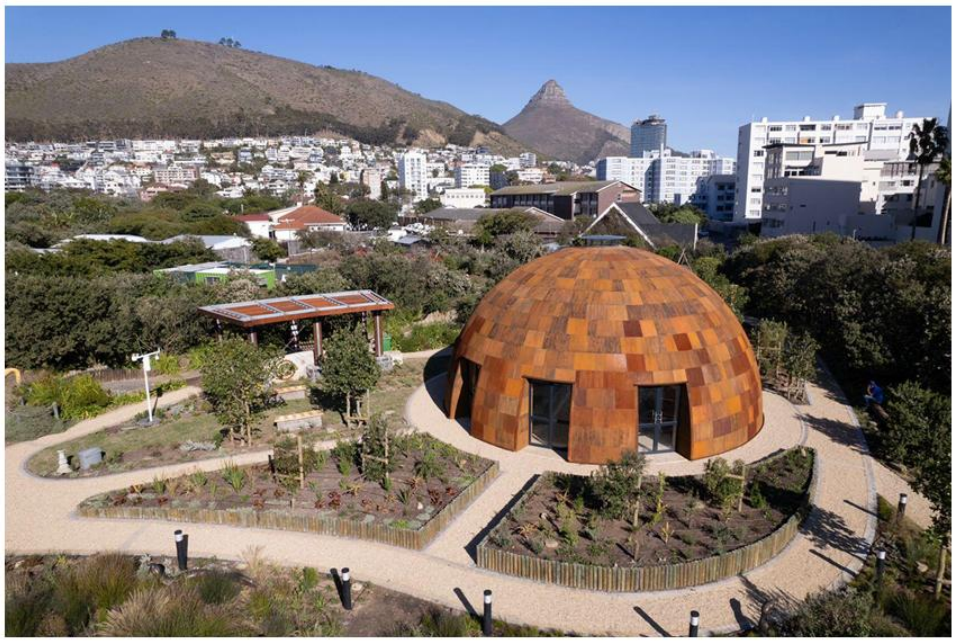

Figure 1: The Green Point Dome, Cape Town
Source: (MEWA Engineering, 2025)

urban infrastructure. Using a mixed-methods case study of the Green Point Dome, it examines how project professionals perceive success, which delivery and planning mechanisms they associate with positive outcomes, and how long-term value informs these assessments. The analysis is limited to professional perspectives; community and end-user views were not included.

2. Literature Review

2.1 Project success in construction and infrastructure

Conceptualisations of project success have expanded beyond the traditional "iron triangle" of time, cost, and quality (Atkinson, 1999). Later work incorporates stakeholder satisfaction, organisational learning, and strategic alignment (Cooke-Davies, 2002). Baccarini's (1999) distinction between project management success (delivery efficiency) and product success (long-term effectiveness) remains influential. In public infrastructure, success is inherently more complex due to multiple stakeholders (Aaltonen & Kujala, 2016; Freeman, 1984), long time horizons, and intangible outcomes (Samset, 2010).

2.2 Public value and long-term benefit

Public value theory reframes success in terms of societal outcomes rather than outputs (Moore, 1995, 2013; Benington & Moore, 2011; Meynhardt, 2015). In infrastructure, this includes accessibility, sustainability, cultural relevance, and intergenerational equity (Gilbert et al., 2022). However, critics highlight its ambiguous operationalisation and tendency to obscure stakeholder conflict and assumed consensus (Rhodes & Wanna, 2007). Accordingly, this study treats public value as professionally perceived, not objective.

2.3 Governance, planning and innovation in infrastructure projects

Planning and governance particularly staged planning, cross-disciplinary collaboration, and stakeholder engagement are key to project success (Davis, 2017; Eriksson & Szentes, 2017). Innovative projects, lacking established standards, require stronger governance frameworks (Brady & Davies, 2014; Denicol et al., 2020). Effective planning plays a central role in risk mitigation.

Timber construction is increasingly valued for environmental benefits (Ramage et al., 2017), yet uptake in South Africa is constrained by limited supply chains and regulatory barriers (Kunze & Pienaar, 2020). It therefore provides a lens for examining how technical innovation interacts with governance and planning.

2.5 Conceptual framework

The study conceptualises project success as emerging from interactions between technical innovation, governance and planning, stakeholder collaboration, and public value outcomes (See Figure 2). Technical innovation introduces complexity, requiring coordinated governance and collaboration, which in turn influence long-term public value and shape professional perceptions of success beyond traditional metrics. The conceptual framework guiding this study is presented in Figure 2.

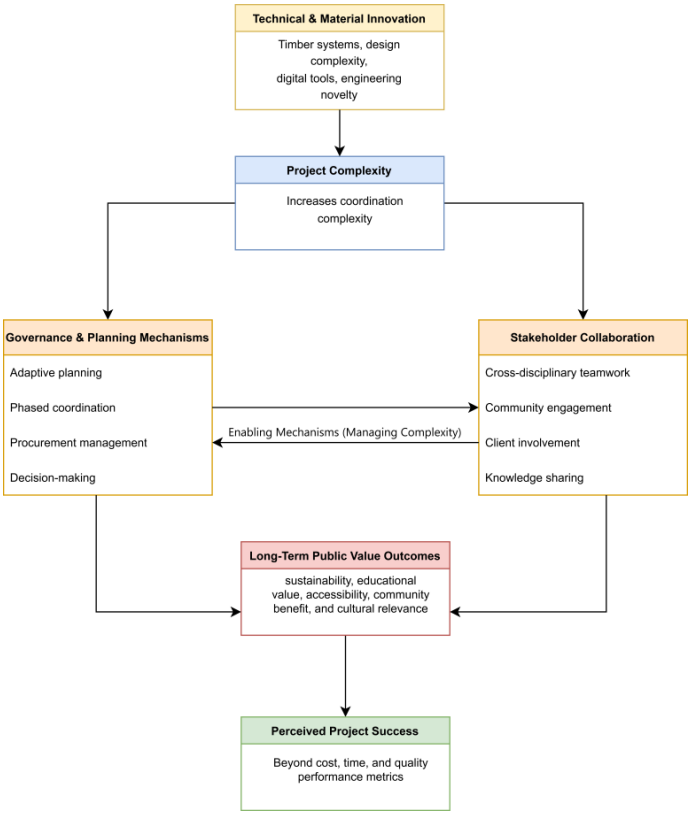

Figure 2: Conceptual Framework

The framework proposes that technical innovation drives project complexity, which must be managed through the interaction of governance and stakeholder collaboration. These enabling mechanisms influence the extent to which projects generate long-term public value, which in turn shapes overall perceptions of project success beyond traditional performance measures.

3 Research Methodology

3.1 Research design

This study adopts a mixed-methods case study design (Yin, 2018). The Green Point Dome project was purposively selected as an information-rich case due to its uniqueness in South Africa, innovative design, stakeholder complexity, and external validation through awards (HHO Consulting Engineers, 2025). The actual capital cost was ZAR 7.8 million (approximately USD 410 000 at the time of construction), placing it within the small-scale definition. The participant were asked to complete interview or survey of which all selected survey.

3.2 Case context

The dome is situated within the Green Point Urban Park in Cape Town (City of Cape Town, 2024; Companie & Windapo, 2024). The structure consists of a timber dome constructed using laminated veneer lumber (LVL) and glulam components, integrated with an experiential education garden. Stakeholders included architects, engineers, quantity surveyors, project managers, municipal representatives, and community actors. Technical achievements include 20 curved glulam beams (each 200 kg) radiating from a central compression ring (HHO Consulting Engineers, 2025; MEWA Engineering, 2025).

3.3 Data collection

A structured questionnaire was administered electronically to 23 professionals involved in the project's planning, design, and construction; 17 valid responses were received (73.9%). The instrument included closed- and open-ended items covering respondent profile, delivery mechanisms, perceived public value, and project success. The sample reflects key professional roles (82% professionally registered and 18% non-registered); community and end-user perspectives were excluded by design, limiting conclusions on broader public value.

Data were collected in 2024, approximately two years post-completion, enabling reflective yet recent insights, though focused on anticipated rather than realised long-term value. Ethical protocols (voluntary participation, informed consent) were followed, and no conflicts of interest were declared. The authors are independent academics with no project involvement, though prior research interests may introduce theoretical bias.

Quantitative data were analysed descriptively (frequencies, medians), with Likert items treated as ordinal; no inferential analysis was undertaken (n=17). Qualitative responses were examine through a thematic analysis.

Limitations include the single-case design, small sample, gender imbalance, reliance on self-reported perceptions, and absence of longitudinal and community perspectives. Findings are therefore indicative rather than generalisable.

4 Findings and Discussion

The sample (n=17) comprised predominantly 16 male (94.1%) and 1 female (0.059%), experienced built-environment professionals, with over half exceeding 10 years' experience and 52.9% professionally registered.

The results reflection as per table 1, planning perceptions were generally positive (64.7%), though not uniform. Collaboration, digital tools (both 82.4%), and stakeholder engagement (64.7%) emerged as dominant delivery mechanisms. Qualitative responses emphasised the importance of coordination and adaptability in managing technical complexity:

"Daily coordination… brought all stakeholders together to understand the new innovative design." (R9)

"The ability… to adapt and modify designs as the project progressed was critical." (R4)

Strong consensus (88.2%) indicated that the project was designed to benefit future users. Long-term value was primarily associated with educational use (88.2%), accessibility (82.4%), and cultural fit (82.4%), outweighing material durability.

All respondents agreed that success should include social and environmental outcomes. User satisfaction (76.5%) and long-term community benefit (64.7%) ranked highest, while time (11.8%) and cost (23.5%) were deprioritised.

"The dome… genuinely owned by the people they serve." (R17)

While most (82.4%) viewed planning and long-term goals as well integrated, critical perspectives mainly from execution-phase participants highlighted coordination gaps:

"Not involved sufficiently in planning… execution stage was very poor." (R16)

Overall, findings indicate that governance, collaboration, and adaptive planning are central to perceived project success and public value.

In line with the framework, governance and collaboration processes were strongly associated with the generation of long-term public value outcomes. The prioritisation of user satisfaction (76.5%) and long-term community benefit (64.7%) confirms that public value outcomes are central to how project success is perceived beyond traditional performance metrics.

Table 1: Summary of Key Findings Across Dimensions (n=17)

Dimension	Key Indicators	Dominant Findings (%)	Interpretation
Planning & Delivery	Collaboration, digital tools, stakeholder input	82.4%, 82.4%, 64.7%	Emphasis on integrated, cross-disciplinary coordination
Long-Term Value	Education, accessibility, cultural fit	88.2%, 82.4%, 82.4%	Social and functional value prioritised
Success Metrics	User satisfaction, community benefit	76.5%, 64.7%	Shift toward value-based success definitions
Traditional Metrics	Time, cost	11.8%, 23.5%	Deprioritised in professional assessment

5 Results and Discussion

5.1 Interpretation of Findings

Findings provide indicative support that, in small-scale innovative infrastructure, managerial and planning mechanisms are more strongly associated with perceived success than traditional metrics. High levels of collaboration and technology use (both 82.4%), supported by qualitative emphasis on coordination and adaptability, suggest governance processes are central to delivery. These findings support previous research emphasising stakeholder collaboration as a critical determinant of infrastructure project success (Aaltonen & Kujala, 2016; Davis, 2017). The prominence of governance and adaptive planning also aligns with Brady and Davies (2014), who argue that innovative projects require stronger coordination mechanisms to manage complexity.

Furthermore, the prioritisation of social and community outcomes over traditional delivery metrics supports Silvius and Schipper's (2020) contention that contemporary project success extends beyond the iron triangle toward broader stakeholder value creation. The

findings are similarly consistent with Moore's (1995; 2013) public value perspective, which emphasises societal benefits as a fundamental dimension of public-sector performance. Lower emphasis on formal staging (47.1%) and varied planning assessments indicates an adaptive, iterative approach consistent with innovation literature. A key insight is the dominance of long-term public value. Universal agreement (100%) that success includes social and environmental outcomes, alongside the prioritisation of user satisfaction (76.5%) and community benefit (64.7%), reflects a shift toward value-based evaluation. Educational use and accessibility further reinforce this orientation. However, the absence of community perspectives limits claims about realised public value. Technical innovation (timber) appears to act indirectly driving coordination complexity rather than independently determining success suggesting that governance capability mediates innovation outcomes.

5.2 Implications for practice

The findings carry several implications for public infrastructure planning and delivery, particularly in South African and similar Global South contexts. First, procurement and governance frameworks should explicitly accommodate expanded success criteria. Current public-sector procurement models in South Africa remain heavily weighted toward cost and time compliance (National Treasury, 2022; Republic of South Africa, 2017). Reforms incorporating social value, user satisfaction, and long-term benefit metrics for example, weighted criteria in tender evaluations that increase the proportion assigned to social and environmental outcomes beyond current compliance-heavy frameworks would align more closely with professional perceptions of genuine project success.

Second, investment in cross-disciplinary collaboration mechanisms integrated project delivery models, digital collaboration platforms (e.g., Building Information Modelling), structured stakeholder forums may yield returns that exceed those from technical optimisation alone. For small-scale projects with limited budgets, low-cost coordination mechanisms (regular cross-disciplinary workshops, shared digital dashboards) can be effective.

Third, continuous monitoring and adaptive management are essential. The divergence between the majority positive assessment and minority critical perspectives on planning integration highlights that even projects achieving overall positive evaluation may have process deficiencies that undermine value creation for particular stakeholder groups. Post-occupancy evaluations and lifecycle asset management plans should be contractually required.

Fourth, contractor capability development should address the gap identified by respondents: the tendency to appoint the lowest-cost contractor without sufficient quality weighting. Implementing a quality-cost ratio that increases the weighting of technical and capability criteria relative to price (for example, from the commonly used 90:10 toward a more balanced 70:30 or 60:40) would help address this, consistent with the National Treasury's (2022) emphasis on value-for-money over lowest-cost procurement.

5.3 Theoretical contribution

This study contributes to project management and infrastructure literature in three important ways. First, it extends project success literature by demonstrating that professional perceptions in small-scale urban infrastructure projects prioritise public value outcomes, such as user satisfaction, educational benefit, accessibility, and community benefit, over traditional delivery measures of time and cost. Second, the findings provide empirical support for the argument that governance capability, stakeholder collaboration, and adaptive planning are central mechanisms through which technical innovation contributes to project success.

The study therefore suggests that governance and collaborative processes mediate the relationship between innovation and perceived project success. Third, the study contributes context-specific evidence from South Africa and the broader Global South, where empirical research on small-scale urban infrastructure remains limited. By focusing on a small-scale public infrastructure project, the research broadens understanding of how project success and public value are conceptualised outside the large infrastructure and megaproject contexts that dominate existing scholarship.

5.4 Limitations and future research

Several limitations are acknowledged. The single-case design restricts generalisability, though it provides in-depth insight into a unique project. The sample size (n = 17) limits advanced statistical analysis and means findings are indicative. The gender imbalance (94.1% male) reflects sectoral demographics but may constrain diversity of perspectives. The limited representation of female professionals means that perspectives relating to relational stakeholder engagement and inclusive design may be underrepresented. The cross-sectional design captures perceptions at a single point; longitudinal assessment would be required to evaluate whether anticipated long-term benefits are realised in practice. Most critically, the absence of community and end-user voices means this study captures only one side of the public value equation.

Future research should extend this investigation through: (i) comparative case studies across multiple small-scale infrastructure projects in different South African municipalities; (ii) longitudinal benefit realisation assessment (e.g.,5–10-year post-completion

evaluation) including both professional and community perspectives; (iii) incorporation of community user perspectives alongside professional evaluations, using methods such as participatory appraisal or citizen panels; (iv) larger-sample surveys to enable inferential testing of relationships identified here; (v) experimental or quasi-experimental studies of procurement reforms (e.g., quality-weighted tendering) to establish causality; and (vi) forced-choice or budget-allocation exercises to explore what professionals prioritise when trade-offs between time, cost, and social value are made explicit.

5.5 Conclusion

This study investigated how project success and long-term public value are perceived by professionals involved in a small-scale, innovative urban infrastructure project the Green Point Dome in Cape Town, South Africa. Through structured questionnaire data from 17 practitioners, the research examined relationships between planning mechanisms, technical factors, and success definitions. The findings suggest that perceived project success is more strongly associated with managerial and planning mechanisms (cross-disciplinary collaboration, stakeholder engagement, adaptive planning) than with traditional time and cost compliance. Long-term public value encompassing educational utility, community accessibility, cultural relevance, and environmental sustainability emerges as the dominant dimension through which professionals in this study evaluate success. The innovative use of timber, while recognised as significant, contributes to success primarily through the planning and coordination demands it creates.

These findings contribute indicative empirical evidence that governance and planning processes are central to professional perceptions of both immediate project success and long-term public value generation in small-scale public projects. The findings suggest that procurement and evaluation frameworks should be reformed to capture the multidimensional success criteria that practitioners endorse, and that investment in collaborative planning capabilities may yield substantial returns for public infrastructure value creation. However, the exploratory single-case design, small sample, and absence of community voices mean these conclusions are hypothesis-generating rather than definitive. Future research should test these patterns across larger samples and include the perspectives of end-users to fully understand public value creation.

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Impact of Organizational Subcultures on Barriers to Total Quality Management Implementation in Nigerian Construction Materials Manufacturing firms

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Abstract

This study examines the impact of organisational subcultures on barriers to Total Quality Management (TQM) implementation in Nigerian construction materials manufacturing firms. Despite the strategic importance of this sector in influencing construction quality and infrastructure performance, persistent challenges such as substandard materials, inconsistent production quality, and weak regulatory compliance continue to undermine outcomes. Drawing on organizational culture theory and the Competing Values Framework (CVF), the research employs a quantitative approach, utilising survey responses gathered from a sample of 150 participants across construction materials manufacturing firms. Organisational subcultures (clan, adhocracy, market, and hierarchical) were analysed alongside six TQM Implementation barrier constructs: top management support, employee, customer Support, planning, process management, and information management. Data collected were analysed using descriptive statistics and Structural Equation Modelling (SmartPLS). The results reveal that organisational subcultures significantly influence TQM barriers, with clan culture emerging as the most supportive orientation, demonstrating significant relationships with multiple TQM dimensions. Adhocracy and hierarchical cultures showed moderate influence, particularly in process and strategic dimensions, while market culture exhibited limited but targeted effects. Quantitatively, the strongest associations were observed for hierarchical culture with customer-focus barriers ($\beta = 0.76$, $p < 0.01$); clan culture with strategic-planning barriers ($\beta = 0.58$, $p < 0.01$), top-management barriers ($\beta = 0.42$, $p < 0.05$) and measurement-and-analysis barriers ($\beta = 0.41$, $p < 0.05$); market culture with workforce-management barriers ($\beta = 0.52$, $p < 0.01$) and process-management barriers ($\beta = 0.41$, $p < 0.01$); and adhocracy culture with workforce-management barriers ($\beta = 0.46$, $p < 0.01$).The findings confirm that TQM barriers are culturally embedded and that effective implementation requires alignment between subcultural orientations and quality management practices. The study contributes to theory by integrating subculture perspectives into TQM research and provides practical insights for improving quality performance and regulatory compliance in developing-country contexts.

Keywords: Competing Values Framework (CVF); Construction materials manufacturing; Nigeria; Organisational subculture; Total Quality Management (TQM); TQM barriers

1. Introduction

The construction materials manufacturing sector occupies a critical position within the Nigerian construction ecosystem, directly influencing the quality, safety, and sustainability of the built environment. Materials such as cement, blocks, steel, and coatings account for a substantial proportion of construction costs often exceeding 60–70% of total project expenditure and therefore play a decisive role in determining project performance, durability, and lifecycle value (Makhdoomi, 2018; Ofori, 2015). This makes the sector particularly important to study, as defects originating at the production stage often propagate across the entire construction value chain, ultimately affecting project outcomes and public safety. However, the sector continues to face persistent quality deficiencies, including substandard materials, inconsistent production outputs, and non-compliance with regulatory standards, which have been linked to building collapse and reduced infrastructure lifespan in Nigeria (Egwunatum et al., 2021; Okonta et al., 2024). Despite operating under strict regulatory oversight from the Standards Organisation of Nigeria (SON), enforcement challenges and weak internal quality systems continue to undermine consistent compliance (Oke et al., 2023). These challenges point to systemic weaknesses in quality management practices and justify the need for deeper investigation into the organisational factors underpinning quality performance in this sector.

Total Quality Management (TQM) has been widely advocated as an all-encompassing approach for improving product quality, operational efficiency, and organisational competitiveness through principles such as continuous improvement, process integration, and employee involvement (Deming, 1993; Oakland,

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2003). However, evidence suggests that TQM implementation often falls short of expected outcomes, particularly in developing-country contexts, due largely to organisational and behavioural factors rather than technical limitations (Hilma et al, 2020; Jum'a et al 2023;Sony et al., 2020; Oke et al., 2023). Drawing on organisational culture theory, this study argues that these limitations can be better understood through the lens of organisational subcultures distinct patterns of values and practices that emerge across departments and hierarchical levels and shape how quality initiatives are interpreted and enacted (Schein, 1985; Martin, 2002). Using the Competing Values Framework (Cameron & Quinn, 2005), the study examines how subcultural orientations influence barriers to TQM implementation in Nigerian construction materials manufacturing firms. By linking subculture theory with TQM barrier constructs, the study provides a context-specific and theoretically grounded perspective for improving quality performance, regulatory compliance, and organisational effectiveness in the sector. In the context of Nigerian construction materials manufacturing firms, where operational processes are highly interdependent, such subcultural variations are likely to have significant implications for TQM barriers. However, empirical evidence in this area remains limited, particularly in terms of quantitative analysis linking subculture types to specific barrier constructs. This paper is aimed at examining how organizational subcultures influence barriers to TQM implementation in Nigerian construction materials manufacturing firms. This was achieved by identifying the organizational subcultures (clan, adhocracy, market and hierarchy) present in the sector and to determine which subcultural orientations most strongly shape these barriers.

2. Literature Review

2.1 Total Quality Management (TQM) in Manufacturing and Construction Materials Firms

Total Quality Management (TQM) remains a foundational managerial philosophy for enhancing operational efficiency, product quality, and organisational competitiveness in manufacturing environments (lagrosen & Lagrosen, 2019; Palumbo & Douglas, 2024; Patyal et al, 2020). Contemporary research demonstrates that TQM continues to deliver performance improvements through continuous improvement, process discipline, and customer orientation, although outcomes are highly contingent on organisational context and capability (Carvalho et al., 2021; Sony et al., 2022).

Within the construction materials manufacturing sector, TQM assumes heightened importance due to its strong effect on the quality and safety of the built environment. Materials significantly influence construction performance and durability, often accounting for a substantial proportion of project costs (Makhdoomi, 2018; Ofori, 2015; Ogunyemi et al., 2022). However, persistent quality failures including non-conforming cement strength and inconsistent material specifications have been linked to weak quality systems and uneven TQM implementation (Sinha & Dhall, 2020; Twaissi et al, 2025; Egwunatum et al., 2021; Okonta et al., 2024). Furthermore, firms operate under strict regulatory oversight from the Standards Organisation of Nigeria (SON), making quality management not only a strategic necessity but also a compliance requirement (Oke et al., 2023). Despite this, evidence suggests that TQM implementation in such contexts is often constrained less by technical limitations than by organisational and behavioural factors (Sony & Naik, 2021). Nevertheless, the TQM–performance relationship remains contested: while some studies report strong positive effects, others find weak or context-dependent outcomes, indicating that TQM's benefits are neither automatic nor universal but depend on organizational and cultural readiness Coelho (2022), Ndlovu (2016), Novena (2012). This unresolved debate justifies a closer, culturally grounded examination of why implementation barriers persist.

2.2 Organisational Culture and Subcultures in TQM Implementation

Organisational culture has been acknowledged as a critical determinant of TQM success or failure. It shapes how employees interpret quality goals, adhere to procedures, and engage in continuous improvement initiatives (Sony & Naik, 2021; Hartnell et al., 2019). Recent literature confirms that alignment between organisational culture and quality management systems is essential for effective TQM implementation, particularly in complex and process-driven environments (Palumbo & Douglas, 2024).However, organisations rarely exhibit a single, unified culture. Instead, subcultures emerge within departments, plants, hierarchical levels, and professional groups, reflecting distinct norms, values, and practices (Palumbo et al, 2024)). In construction materials manufacturing, where operations are highly standardised and inspection-driven, these subcultures play a decisive role in shaping how quality routines are interpreted and enacted at the operational level. Empirical evidence from emerging economies indicates that rigid, hierarchical, or fragmented subcultures tend to intensify TQM barriers such as resistance to change, weak communication, limited skills development, and poor cross-functional coordination (Aquilani et al., 2020; Oke et al., 2023). Conversely, participative and learning-oriented subcultures characterised by trust, teamwork, and openness have been shown to reduce human and managerial barriers to TQM adoption (Sony et al., 2022). These findings imply that understanding subcultural dynamics is vital for explaining variations in TQM implementation outcomes.

2.3 Conceptualising Organisational Subcultures: The Differentiation Perspective

Organisational culture is commonly defined as a system of shared values, beliefs, and assumptions that guide behaviour and interpretation within an organisation (Schein, 1985; Cameron & Quinn, 2005). However, the differentiation perspective of organisational culture emphasises that multiple subcultures coexist within organisations, each shaped by functional roles, hierarchical levels, and operational contexts (Patyal et al, 2020; Twaissi et al, 2025). This view is particularly relevant in manufacturing settings, where different units such as production, quality control, procurement, and management may exhibit distinct cultural orientations. These subcultures may either align with or contradict TQM principles. For example, production units may prioritise output and efficiency, while quality units emphasise compliance and standardisation. Where such subcultures are misaligned, they can create friction, resistance, and inconsistencies in TQM implementation (Juma'a et al, 2023).

2.4 Measuring Organisational Culture: The Competing Values Framework (CVF)

The evaluation of organisational culture remains a complex challenge due to its multidimensional nature. Various instruments have been developed, including the Organisational Culture Profile and Organisational Culture Inventory; however, the Competing Values Framework (CVF) has emerged as one of the most widely used and empirically validated models in quality management research. The CVF conceptualises organisational culture along two dimensions: flexibility versus control, and internal versus external focus. These dimensions generate four cultural archetypes: clan, adhocracy, market, and hierarchy. Each archetype reflects distinct organisational priorities, leadership styles, and approaches to coordination and control (Cameron & Quinn, 2005). Recent studies continue to validate the CVF as a robust framework for linking cultural orientations to TQM practices, organisational performance, and change capability (Dimitrantzou et al., 2022; Palumbo & Douglas, 2024). Importantly, the CVF allows for the coexistence of multiple cultural orientations within the same organisation.

2.5 TQM Implementation Barriers: Classical and Contemporary Perspectives

Despite its theoretical appeal, TQM implementation has historically been associated with significant challenges. Foundational studies emphasised that TQM requires deep organisational change and long-term commitment, making it difficult to implement effectively without strong systemic support (Deming, 1993; Oakland, 2003; Dale, 2007). Recent studies confirm that these barriers persist, particularly in developing and emerging economies. In Nigeria, key challenges include weak quality culture, inadequate managerial support, poor communication systems, limited adoption of formal quality management systems, and insufficient technical resources (Oke et al., 2023; Ibrahim et al., 2024). Additionally, organisational fragmentation and lack of cross-functional integration continue to undermine TQM effectiveness in construction-related industries (Onyia et al., 2024). Importantly, contemporary research suggests that TQM barriers are not uniform across contexts. Their nature and intensity vary depending on organisational structure, industry characteristics, and cultural conditions (Sony et al., 2022).

2.6 Linking Organisational Subcultures to TQM Barriers

A growing body of literature highlights the role of organisational culture as both an enabler and constraint of TQM implementation. However, fewer studies explicitly examine how subcultures influence specific categories of TQM barriers. Emerging evidence suggests that subcultural misalignment can amplify implementation challenges by creating inconsistencies in behaviour, communication, and decision-making across organisational units (Palumbo & Douglas, 2024). For instance, hierarchical subcultures may reinforce control and compliance but limit innovation and learning, while clan-oriented subcultures may promote collaboration and continuous improvement (Dimitrantzou et al., 2022). Similarly, market-oriented subcultures may prioritise performance outcomes at the expense of process discipline, thereby affecting quality consistency. Organisational culture shapes TQM, but subculture effects are contested. Clan cultures reportedly lower behavioural barriers (Eniola et al., 2019; Sony et al., 2022), yet hierarchical/market orientations prove equally effective in controlled settings (Patyal et al., 2020), cultural effects appear weak and context-dependent (Coelho et al., 2022) and often operate indirectly through TQM (Sinha & Dhall, 2020).

2.7 Toward a Typology of TQM Barriers

Given the diversity and fragmentation of TQM barrier literature, there is a need for a structured typology that organises barriers into coherent constructs. Aligning with established quality frameworks such as the Baldrige model, barriers can be categorised into six major constructs: top management, employee, customer, planning, process management, and information management barriers (Dale, 2007; Oakland, 2003). This categorisation enables a more systematic analysis of how organisational subcultures influence different dimensions of TQM implementation (Table 1).

Table 1: TQM Barrier Constructs

Barrier Construct	Barrier Indicator
Top Management Barriers	Senior leadership does not visibly support or prioritize quality initiatives. Communication about quality from top management is limited or unclear. Insufficient resources are allocated for employee training and development. Leadership approaches restrict the development of a learning-focused culture. Frequent changes in senior management disrupt organizational stability. Excessive hierarchical layers slow down decision-making processes.
Employee Barriers	Employees are not given enough authority to participate in quality improvement efforts. Staff involvement in improvement initiatives is minimal. There is inadequate training in quality-related skills. Training in communication and teamwork is often neglected. Employee contributions to quality improvements are not properly recognized. Overall employee satisfaction across the organization is low.
Customer Barriers	Employees often resist organizational changes. There is no effective system to evaluate customer satisfaction. Customer needs and expectations are not properly identified. Feedback systems from customers are weak or ineffective. Building strong relationships with key customers is not prioritized.
Planning Barriers	Strategic plans are not aligned with customer requirements. Quality objectives are not included in organizational strategies. There are no clear methods for embedding new tools or practices. Collaboration with suppliers during planning is limited.
Process Management Barriers	There is no comprehensive organization-wide quality programme. Quality is treated as a separate function rather than a shared responsibility. Communication with external stakeholders is ineffective. Resources for implementing TQM are insufficient. Cross-functional teams are not utilized.
Information Management Barriers	Communication across departments and organizations is weak. Employees tend to work in silos without collaboration. Quality and performance data are not widely shared. Quality performance is not regularly or effectively measured. Benchmarking against industry best practices is not carried out. Limited time is available to implement quality initiatives alongside daily operations.

Organisational subculture (Table 2) is examined through six dimensions (Dominant Characteristics, Organisational Leadership, Management of Employees, Organisational Glue, Strategic Emphasis, and Criteria for Success).

Table 2: Dimensions of Organizational subculture

Dimension	Details
Dominant Characteristics	Does the organization operate in a friendly and supportive environment like a close-knit family, where individuals openly share experiences? Alternatively, is it characterized by a fast-paced and innovative culture where employees are encouraged to take initiative and embrace risk? Does the organization focus primarily on achieving targets, with strong competition and performance-driven attitudes? Or is it more formal and structured, where procedures and rules guide daily activities?
Organizational Leadership	Is leadership within the organization supportive and focused on mentoring, guiding, and developing employees? Or does leadership encourage innovation, creativity, and risk-taking? Does management adopt a highly results-driven and assertive approach? Alternatively, is leadership centered on coordination, organization, and ensuring smooth and efficient operations?
Management of Employees	Does the organization promote collaboration, teamwork, and shared decision-making? Or does it prioritize individuality, creativity, and freedom in how employees work? Is there a strong focus on competition, high performance, and achieving demanding targets? Or does the organization value stability, consistency, and secure working relationships?
Organizational Glue	Are loyalty, trust, and long-term commitment key elements that bind the organization together? Or is the organization driven by innovation and continuous improvement? Does it emphasize achieving goals and maintaining a competitive edge? Alternatively, are formal systems, rules, and procedures the main factors ensuring organizational stability and cohesion?
Strategic Emphasis	Does the organization prioritize employee development, trust, openness, and participation? Or is the focus on growth through acquiring resources and exploring new opportunities? Is success driven by competition, market leadership, and achieving ambitious targets? Or does the organization emphasize efficiency, stability, and well-controlled operations?
Criteria for Success	Is success measured through employee development, teamwork, and strong commitment to people? Or is it defined by innovation and being a leader in developing unique products or services? Does the organization prioritize outperforming competitors and achieving market dominance? Or is success based on efficiency, reliability, cost control, and smooth operational delivery?

Source: (Olaleye, 2019)

3. Research Methodology

This study adopts a quantitative, research design grounded in a positivist philosophy to examine the impact of organisational subcultures on barriers to Total Quality Management (TQM) implementation in Nigerian construction materials manufacturing firms. A minimum of 150 survey respondents was determined using Cochran's formula (95% confidence level, 5% margin of error). A structured questionnaire was developed based on established TQM barrier constructs and organizational subcultures were measured using dimensions adapted from the Competing Values Framework (CVF). The target population comprised construction materials manufacturers registered with relevant bodies; the Standards Organization of Nigeria (SON). A multi-stage sampling technique was employed, involving purposive selection of major industrial hubs (e.g., Lagos, Ogun, Abuja), stratified sampling across firm sizes (large, medium, and small) based on the number of departments in the organization, and purposive sampling of respondents including production managers, quality control officers, and senior executives. Data was collected using a 5-point Likert scale. The achieved sample of 150 also satisfies the requirements of PLS-SEM: it exceeds the "ten-times" rule (ten cases per the largest number of structural paths directed at any construct here four predictors, giving a minimum of 40) and provides adequate power for the model estimated.

Data were analysed in two stages. Descriptive statistics (means and standard deviations) were computed in SPSS to assess the prevalence and severity of the TQM barriers. The measurement and structural models were then estimated using partial least squares structural equation modelling (PLS-SEM) in SmartPLS, which is appropriate for predictive, theory-building research and for models with several latent constructs and non-normal data (Figure 1). The measurement model was assessed for internal consistency using Cronbach's alpha and composite reliability (≥ 0.70) and for convergent validity using average variance extracted (AVE ≥ 0.50); the structural model was evaluated through path coefficients (Table 3), with significance established by bootstrapping to obtain t-statistics and p-

Table 3: Path Coefficients

	Customer Focus	Measurement Analysis	Process Management	Strategic Planning	Top Management	Workforce Management
Adhocracy	0.072	0.317	0.086	0.011	0.316	0.445
Clan	-0.210	0.392	0.183	0.563	0.410	0.165
Hierarchical	0.751	0.080	0.348	0.410	0.089	-0.146
Marketing	0.030	0.102	0.416	0.014	0.038	0.523

Source: Field Survey 2025

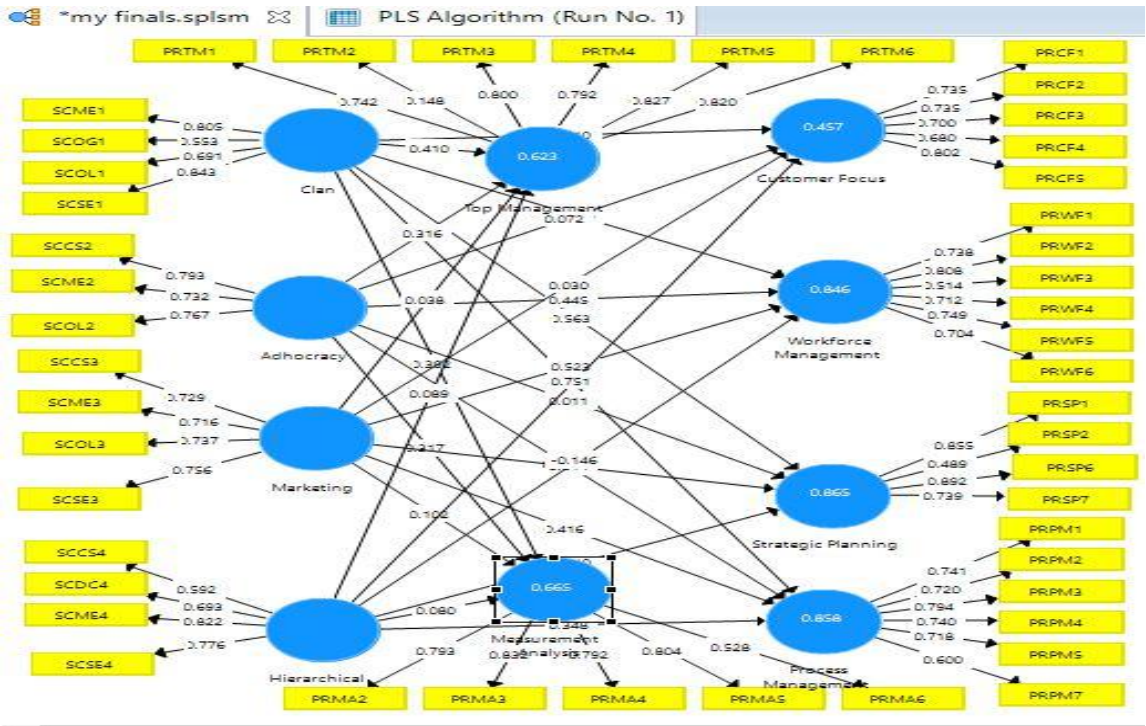

Figure 1: SEM showing Factor Loadings

values. Instrument validity was further supported through expert review and pilot testing. Ethical considerations were strictly observed, including informed consent, confidentiality, and secure data handling. Although the study provides valuable insights into the role of subcultures in shaping TQM implementation, limitations such as potential response bias and constraints associated with non-probability sampling are acknowledged.

4. Findings and Discussion

The findings (Table 4 in Appendix 1) of this study demonstrate that organisational subcultures significantly shape the nature and intensity of barriers to TQM implementation in Nigerian construction materials manufacturing firms. Clan culture emerged as the most supportive orientation, reducing barriers through enhanced teamwork, communication, and employee involvement, consistent with recent studies highlighting the importance of participatory cultures in quality management (Sony et al., 2022; Bogale & Debela, 2024). Adhocracy culture also contributed positively by fostering innovation, learning, and workforce engagement, although its influence on structured planning and customer focus was limited (Eniola et al, 2019). In contrast, hierarchical culture strengthened process control and regulatory compliance but tended to reinforce workforce-related barriers due to rigidity and limited flexibility, while market culture improved efficiency and performance but showed weaker alignment with strategic quality systems in agreement with Dimirantzou et al, 2022. Overall, the results confirm that TQM barriers are culturally embedded and multidimensional, and that effective implementation requires a balanced integration of collaborative, innovative, and control-oriented cultural attributes rather than reliance on a single dominant culture. Interpreted through the Competing Values Framework, these patterns suggest distinct mechanisms: the strong clan–strategic-planning association ($\beta = 0.58$) reflects the role of shared vision and participation in collective goal-setting, whereas the dominant hierarchical–customer-focus association ($\beta = 0.76$) indicates that formalised procedures and standardisation are what translate customer requirements into consistent specifications in this regulated sector. The prominence of market and adhocracy cultures in workforce-management barriers ($\beta = 0.52$ and 0.46) further implies that performance- and innovation-oriented cultures act mainly on human-resource and engagement dimensions rather than on strategic or measurement systems. The practical implication is that firms cannot rely on a single cultural lever; managers should diagnose their dominant subculture and deliberately build complementary orientations to address the specific barriers to which each is most strongly linked.

5. Conclusion and Further research

This study demonstrates that organisational subcultures play a fundamental role in shaping barriers to TQM implementation in Nigerian construction materials manufacturing firms. By integrating the Competing Values Framework with TQM barrier constructs, the research shows that clan and adhocracy cultures tend to mitigate behavioural and managerial barriers through collaboration and innovation, while hierarchical and market cultures enhance process discipline and performance but may reinforce structural and human-related constraints. The study contributes to theory by advancing a culture-based explanation of TQM barriers and to practice by highlighting that successful quality management requires not only technical systems but also deliberate alignment of organisational subcultures with TQM principles. In the context of Nigeria's construction materials sector, improving quality outcomes and regulatory compliance depends significantly on transforming internal cultural dynamics. Theoretically, the study extends TQM research by reconceptualising implementation barriers as culturally embedded phenomena and by demonstrating, through the Competing Values Framework, that different subcultures are associated with distinct and measurable barrier constructs rather than a single, undifferentiated cultural effect.

Future research should assume longitudinal and mixed method approaches to examine how organisational subcultures evolve over time and influence the sustainability of TQM outcomes in dynamic environments. Additionally, comparative studies across industries and developing economies would provide deeper insights into how contextual and institutional factors shape the relationship between organisational subculture and TQM barriers.

6. Recommendations

Firm leadership and senior management should institutionalise participatory management practices by promoting teamwork, employee empowerment, and open communication systems to reduce resistance to change and strengthen TQM implementation.

Regulatory bodies (e.g., SON) and organisational managers should encourage hybrid cultural models that combine hierarchical control with innovation-oriented practices to ensure both compliance and continuous upgrade in quality management systems.

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Appendix 1

Table 4: Size and significance of path estimates

	Sample Mean (M)	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**	**Remarks**
Adhocracy -> Customer Focus barrier	0.091	0.205	0.349	0.727	NS
Adhocracy -> Measurement Analysis barrier	0.317	0.135	2.347	0.019	**
Adhocracy -> Process Management barrier	0.083	0.088	0.971	0.332	NS
Adhocracy -> Strategic Planning barrier	0.006	0.075	0.151	0.880	NS
Adhocracy -> Top Management barrier	0.310	0.135	2.335	0.020	**
Adhocracy -> Workforce Management barrier	0.457	0.081	5.471	0.000	***
Clan -> Customer Focus barrier	-0.198	0.213	0.985	0.325	NS
Clan -> Measurement Analysis barrier	0.406	0.160	2.442	0.015	**
Clan -> Process Management barrier	0.183	0.111	1.655	0.099	*
Clan -> Strategic Planning barrier	0.580	0.090	6.232	0.000	***
Clan -> Top Management barrier	0.424	0.161	2.536	0.012	**
Clan -> Workforce Management	0.152	0.112	1.472	0.142	NS

	Sample Mean (M)	**Standard Deviation (STDEV)**	**T Statistics (|O/STDEV|)**	**P Values**	**Remarks**
Hierarchical -> Customer Focus barrier	0.763	0.185	4.051	0.000	***
Hierarchical -> Measurement Analysis barrier	0.085	0.135	0.589	0.556	NS
Hierarchical -> Process Management barrier	0.353	0.100	3.493	0.001	***
Hierarchical -> Strategic Planning barrier	0.397	0.082	5.001	0.000	***
Hierarchical -> Top Management barrier	0.097	0.149	0.595	0.552	NS
Hierarchical -> Workforce Management barrier	-0.149	0.099	1.477	0.140	NS
Marketing -> Customer Focus barrier	-0.002	0.163	0.182	0.856	NS
Marketing -> Measurement Analysis barrier	0.087	0.114	0.897	0.370	NS
Marketing -> Process Management barrier	0.411	0.086	4.863	0.000	***
Marketing -> Strategic Planning barrier	0.012	0.075	0.189	0.851	NS
Marketing -> Top Management barrier	0.027	0.125	0.301	0.764	NS
Marketing -> Workforce Management barrier	0.524	0.070	7.500	0.000	***

Source: Field Study (2025) Note: NS = not significant. a. Bootstrap confidence intervals for 10% probability of error (a= 0.10). *p < .10. **p < .05. ***p < .01

Sustainable Public-Private Partnerships for Effective Management of South Africa's Public Health Infrastructure

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Abstract

South Africa's public health system continues to face persistent challenges associated with deteriorating infrastructure and limited capital investment. These challenges have contributed to overcrowded healthcare facilities and inequitable service delivery across many parts of the country. While the public sector provides healthcare services to most of the population, the private healthcare sector serves a smaller proportion of citizens and has comparatively greater access to resources and infrastructure. To address these constraints, Public-Private Partnerships (PPPs) have been increasingly used to leverage private sector expertise, resources, and efficiency in delivering infrastructure and public services. Despite their potential, PPP outcomes have been uneven, often hindered by complex stakeholder dynamics, fragmented policy frameworks, weak governance, inadequate risk-sharing, and insufficient long-term planning. While some projects have delivered high-quality facilities, others have stalled due to mismanagement or conflicting priorities, highlighting a critical gap in sustainable implementation. This study acknowledges that the sustainability of healthcare PPPs extends beyond the successful delivery of physical infrastructure and includes the ability of such infrastructure to support accessible, efficient, and quality healthcare service delivery over time. Existing literature tends to examine governance, sustainability, and stakeholder management as separate concepts, with limited focus on how these factors collectively influence public health infrastructure management within the South African context.
This study employs a systematic literature review (SLR) guided by the PRISMA framework and analyses 28 selected studies to examine how sustainability can be integrated into all strategic phases of PPPs, from design and financing to governance and post-project adaptation, to improve infrastructure management and service quality in the public health sector. The findings reveal that fragmented governance structures, stakeholder misalignment, and coordination challenges are among the key barriers affecting the long-term sustainability of healthcare PPPs. The findings provide insights for developing effective, long-term, sustainable PPP models that enhance public health infrastructure resilience and service delivery. This study contributes to the body of knowledge by bringing together previously fragmented literature on healthcare PPPs, emphasising the interconnected role of governance, stakeholder engagement, and sustainability in developing the effective management of public health infrastructure in South Africa.

Keywords: Public-Private Partnerships, sustainability, public health infrastructure, governance.

1. Introduction

The public health sector in South Africa delivers services to millions of its population and is essential in ensuring equal access to healthcare. However, the sector continues to face persistent and complex issues, including outdated infrastructure, inadequate maintenance of healthcare facilities, limited capital investment, and rising demand driven by an expanding population and disease burden (Joudyian et al., 2021). The aforementioned problems have led to overcrowded facilities, inadequate service delivery, and increased inequalities between the public and private healthcare systems.

In response to these challenges, South African governments have come to rely on Public-Private Partnerships (PPPs) as a means of leveraging private sector experience, resources, and efficiency to deliver vital public services and infrastructure projects (Mbaka & Mwange, 2023). The PPP model has been recognised as a vital instrument to enhance public health systems and prevent the growing costs of an already costly and unsustainable healthcare sector (Mazibuko et al., 2023). PPPs are frequently used for public infrastructure projects to address the issues of funding, knowledge, risk sharing, effectiveness, innovation, on-time delivery, and long-term sustainability (Hailu &Tshehla, 2024). PPPs contribute to sustainability by promoting economic growth, infrastructural development, and institutional improvement, aligning with the United Nations Sustainable Development Goals (Kumar et al., 2025). However, to succeed in PPP, stakeholders must be committed, communicate openly, and share risks effectively.

PPPs are widely acknowledged as potential mechanisms for achieving sustainability goals, although empirical data remains unclear (Kumar et al., 2025). They have emerged as a critical strategy for

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improving infrastructure delivery within South Africa's public health sector, although there remains a significant gap in understanding how sustainability can be effectively coordinated across all strategic phases of a PPP, from design and financing to long-term governance and post-project adaptation.

Despite their significant usage, PPPs remain complex and context dependent. Although PPPs can improve infrastructure quality and efficiency, their effects are usually inconsistent due to governance issues, contractual complications, and organisational limitations. Understanding and learning from these obstacles is key to optimising PPP programmes' success. In this study, sustainability and effective management are viewed as interconnected concepts, where long-term infrastructure sustainability depends on effective governance, stakeholder coordination, financial accountability, and continuous operational performance throughout the PPP lifecycle. The study therefore recognises that successful PPP implementation extends beyond infrastructure development to include governance effectiveness, stakeholder coordination, operational sustainability, and healthcare service outcomes. This study, therefore, aims to critically examine sustainable PPPs for the effective management of public health infrastructure in South Africa through a systematic literature review approach.

1.1. Research Objective

The main objective of this study is to critically examine sustainable PPPs for the effective management of public health infrastructure in South Africa through a systematic literature review approach.

The study specifically seeks to:

- examine the role of governance in the sustainability of healthcare PPPs;
- explore the influence of stakeholder alignment and collaboration in PPP healthcare infrastructure management.

2. Literature review

This section critically reviews the literature on sustainable Public–Private Partnerships (PPPs) for Effective Management of South Africa's Public Health Infrastructure. The review is organised around five interrelated themes derived from the study objectives, study title, keywords and existing PPP literature, namely: PPPs in healthcare, sustainability, governance, stakeholder engagement, and an integrated perspective on sustainable PPPs for effective management. These themes collectively provide a broader understanding of the factors influencing the long-term sustainability and operational effectiveness of healthcare PPPs.

2.1. Overview of Public–Private Partnerships

PPP is defined as a contractual arrangement between the public and private sectors/entities for the provision of public goods and services, founded on mutually agreed-upon objectives (Kanti et al., 2020). It entails long-term cooperation between the public and private sectors, as stated by (Liu et al., 2023).

In practice, PPPs are widely employed in public infrastructure projects to address challenges such as funding shortages, knowledge gaps, risk allocation, efficiency, innovation, timely delivery, and long-term sustainability (Hailu & Tshehla, 2024). In this context, PPPs shift the government's role from direct investor and operator to policymaker, regulator, and supervisor of service quality and quantity, with the private sector assuming substantial operational and development risks (Tabrizi et al., 2020). PPPs in healthcare are joint efforts by government bodies, private organisations, and occasionally non-profit institutions to address healthcare concerns via innovation (Ebulue et al., 2024). In the healthcare sector, PPPs have evidently played a vital role in boosting service delivery and infrastructure development in developing nations (Salangwa et al., 2025). They have gained popularity for improving healthcare funding and service delivery, especially in a resource-constrained setting (Sarkar, et al.,2025). PPPs attempt to strengthen the healthcare system by boosting many components, including service delivery, governance, financing, and the availability of medical products (Salangwa et al., 2025). These collaborations can range from straightforward franchising, which aims to privately run an already-existing hospital, to full-service provision at all levels of care, which is essentially defined by combining the hospital and primary care facilities to offer community care (Ferreira & Marques, 2020). By combining resources, knowledge, and responsibilities, PPPs aim to exploit the capabilities of each sector for the collective benefit of society (Ebulue et al., 2024)

Despite their theoretical advantage, other literature reports that as more projects enter the implementation phase, the effectiveness of PPPs is being called into question due to emerging conflicts that threaten their sustainability (Onyoin, 2022). Samira Abdul et al., (2024) 's research supported that there is a growing need to rigorously evaluate and assess the impact of PPPs initiatives to determine their real contribution to healthcare outcomes, sustainability, and long-term effectiveness.

In recent years, PPPs have played an important role in addressing South Africa's healthcare needs, especially given limited resources and rising healthcare service demand (Sarkar, et al.,2025). This is reflected in collaborative initiatives between government and private entities, such as the co-location of clinical care management at Humansdorp District Hospital in the

Eastern Cape and at Universitas and Pelanomi Hospitals in the Free State (Mbaka & Mwange, 2023). Dlamini & Botes (2022) contend that, despite more than two decades of PPP implementation, the results have been largely unsatisfactory, particularly regarding infrastructure development, upgrading, operations, maintenance, and management across all spheres of government. Furthermore, PPP projects are frequently characterised by delays in completion, failure to achieve intended delivery targets, and challenges related to financial mismanagement and corruption (Dlamini & Botes, 2022).

2.2. Sustainability in the health sector

The sustainable development agenda recognises health as a component of all the SDGs and a critical feature of the process of achieving an equal and sustainable future (Kimario et al., 2020). Sustainability is conceptualised as the capacity to make responsible decisions regarding the allocation and use of resources in both economic and non-economic activities to generate desired social, economic, and environmental outcomes (Ozili, 2022), or, more broadly, as the ability to persist consistently over time (Tipu et al., 2024). Within healthcare infrastructure, sustainability specifically refers to the capacity of facilities to maintain operational performance, deliver continuous services, and remain economically viable over the long term (Njuguna et al., 2024). Strasser et al. (2021) emphasise that sustainability enables healthcare organisations to adapt to changing demands without compromising service quality or accessibility. Correspondingly, sustainable healthcare projects focus on cost-effective operations, alleviating financial pressures on the public sector while ensuring the consistent provision of high-quality services (Njuguna et al., 2024).

2.3. Governance and stakeholder engagement

Governance can be viewed as the set of activities and actions undertaken by a governing body to provide strategy and steer the organization toward achieving its goals (Oliveira et al., 2023). Core functions include defining objectives, determining how to achieve them, monitoring progress to ensure performance, and managing stakeholder relationships (Oliveira et al., 2023). Governance practices align the interests of many stakeholders, converting principles into objective recommendations (Oliveira, Fernandes & Pardini, 2023). In the context of PPPs, extensive stakeholder engagement supports transparency and fosters sustainability (Sheppard & Beck, 2020). Strong governance structures and active collaboration among stakeholders are therefore critical for the long-term success of PPP initiatives (Kumar et al., 2025). They take action to maximise long-term value, extending the organization's lifespan and quality of management (Oliveira et al., 2023).

However, the differing perspectives, interests, and value systems of the public and private sectors present challenges for coordination and alignment (Verweij & Van Meerkerk, 2020). The literature indicates that PPPs are distinguished from other interdependent alliances by their contractual arrangements, partner characteristics, and expected public outputs (Liu et al., 2023). Success in PPP projects is closely linked to the quality of relationships and coordination between partners (Tipu & Yousaf, 2022). Considering the complexity of governance in healthcare organisations, critically examining governance configurations provides managerial insights for implementing sustainability-oriented PPPs (De Matteis et al., 2024).

3. Research methodology

This study uses a systematic literature review (SLR) as the main research design to investigate sustainable PPPs for the effective management of public health infrastructure in South Africa.

The SLR methodology establishes an organised, transparent, and replicable procedure for discovering, analysing, and synthesising existing scholarly data. Using systematic reviews facilitates the distribution of research findings and promotes debate (Nazir & Das, 2025). Systematic reviews offer comprehensive information on a certain relevant subject, pointing out inconsistencies and knowledge gaps that prevent empirical generalisations in an area of study (Kumar et al., 2025). The author of this study used the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) methodology to report the systematic review. The PRISMA framework used in this study aims to ensure high-quality reporting and an efficient peer-review process (Nazir & Das, 2025).

The use of a systematic literature review is justified by the study's goal of synthesising current knowledge and identifying best practices for sustainable PPPs in healthcare infrastructure. Unlike primary research methods, the SLR enables a broad and in-depth examination of existing information, making it ideal for theory formulation and framework development.

Data were gathered through a systematic search of trusted academic databases, including Scopus, my UNISA library, ScienceDirect, and Google Scholar, to ensure broad, multidisciplinary coverage of peer-reviewed literature. The timeframe for the search was limited to studies published between 2010 and 2026 to capture contemporary developments in healthcare PPPs. Keywords were carefully chosen to reflect the various terminologies on the concept of the research topic. A specified search strategy was formulated by employing relevant keywords such as "public-private partnerships," "PPP," "healthcare infrastructure," "sustainability," "governance, and "public-private partnership."

3.1. Inclusion and exclusion

To ensure the quality and relevance of the selected studies, established inclusion and exclusion criteria were used:

Inclusion requirements included peer-reviewed articles Publications between 2010 and 2026, Studies focusing on PPPs in healthcare or infrastructure, and key policy reports addressing health-sector PPPs in any South African context, with explicit discussion of sustainability in at least one lifecycle phase.

Exclusion criteria encompassed non-peer-reviewed sources, studies unrelated to PPP healthcare infrastructure, non-health PPPs, and duplicate records. To promote transparency and reproducibility, the study selection process was conducted using the PRISMA methodology. The PRISMA method is a widely established guideline for conducting systematic reviews (SR) in clinical publications (Mishra & Mishra, 2023).

3.2. Study selection process

The study selection procedure followed the PRISMA framework, to improve transparency, reproducibility, and methodological rigour (Moher et al., 2009), which consists of four essential stages. The stages are as follows: Identification: retrieval of studies from selected databases, Screening: removing duplicates and unnecessary studies, Eligibility: analysis of full-text publications against criteria, and Inclusion: final selection of studies for analysis (Figure 1).

A total of 168 were initially identified through database searching. After removing duplicates, 120 were screened based on title and abstract relevance. Full-text screening was conducted on 52 articles, after which 28 studies met the inclusion criteria and were included in the final synthesis. The following diagram was developed to illustrate the study selection process:

3.3. Justification of Final Sample

The final inclusion of 28 studies was based on strict relevance criteria aligned with the research objectives. Only studies that explicitly addressed Public–Private Partnerships in healthcare infrastructure and included discussions on sustainability, governance, or stakeholder engagement were retained. This ensured that the final synthesis was focused, methodologically rigorous, and directly relevant to the research.

3.4. Data analysis

Thematic analysis was used to analyse the selected studies, which is suitable for synthesising qualitative data from diverse sources. Thematic analysis (TA) is a common technique for analysing qualitative data. It provides a structured but flexible framework for

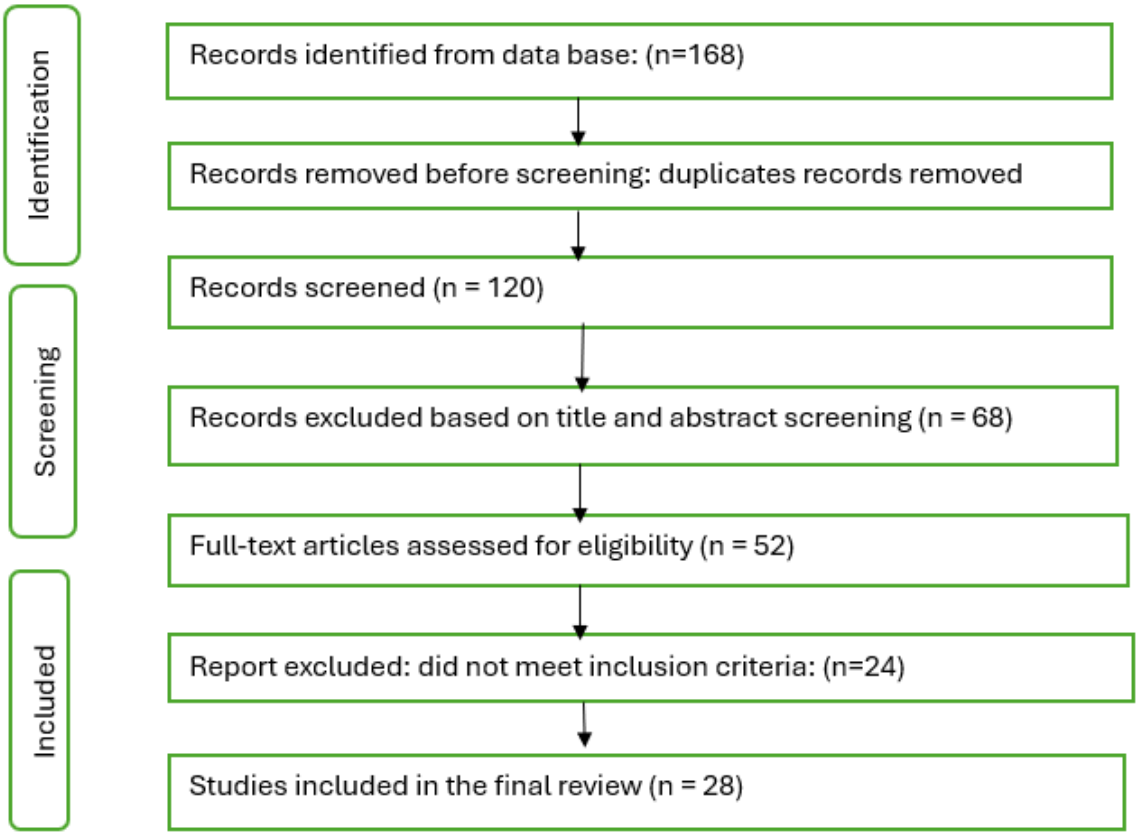

Figure 1: PRISMA Flow Diagram of Study Selection Process

identifying and interpreting patterns of meaning within data sets (Ahmed et al., 2025). This approach enabled the identification and classification of recurring themes relevant to the study topics.

4. Findings

This research study adopted a systematic review of published literature guided by the PRISMA 2020 framework. After applying inclusion/exclusion criteria to ensure relevance to sustainable PPP management in healthcare, 28 papers were selected for analysis (see Table 1). These studies focus on PPP definitions, implementation, sustainability, governance frameworks, and stakeholder alignment in healthcare infrastructure. The study conducted a systematic literature review to map out the main research areas on sustainable PPP management in the health sector. Most of the studies used mixed methodologies, including qualitative, quantitative, descriptive, and systematic review methods.
This section presents the findings from the systematic literature review and analyses how they relate to the study's research questions. The research is based on a thematic analysis of selected studies, with an emphasis on sustainability, governance, and stakeholder management in PPP healthcare infrastructure.

The findings indicate that, while PPPs have great potential to improve public health infrastructure, their performance relies on the integration of numerous interconnected factors. A common pattern in the literature is the fragmented implementation of PPP components, which threatens long-term sustainability and operational performance. Table 1 demonstrates the themes and authors used in the inclusion of this literature

4.1. Stakeholder management alignment in the PPP Health sector

Stakeholder alignment has been identified as a significant aspect determining the sustainability of public-private partnerships in healthcare infrastructure. PPPs involve a variety of stakeholders, including government organisations, private sector partners, healthcare professionals, and communities, each with their own goals and expectations.

South Africa's approach to healthcare PPPs is based on a comprehensive framework supported by national regulations, including the National Health Act and the Public Finance Management Act (Sarkar et al., 2025). These policies define the engagements and duties in health partnership projects (Sarkar et al., 2025).

Authors acknowledge that stakeholder involvement and participation are critical components of governance and accountability models for public-private partnerships in healthcare infrastructure management (Aminu-Ibrahim & Ogbete, 2024).

Table 1: Themes and Authors in Sustainable Healthcare PPP Literature

Themes	Authors
Stakeholder management alignment in the PPP Health sector	Aminu-Ibrahim & Ogbete, 2024; Sarkar, et al., 2025; Rybnicek, 2020; Mazibuko et al., 2025, Oliveira, et al., 2023
Governance	Oliveira, et al., 2023; Kumar, et al., 2025; Moro-Visconti, 2025; De Matteis et al., 2024; Sheppard & Beck, 2020; Verweij & van Meerkerk, 2021; Liu et al., 2023; Tipu & Yousaf, 2022; Aminu-Ibrahim & Ogbete, 2024
Public-Private Partnerships (PPPs) in healthcare	Sarkar, et al., 2025; Mbaka & Mwange, 2023; Dlamini & Botes, 2022; Hailu & Tshehla, 2024; Liu, Shi et al., 2023; Ferreira & Marques, 2020; Ebulue, et al., 2024; Onyoin, 2022; Samira Abdul et al., 2024; Joudyian, et al., 2021; Kanti et al., 2020; Tabrizi, et al., 2020
Integrated Perspective on Sustainable Public-Private Partnerships for Effective Management	Kimario et al., 2020; Ozili, 2022; Tipu et al., 2024; Njuguna, Nteere & Kirima, 2024a; Strasser et al., 2021; Salangwa, Munthali et al., 2025; Sarkar, Singhal et al., 2025; Moro-Visconti, 2025

Some authors believe that PPPs are riskier than ordinary projects due to multiple stakeholders, complex project arrangements, specific funding, documentation, and tax laws, and a lack of skilled partners (Rybnicek, 2020). The literature indicates that misalignment of stakeholder interests often leads to conflicts, inefficiencies, and compromised service delivery, hence the risky mentality. Stakeholder complexity is particularly evident in healthcare PPPs, necessitating inclusive and participatory approaches to ensure that diverse interests align with shared objectives. In contrast, good stakeholder involvement and collaboration help to increase coordination and project success.

4.2. Governance

Governance emerges as a critical determinant of PPP success. According to the literature, governance structures and stakeholder engagement are essential to the long-term success and sustainability of PPP initiatives (Kumar et al., 2025). The literature emphasises that successful PPP implementation depends on strong governance structures, supported by transparent regulatory frameworks, well-defined accountability mechanisms, and effective institutional coordination.

Governance quality revealed as a key mediator of sustainability outcomes, increasing the benefits of PPPs in all three dimensions (Moro-Visconti, 2025). A significant takeaway from the findings is that governance should be understood as a dynamic and adaptive process rather than a static framework. Continuous oversight and institutional development are required to support long-term PPP outcomes.

4.3. Integrated Perspective on Sustainable Public-Private Partnerships for Effective Management

PPPs have become critical components in achieving sustainable development (Kumar et al., 2025). By utilising the resources and experience of the private sector, this collaborative strategic alignment can improve the sustainability of government services and promote a more equitable healthcare system (Mazibuko et al., 2025).

The findings of this study add to the current body of knowledge by indicating that the efficiency of PPPs in healthcare infrastructure depends not only on the model itself but also on how key components are integrated and managed. A critical integration of the research demonstrates that governance frameworks and stakeholder alignment impact sustainability in PPP healthcare infrastructure management. These factors are frequently discussed separately in the literature, resulting in fragmented implementation and uneven results.

5. Conclusions

PPPs represent a promising strategic approach to addressing healthcare infrastructure challenges, particularly in resource-constrained environments. This review has demonstrated that PPPs can enhance service delivery, improve infrastructure quality, and promote innovation when effectively implemented. In contrast, the findings show that the sustainability of healthcare PPPs is significantly affected by governance quality, stakeholder alignment, and institutional coordination throughout the PPP period. The study further found that fragmented implementation approaches, weak coordination among stakeholders, and governance limitations often undermine operational performance and sustainability outcomes.

Despite the growing body of literature, significant gaps remain most notably the absence of comprehensive and standardised frameworks to assess PPP performance and outcomes over time. This study contributes to the body of knowledge by integrating previously fragmented literature on healthcare PPPs, emphasising the interconnected role of governance, stakeholder engagement, and sustainability in ensuring the effective management of public health infrastructure in South Africa. The study therefore recommends stronger governance and accountability frameworks, continuous stakeholder collaboration, and integrated monitoring systems to support long-term sustainability and operational effectiveness within healthcare PPPs. Future research should therefore prioritise the development of integrated evaluation models and empirical studies that capture long-term impacts. Strengthening these areas will be critical to maximising the effectiveness of PPPs and ensuring their contribution to resilient and sustainable healthcare systems.

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Construction Materials Transport Vehicle Utilisation Efficiency: A Case Study of Gqeberha

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Abstract

This study examines the efficiency of construction materials transport vehicle (CMTV) utilisation, with the aim of identifying the principal factors that undermine logistics performance in material delivery and proposing targeted interventions to enhance operational efficiency. The quantitative study entailed an online survey of general contractors and material suppliers, yielding 27 valid responses from an initial sample of 92, which equates to a 29.3% response rate. Findings reveal pervasive systemic inefficiencies in vehicle deployment, including frequent empty return trips, partial loads, delayed deliveries, and prolonged vehicle dwell times factors that contribute to elevated costs, reduced productivity, and increased carbon emissions. Supplier-led deliveries dominate current practices, often resulting in sub-optimal routing and coordination. Respondents highlighted the need for improved communication, scheduling, and coordination, alongside the adoption of real-time tracking, monitoring tools, and enhanced training for logistics personnel. Basic ICT tools such as mobile communication and GPS tracking are relatively well-adopted, while more advanced solutions such as data analytics and route optimisation systems show lower utilisation. The findings suggest that strengthening internal coordination, building staff capacity, and integrating digital logistics technologies within a comprehensive supply-chain framework are essential for sustained improvements in CMTV efficiency. Isolated interventions are unlikely to deliver meaningful gains without alignment across stakeholders.

Keywords: Construction, Efficiency, Materials, Transport, Utilisation, Vehicle

1 Introduction

Material transport is a critical component of construction project performance, directly influencing cost, productivity, and operational efficiency. Materials typically account for a substantial proportion of total project costs, and inefficiencies in logistics such as delayed deliveries, underutilised vehicles, and poor scheduling can significantly increase project expenditure and reduce productivity (Patel *et al*., 2015). Sezer and Fredriksson (2021) in turn, contend that construction logistics offer useful solutions to improve both the productivity and sustainability of the industry. Furthermore, Guerlain *et al.* (2019) state that the transport of construction materials represents up to 30% of freight movements in cities and even more in terms of pollutant emissions.

Despite the recognised importance of construction logistics, limited empirical research has been conducted relative to CMTV utilisation efficiency within the South African context, and therefore there is a paucity of related literature. Within the global context, this contention is underscored by Naz *et al.* (2022) who state that although it has been determined that there is great potential to improve construction transport, little research has been conducted within this field. Their research determined that in terms of construction transport time efficiency, over 40% of the time was used for non-value-adding activities (NVAAs). Therefore, this study addresses this gap by evaluating CMTV utilisation practices in the local industry, the aim being to identify the principal factors that undermine CMTV utilisation and propose interventions to enhance CMTV utilisation. The summarised objectives being to determine: construction materials logistics practices; the experience of phenomena, and the extent to which potential interventions can reduce inefficiencies and improve construction materials logistics.

2 Construction Logistics and Vehicle Utilisation: Critical International Perspectives

2.1 Construction logistics and supply chain inefficiencies

Construction logistics plays a critical role in project cost, productivity, delivery reliability, and environmental performance. Transport inefficiencies such as empty return trips, partial loading, and poor scheduling are widely associated with congestion, cost overruns, and underutilised vehicle capacity (Ying *et al*., 2018). Construction supply chains are inherently fragmented, involving temporary collaborations that weaken coordination and information flow (Ghanem *et al*., 2018). As a result, logistics planning is often overlooked in early project stages, leading to reactive

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practices such as inaccurate scheduling, communication breakdowns, and inefficient deliveries. Although early integration is widely recommended, its implementation in decentralised construction environments remains limited, particularly in developing urban contexts such as Gqeberha.

2.2 Vehicle utilisation and operational inefficiencies

Vehicle utilisation efficiency refers to maximising load capacity while minimising empty running and idle time. Inefficiencies reflect poor asset utilisation and reduced operational performance (Rushton *et al*., 2022). In practice, inefficiencies arise from empty return trips, partial loading, and operational constraints such as vehicle design limitations, material compatibility, and contamination risks. Fragmented ordering and low delivery volumes further contribute to underutilised capacity, while manual data practices limit effective monitoring and optimisation. Although consolidation strategies and coordinated delivery systems have demonstrated improvements in load efficiency (El Moussaoui *et al*., 2021), their implementation is constrained by limited governance, weak coordination, and the operational realities of small and specialised suppliers in decentralised markets.

2.3 Cost, performance and environmental implications

Transport inefficiencies contribute directly to increased project costs and delivery delays, with high fixed vehicle costs resulting in disproportionate pricing for partial loads (Ying *et al*., 2018). Poor coordination further reduces scheduling efficiency and increases unnecessary transport movements. In addition, construction transport contributes to environmental impacts, with studies indicating that improved logistics coordination can reduce emissions and enhance overall project performance. Research conducted by Naz *et al.* (2022) determined that there is major potential for improving construction transport time efficiency as over 40% of the time was used for non-value-adding activities (NVAAs). Guerlain *et al.* (2019) in turn refer to the major impact of the transport of construction materials in terms of pollutant emissions.

2.4 Synthesis and research gap

The literature highlights the importance of integrated planning and coordination in improving logistics efficiency; however, key gaps remain, including limited empirical measurement of vehicle utilisation in developing urban contexts, insufficient understanding of operational constraints affecting dedicated-use vehicles, and the limited transferability of coordination models to decentralised markets. Most studies focus on well-regulated environments, whereas secondary cities such as Gqeberha, lack comparable institutional and technological conditions. This study addresses these gaps by empirically assessing vehicle utilisation and associated inefficiencies within a developing urban context.

3 Research Methodology

A quantitative survey approach was adopted to assess construction vehicle utilisation in Gqeberha due to the nature and extent of the data required. An initial sample of 92 medium and large general contractor and material supplier members of the East Cape Master Builders Association (ECMBA) were provided with the URL of the structured online questionnaire via the Executive Director of the ECMBA via e-mail. The related ECMBA members were surveyed as the ECMBA is the only employer building construction organisation represented in Gqeberha. Furthermore, due to the number of related members sampling was not required. The self-developed survey instrument, based upon the survey of the literature, was comprised of closed-ended and mostly five-point Likert-scale type questions addressing delivery coordination, load planning, operational constraints, and logistics performance. Due to the tight timeline of the study, the supervisor of the study validated the factors. A total of 27 valid responses were received, which equates to a 29.3% response rate. According to Soetanto (2002) a response rate of 14.6% is the accepted rate for lengthy and comprehensive questionnaires. Given that an online questionnaire was completed the data was automatically captured in a MS Excel data file. The data was analysed to compute descriptive statistics, including frequencies and mean scores (MSs), to rank key factors influencing CMTV utilisation.

4 Findings and Discussion

Table 1 indicates the frequency at which different material delivery arrangements are utilised on construction sites in Gqeberha in terms of percentage responses to a scale of never to always, and MSs ranging from 1.00 to 5.00. All three delivery arrangements recorded MSs > 3.00, which in general

Table 1: Frequency of material delivery arrangements to construction sites in Gqeberha

Arrangement	Response (%)						MS	Rank
	Unsure	Never	Rarely	Sometimes	Often	Always		
Supplier-owned vehicles	0.0	0.0	11.7	17.6	29.4	41.2	4.00	1
Mixed (combination of both)	0.0	5.8	5.8	29.4	17.6	41.2	3.82	2
Contractor-owner vehicles	5.3	0.0	10.5	36.8	26.3	21.1	3.61	3

indicates frequent, as opposed to infrequent use. However, in terms of MS ranges, all the MSs are > 3.40 ≤ 4.20, which indicates the delivery arrangements occur sometimes to often / often. It is notable that supplier-owned vehicles is ranked first, which is the ideal arrangement.

Table 2 indicates the frequency at which selected logistics-related phenomena occur on construction sites in Gqeberha in terms of percentage responses to a scale of never to always, and MSs ranging from 1.00 to 5.00. It is notable that 4 / 5 (80.0%) phenomena recorded MSs > 3.00, which in general, indicates frequent, as opposed to infrequent occurrence. However, in terms of MS ranges, the same four phenomena have MSs > 3.40 ≤ 4.20, which indicates they occur sometimes to often / often - vehicles leaving site empty is ranked first, followed by delays due to late delivery of materials, long vehicle dwell times on site, and unplanned or unscheduled deliveries. These findings indicate vehicle inefficiency, inadequate materials management and planning, and site layout and organisation. Site congestion delaying deliveries recorded a MS of 2.95, indicating it occurs rarely to sometimes / sometimes as the MS is > 2.60 ≤ 3.40. It is notable that first ranked 'vehicles leaving site empty' is highlighted by Ying *et al.* (2018).

Table 3 indicates the extent to which various interventions are required to improve construction vehicle utilisation on sites in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All five interventions recorded MSs > 3.00, indicating a major, as opposed to a minor need, for the interventions. Better scheduling and coordination is ranked first, followed by improved communication with suppliers, which indicates a near major to major / major extent, as the MSs are > 4.20 ≤ 5.00. Real-time tracking and monitoring tools, training for logistics personnel, and shared or centralised delivery hubs have MSs > 3.40 ≤ 4.20, which indicates there is a moderate to near major / near major need for these interventions. All five interventions will address the inherent fragmentation of construction supply chains, involving temporary collaborations that weaken coordination and information flow, as referred to by Ghanem *et al.* (2018).

Table 4 indicates the frequency of material delivery scheduling approaches in terms of percentage responses to a scale of never to always, and MSs ranging from 1.00 to 5.00. It is notable that 2 / 3 (66.7%) approaches recorded MSs > 3.00, which in general, indicates frequent, as opposed to infrequent occurrence. However, in terms of MS ranges, only the MS of mixed scheduling (both) is > 3.40 ≤ 4.20, which indicates it occur sometimes to often / often. The remaining 2 / 3 (66.7%) MSs are > 2.60 ≤ 3.40, which indicates they occur rarely to sometimes / sometimes - fixed daily routes, and on-demand orders.

Table 2: Frequency of logistics-related phenomena on construction sites

Phenomenon	Response (%)						MS	Rank
	Unsure	Never	Rarely	Soemt-imes	Often	Always		
Vehicles leaving site empty	20.0	10.0	0.0	20.0	30.0	20.0	3.69	1
Delays due to late delivery of materials	5.0	5.0	25.0	25.0	40.0	0.0	3.58	2
Long vehicle dwell times on site	15.0	0.0	30.0	30.0	15.0	10.0	3.47	3
Unplanned or unscheduled deliveries	10.0	10.0	30.0	15.0	35.0	0.0	3.44	4
Site congestion delaying deliveries	5.0	15.0	45.0	15.0	5.00	15.0	2.95	5

Table 3: Extent of interventions required to improve construction vehicle utilisation

Intervention	Response (%)						MS	Rank
	Unsure	Minor …… Major						
		1	2	3	4	5		
Better scheduling and coordination	0.0	4.5	0.0	13.6	22.7	59.1	4.32	1
Improved communication with suppliers	0.0	0.0	9.1	9.1	22.7	59.1	4.26	2
Real-time tracking and monitoring tools	4.5	0.0	13.6	9.9	27.3	45.5	4.00	3
Training for logistics personnel	0.0	4.5	4.5	27.3	27.3	36.4	3.79	4
Shared or centralised delivery hubs	9.1	4.5	9.1	22.7	31.8	22.7	3.71	5

Table 4: Frequency of material delivery scheduling approaches

Approach	Response (%)						MS	Rank
	Unsure	Never	Rarely	Soemt-imes	Often	Always		
Mixed scheduling (both)	20.0	0.0	0.0	60.0	0.0	20.0	3.50	1
Fixed daily routes	0.0	0.0	25.0	50.0	25.0	0.0	3.25	2
On-demand orders	0.0	0.0	0.0	75.0	25.0	0.0	3.00	3

Table 5 indicates the frequency at which selected logistics-related phenomena occur within respondents' own organisations in terms of percentage responses to a scale of never to always, and MSs ranging from 1.00 to 5.00. Ony two phenomena recorded MSs > 3.00, indicating frequent, as opposed to infrequent occurrence as in the case of the other six phenomena. Vehicles returning empty is ranked first, followed by individual delivery, indicating that these phenomena occur sometimes to often / often, as the MSs are > 3.40 ≤ 4.20. Order consolidation is ranked third, followed by tight schedules causing late deliveries, part loads, deliveries affected by poor communication, and long waiting or offloading times, which indicates these phenomena occur rarely to sometimes / sometimes, as the MSs are > 2.60 ≤ 3.40. Congestion on constrution sites has a MS > 1.80 ≤ 2.60, which indicates it occurs never to rarely / rarely. The first two ranked phenomena, which occur frequently, as opposed to infrequently are highlighted by Ying *et al.* (2018) and Rushton *et al.* (2022).

Table 6 indicates the extent to which selected efficiency-oriented measures would improve construction vehicle utilisation on sites in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All six measures recorded MSs > 3.00, indicating major, as opposed to minor potential for improvement. Accurate early orders is ranked first with a MS > 4.20 ≤ 5.00, indicating near major to major / major potential to improve vehicle utilisation. The measures ranked second to fourth, namely digital procurement and dispatch records, route optimisation software, and consolidation or shared depots have MSs > 3.40 ≤ 4.20, indicating moderate to near major / near major potential. Using return trips to transport materials and ICT-based coordination tools have MSs > 2.60 to ≤ 3.40, indicating near minor to moderate / moderate potential. Using return trips to transport materials is a key issue identified by Ying *et al.* (2018) and Rushton *et al.* (2022).

Table 7 indicates the extent of organisational awareness or use of selected logistics technologies on construction sites in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. It is notable that 3 / 5 (60.0%) technologies recorded MSs > 3.00, indicating a major level of awareness or use, as opposed to a minor level. Mobile communication tools and GPS vehicle tracking have MSs > 3.40 ≤ 4.20, which indicates that awareness or use of these technologies is between a moderate to near major / near major extent. Data analytics for logistics

Table 5: Frequency at which selected logistics-related phenomena occur within respondents' organisations

Phenomenon	Response (%)						MS	Rank
	Unsure	Never	Rarely	Soemt-imes	Often	Always		
Vehicles returning empty	0.0	25.0	0.0	0.0	25.0	50.0	3.75	1
Individual delivery	0.0	0.0	25.0	25.0	25.0	25.0	3.50	2
Order consolidation	25.0	0.0	0.0	75.0	0.0	0.0	3.00	3
Tight schedules causing late deliveries	0.0	0.0	25.0	50.0	25.0	0.0	3.00	4
Part loads	0.0	0.0	25.0	50.0	25.0	0.0	3.00	5
Deliveries affected by poor communication	0.0	25.0	0.0	50.0	0.0	25.0	3.00	6
Long waiting / offloading times	0.0	0.0	40.0	40.0	20.0	0.0	2.80	7
Congestion on construction sites	0.0	25.0	0.0	75.0	0.0	0.00	2.50	8

Table 6: The extent to which selected efficiency-oriented measures would improve construction vehicle utilisation in Gqeberha

Measure	Response (%)						MS	Rank
	Unsure	Minor …… Major						
		1	2	3	4	5		
Accurate early orders	0.0	0.0	0.0	25.0	0.0	75.0	4.50	1
Digital procurement and dispatch records	0.0	0.0	0.0	33.3	66.7	0.0	4.00	2
Route optimisation software	0.0	0.0	0.0	33.3	33.3	33.3	4.00	3
Consolidation or shared depots	0.0	0.0	33.3	33.3	0.0	33.3	3.67	4
Using return trips to transport materials	33.3	0.0	0.0	33.3	0.0	33.3	3.33	5
ICT-based coordination tool	33.3	0.0	0.0	33.3	0.0	33.3	3.33	6

Table 7: Awareness or use of logistics technologies

Technology	Response (%)						MS	Rank
	Unsure	Minor …… Major						
		1	2	3	4	5		
Mobile communication tools	5.6	11.1	5.6	11.1	33.3	33.3	3.76	1
GPS vehicle tracking	10.5	21.1	5.3	10.5	10.5	42.1	3.53	2
Data analytics for logistics planning	5.6	33.3	0.0	16.7	16.7	27.8	3.06	3
Route optimisation systems	5.6	33.3	5.6	16.7	22.2	16.7	2.82	4
Delivery management software	5.6	33.3	11.1	16.7	22.2	11.1	2.65	5

planning, route optimisation systems, anddelivery management software have MSs > 2.60 ≤ 3.40, indicating that awareness or use is between a near minor to moderate / moderate extent.

Table 8 indicates the potential of logistics management technologies to reduce inefficiencies / issues on construction sites in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All five inefficiencies / issues recorded MSs > 3.00, indicating major potential for reduction, as opposed to minor potential. Communication breakdowns, delivery delays and poor scheduling have MSs > 3.40 ≤ 4.20, which indicates thatlogistics management technologies have between moderate to near major / near major potential to address these inefficiencies issues. Empty return trips, andsite congestion have MSs > 2.60 ≤ 3.40, which indicates that logistics management technologies have between near minor to moderate / moderate potential to address these inefficiencies / issues. The potential of logistics management technologies to reduce inefficiencies is highlighted by Ying *et al.* (2018), Rushton *et al.* (2022), and El Moussaoui *et al.* (2021).

Table 9 indicates the potential of technology and coordination strategies to enhance selected logistics outcomes on construction sites in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All five outcomes recorded MSs > 3.00, indicating major, as opposed to minor, potential for enhancement. Furthermore, all five outcomes have MSs > 3.40 ≤ 4.20, indicating moderate to near major / near major potential - delivery time reliability is ranked first, followed by reduction of site congestion and environmental performance (reduced emissions), cost efficiency in transport, and vehicle utilisation efficiency.

Table 10 indicates the extent to which selected logistics-related records and documentation are accurately recorded or used on construction sites in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All four records recorded MSs > 3.00, indicating a major, as opposed to a minor, level of accuracy or use. MS Only 1 /5 (20.0%) of MSs is > 4.20 to ≤ 5.00, namely delivery documentation checked and signed off, indicating the accuracy and use is between near major to major / major. The remaining 4 / 5 (80.0%) of MSs are > 3.40 ≤ 4.20, indicating the accuracy and use is between a moderate to near major / near major extent

Table 8: Potential of logistics management technologies to reduce inefficiencies

Inefficiency / Issue	Response (%)						MS	Rank
	Unsure	Minor ……. Major						
		1	2	3	4	5		
Communication breakdowns	0.0	5.6	16.7	11.1	22.2	44.4	3.83	1
Delivery delays	0.0	15.8	10.5	21.1	10.5	42.1	3.65	2
Poor scheduling	5.6	16.7	5.6	11.1	22.2	38.9	3.53	3
Empty return trips	25.0	15.0	10.0	10.0	10.0	30.0	3.40	4
Site congestion	0.0	5.6	16.7	27.8	33.3	16.7	3.39	5

Table 9: Potential of technology and coordination strategies to enhance selected logistics outcomes on construction sites

Outcome / Metric	Response (%)						MS	Rank
	Unsure	Minor ……. Major						
		1	2	3	4	5		
Delivery time reliability	0.0	10.5	5.3	5.3	31.6	47.4	4.00	1
Reduction of site congestion	5.6	0.0	11.1	22.2	22.2	38.9	3.94	2
Environmental performance (reduced emissions)	5.3	5.3	10.5	15.8	15.8	47.4	3.94	3
Cost efficiency in transport	0.0	10.5	10.5	0.0	36.8	42.1	3.89	4
Vehicle utilisation efficiency	5.0	10.0	5.0	15.0	30.0	35.0	3.79	5

Table 10: Accuracy and use of logistics-related records and documentation

Record / Documentation	Response (%)						MS	Rank
	Unsure	Minor ……. Major						
		1	2	3	4	5		
Delivery documentation checked and signed off	0.0	0.0	10.5	5.3	26.3	57.9	4.32	1
Formal material requisition logs maintained	5.0	5.0	5.0	15.0	30.0	40.0	4.00	2
Order frequency and delivery records tracked	5.3	5.3	0.0	26.3	26.3	36.8	3.94	3
Digital logistics documentation	0.0	5.3	26.3	5.3	31.6	31.6	3.58	4

- formal material requisition logs maintained, followed by order frequency and delivery records tracked, and digital logistics documentation.

Table 11 indicates the extent to which six selected efficiency-oriented measures would improve CMTV utilisation on sites in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All six measures recorded MSs > 3.00, indicating major, as opposed to minor potential for improvement. Only 1 / 6 (16.7%) MSs is > 4.20 ≤ 5.00, indicating near major to major / major potential to enhance CMTV utilisation, namely accurate early orders. Thereafter, 3 / 6 (50.0%) of MSs are > 3.40 ≤ 4.20, indicating moderate to near major / near major potential, namely digital procurement and dispatch records, route optimisation software, and consolidation or shared depots. The remaining 2 / 6 (33.3%) MSs are > 2.60 to ≤ 3.40, indicating near minor to moderate / moderate potential, namely using return trips to transport materials, and ICT-based coordination tools. The potential of the measures to improve CMTV utilisation is underscored by the role of consolidation strategies and coordinated delivery systems cited by El Moussaoui *et al.* (2021),

Table 12 presents respondents' ratings of staff capacity and internal organisational capabilities related to construction logistics and CMTV utilisation, in terms of percentage responses to a scale of 1 (very poor) to 5 (very good), and MSs ing from 1.00 to 5.00. It is notable that all five capacities / capabilities have MSs > 3.00, indicating that the ratings are above average, as opposed to below average. It is notable that only 1 / 5 (20.0%) MSs is > 4.20 to ≤ 5.00, indicating a good to very / very good rating - availability of delivery procedures. . Thereafter, the remaining 4 / 5 (80.0%) MSs are > 3.40 to ≤ 4.20 indicating that the ratings are average to good / good - awareness of vehicle use efficiency (petrol / load),training for logistics or transport staff, internal coordination (sales, dispatch, & drivers), and driver training on loading and routing.

Table 13 indicates the extent to which logistics technologies are used by organisations to support performance enhancement and CMTV utilisation

Table 11: The extent to which selected efficiency-oriented measures would improve CMTV utilisation in Gqeberha

Measure	Response (%)						MS	Rank
	Unsure	Minor ……. Major						
		1	2	3	4	5		
Accurate early orders	0.0	0.0	0.0	25.0	0.0	75.0	4.50	1
Digital procurement and dispatch records	0.0	0.0	0.0	33.3	66.7	0.0	4.00	2
Route optimisation software	0.0	0.0	0.0	33.3	33.3	33.3	4.00	3
Consolidation or shared depots	0.0	0.0	33.3	33.3	0.0	33.3	3.67	4
Using return trips to transport materials	33.3	0.0	0.0	33.3	0.0	33.3	3.33	5
ICT-based coordination tools	33.3	0.0	0.0	33.3	0.0	33.3	3.33	6

Table 12: Rating of staff capacity and internal organisation capabilities related to construction logistics and CMTV utilisation

Capacity / Capability	Response (%)						MS	Rank
	Unsure	Very poor ……Very good						
		1	2	3	4	5		
Availability of delivery procedures	0.0	0.0	0.0	0.0	66.7	33.3	4.33	1
Awareness of vehicle use efficiency (petrol / load)	0.0	0.0	0.0	0.0	100.0	0.0	4.00	2
Training for logistics or transport staff	0.0	0.0	0.0	33.3	33.3	33.3	4.00	3
Internal coordination (sales, dispatch, & drivers)	0.0	0.0	0.0	25.0	75.0	0.0	3.75	4
Driver training on loading and routing	0.0	0.0	33.3	0.0	33.3	33.3	3.67	5

Table 13: Extent to which logistics technologies are used by organisations to support performance enhancement and CMTV utilisation efficiency in Gqeberha

Technology	Response (%)						MS	Rank
	Unsure	Minor ……. Major						
		1	2	3	4	5		
GPS vehicle tracking	0.0	0.0	0.0	0.0	33.3	66.7	4.67	1=
Mobile communication tools	0.0	0.0	0.0	0.0	33.3	66.7	4.67	1=
Route optimisation systems	0.0	0.0	33.3	0.0	33.3	33.3	3.67	3
Data analytics for logistics planning	0.0	0.0	25.0	25.0	25.0	25.0	3.50	4
Delivery management software	0.0	0.0	66.7	0.0	0.0	33.3	3.00	5

efficiency in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All five technologies recorded MSs > 3.00, indicating major, as opposed to minor use. The 2 / 5 (40.0%) very high MSs > 4.20 ≤ 5.00 are notable, indicating GPS vehicle tracking, and mobile communication tools are used between a near major to major / major extent. Thereafter, 2 / 5 (40.0%) MSs are are > 3.40 to ≤ 4.20, indicating they are used between a moderate to near major / near major extent - route optimisation systems, and data analytics for logistics planning. Delivery management software is ranked fifth, indicating between near minor to moderate / moderate use as the MS is > 2.60 to ≤ 3.40.

Table 14 indicates the potential of advanced logistics technologies and ICT integration to enhance key logistics and performance outcomes within construction operations in Gqeberha in terms of percentage responses to a scale of 1 (minor) to 5 (major), and MSs ranging from 1.00 to 5.00. All five outcomes recorded MSs > 3.00, indicating major, as opposed to minor potential. It is notable that 3 / 5 (60.0%) of MSs are > 4.20 to ≤ 5.00, indicating near major to major / major potential - reduction of site congestion ranked first, is followed by environmental performance (reduced emissions), and vehicle utilisation efficiency. The remaining 2 / 5 (40.0%) MSs are > 3.40 to ≤ 4.20, indicating moderate to near major / near major potential -delivery time reliability, and cost efficiency in transport. The potential enhancement addresses the key issues identified by Ying *et al.* (2018), Rushton *et al.* (2022), and Naz *et al.* (2022)

Table 14: The potential of advanced logistics technologies and ICT integration to enhance key logistics and performance outcomes within construction operations in Gqeberha

Outcome	Response (%)						MS	Rank
	Unsure	Minor …… Major						
		1	2	3	4	5		
Reduction of site congestion	0.0	0.0	0.0	0.0	33.3	66.7	4.67	1
Environmental performance (reduced emissions)	0.0	0.0	0.0	0.0	50.0	50.0	4.50	2
Vehicle utilisation efficiency	0.0	0.0	0.0	0.0	66.7	33.3	4.33	3
Delivery time reliability	0.0	0.0	0.0	33.3	33.3	33.3	4.00	4=
Cost efficiency in transport	0.0	0.0	33.3	0.0	33.3	33.3	4.00	4=

5 Conclusions

Limitations of the study include the single geographical location, and the sample size, therefore the findings cannot be deemed representative, but indicative.

Given that the study identified CMTV utilisation inefficiencies, including partial loading, empty return trips, and poor scheduling, largely resulting from limited coordination among project stakeholders it can be concluded that construction logistics is a critical performance driver, with fragmented practices leading to underutilised CMTV capacity and inefficient transport movements.

The study contributes scientific and context-specific empirical evidence from a South African urban setting, demonstrating that improved coordination, planning, and contractor supplier integration can significantly enhance CMTV utilisation without substantial capital investment. Furthermore, the findings provide practical guidance in terms of the current practices, including interventions, and potential interventions and outcomes in terms of enhancing CMTV utilisation efficiency, thereby contributing to the related body of knowledge.

6 Recommendations

Improving CMTV utilisation requires coordinated action across stakeholders. Contractors and suppliers should enhance delivery coordination, integrate suppliers early, and use basic logistics tools to reduce idle time and inefficiencies.

At industry level, best-practice guidelines, collaborative delivery planning, and targeted training are needed to improve logistics performance. From a policy perspective, construction logistics should be integrated into urban planning, with support for pilot initiatives such as consolidation hubs and coordinated deliveries.

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Impediments hindering higher education Institutions in readiness for future pandemics: A case of Eastern Cape province, South Africa

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Abstract

Higher institutions of learning are critical to the generation of knowledge among a country's citizens. Despite their importance to knowledge empowerment, they are not immune to future pandemic occurrences. Therefore, this study aims to determine the barriers hindering higher education institutions (HEIs) in the Eastern Cape readiness for future pandemics. A qualitative research method was adopted to achieve the study's aim. Data was collected using semi-structured interviews with seven respondents who were purposively sampled from two public universities. Thematic analysis was used to identify the impediments after the data were transcribed. The findings revealed that institutions readiness is constrained by a lack of governance structures, inconsistent operational preparedness, poorly communicated emergency response plans, and uneven institutional capacity. Although HEIs demonstrated adaptability during COVID-19, particularly by continuing academic activities through digital platforms, their preparedness was largely reactive rather than proactive. The absence of institutionalised disaster management frameworks, limited training, and gaps in policy implementation were identified as critical barriers to effective pandemic readiness. The study's geographical focus was the Eastern Cape province of South Africa, and its reliance on semi-structured interviews prevented the results from being generalised. These barriers reveal the need for sustainable institutional commitment, resource investment, and clear accountability structures.

Keywords: Future pandemic, Higher Education Institutions, Impediments, Readiness.

1. Introduction

The COVID-19 outbreak revealed significant weaknesses in global systems, with higher education among the most affected (Du Plessis et al., 2022; Aruleba, Jere & Matarirano, 2022). Woldegiorgis (2022) reveals that institutions were forced to shift immediately from traditional face-to-face learning strategies to remote and hybrid learning methods, often without adequate preparation. The literature review by Newlin and Grasia (2021) highlighted that the higher education sector should ensure that students are equipped with the necessary skills, professional attributes, and learning techniques to deal with outbreaks such as the COVID-19 pandemic. According to Landa, Zhou, and Marongwe (2021), these challenges require systemic flaws in institutional preparation, particularly in developing countries, where resource constraints, infrastructure limitations, and socioeconomic inequities are more severe. Other challenges affecting higher education include overcrowded classrooms, poor infrastructure, and linguistic and cultural diversity among the population, all of which complicate the development of inclusive and critical learning environments (Islam et al., 2023). Ndebele and Mbodila (2022) argued that the pandemic disrupted academic continuity and raised serious concerns about the resilience and preparedness of higher education institutions (HEIs) for future crises that might affect the delivery of learning.

In South Africa, the pandemic had an unequal impact, with historically impoverished and rural provinces, such as the Eastern Cape Province, facing more serious challenges (Olawale et al., 2021). Du Plessis et al. (2022) and Muller and Shackleton (2014) uncover that higher education institutions in this region faced multiple challenges, including poor digital infrastructure, limited access to dependable internet connectivity, and insufficient institutional support systems. Furthermore, Mokoena (2023) states that the impact of COVID-19 exposed the vulnerability to limited access to online teaching and learning due to data unaffordability, poverty, no internet connectivity, lack of IT equipment (e.g. computer, laptop, tablet, smartphone, etc.) and lack of skills by some lecturers and students to work online, among other reasons. Research conducted by Tantoh, McKay and Llewellyn (2026), Ndebele and Mbodila (2022) and Woldegiorgis (2022) found that these issues were exacerbated by high levels of poverty and inequality in the province, which negatively affected students' ability to participate effectively in distant learning settings. The pandemic revealed profound structural and operational shortcomings that affect institutional readiness to deal with outbreaks such as COVID-19 (Salmi, 2020).

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Institutional readiness for future pandemics extends beyond emergency response; it includes HEIs' ability to anticipate, plan for, and adjust to disruptions while sustaining academic and operational stability (Babbar & Gupta, 2022). For institutions to effectively adjust, there is a need for resilient infrastructure, strong governance frameworks, long-term financial planning, and the use of digital technology in education and learning (Agbeyangi & Lukose, 2025). However, Mbunge and Batani (2023) stressed that several institutions remain reactive rather than proactive and lack comprehensive policies. These problems include infrastructure development, risk management, and academic continuity planning (Salmi, 2020). According to Boro and Stoll (2022), deferred maintenance, restricted building design, and ineffective asset management systems all undermine institutions' ability to respond effectively to emergencies.

Despite the expanding corpus of work on the impact of COVID-19 on higher education, there is a lack of context-specific studies examining the underlying barriers to institutional preparedness, particularly in rural and underserved areas such as the Eastern Cape province (Nguyen & Bandur, 2026). Considering the challenges confronting the Eastern Cape Province, including socioeconomic and infrastructure issues, the province has become an excellent candidate for such an examination (Dudley et al., 2023). Understanding these barriers is critical to this study to develop a sustainable framework and culturally relevant interventions to enhance resilience in higher education (Kuguyo, Kengne & Dandara, 2020) in future.

Therefore, the purpose of this study is to investigate the challenges faced by higher education institutions in terms of readiness for future pandemics, with a focus on the Eastern Cape Province

2. Literature Review

2.1. Readiness and resilience in higher education

Institutional readiness and resilience have emerged as significant factors in higher education in response to COVID-19 disruptions and have remained sustainable amid the difficult times it caused (Whittaker & Montgomery, 2025). A study by Prayogo et al. (2025) defines readiness as HEIs' ability to anticipate, plan for, and successfully respond to challenges, whereas resilience is the institutions' ability to adapt and sustain key academic and operational functions under adverse conditions. However, HEIs recognise the need to introduce new academic programs in areas such as data science, cybersecurity and smart systems engineering to align education with evolving workforce requirements (Pasi & Dhamak, 2026).

Storms et al. (2019) note that the global move to remote learning and teaching revealed that most institutions were underprepared, relying on reactive practices rather than established contingency plans to deal with these challenges posed by COVID-19. Islam et al. (2023) argue that the COVID-19 pandemic has revealed gaps in strategic planning, digital infrastructure, and coordinated institutional responses, with numerous universities relying on emergency remote teaching rather than established online learning strategies.

According to Kaeane and Molokomme (2025), these challenges have a significant impact in South Africa, particularly in rural and underserved areas such as the Eastern Cape Province. Institutions in the Eastern Cape Province have more challenges, including but not limited to poor ICT infrastructure, inadequate maintenance of education facilities, and financial difficulties that affect both staff and students (Landa, Zhou & Marongwe, 2021). In terms of the built environment, ageing infrastructure, constrained space design, and inadequate asset management strategies for institutions all significantly contribute to institutional vulnerability (Landa, Zhou & Marongwe, 2021; Nguyen & Bandur, 2026). As a result, resilience in higher education institutions is understood as a multidimensional construct encompassing infrastructure, technology, financial capacity, and human capabilities for responding to this integrated challenge (Nguyen & Bandur, 2026); hence the need for context-specific research to better identify and solve these interconnected challenges affecting the Eastern Cape's higher education.

2.2. Infrastructure and digital inequality in higher education

Dyantyi and Mkabile-Masebe (2025) reveal that COVID-19 revealed serious disruptions to both physical and digital infrastructure at HEIs, requiring a significant shift in HEIs systems to ensure continuous quality education delivery. Furthermore, Vishnu et al. (2024) claim that the rapid shift to online learning across tertiary education institutions exposed ICT capacity gaps, including poor learning management systems, unreliable connectivity, and limited access to digital devices. According to Sydorenko et al. (2024), many educational institutions were challenged by their inability to manage assessments during the COVID-19 outbreak. These issues were further complicated by persisting digital inequality, particularly in rural and underserved areas such as the Eastern Cape Province, where the majority of students lack inexpensive internet access and appropriate or conducive learning spaces (Sydorenko et al., 2024). A study conducted by Timmis and Valladares-Celis (2025) pointed to the need for conceptualisation of 'haves' and 'have-nots' places a narrow emphasis on technological access, masking myriad social, spatial, cultural and material issues which are neither acknowledged nor addressed.

Moreover, Miah (2024) highlighted that HEIs were unable to provide effective spaces that enabled the adoption of hybrid or socially distanced learning methods, a situation that was most significant during the COVID-19 pandemic. Rydzewski (2025) indicates that this combination of infrastructure shortfalls poses a significant barrier to institutional preparedness, emphasising the importance of integrated and equitable infrastructure design that can respond to future pandemics in higher education.

2.3. Financial and policy constraints in higher education pandemic preparedness

Higher education institutions' (HEIs) response to COVID-19 exposed inadequate financial resources and insufficient policy frameworks (El Masri & Sabzalieva, 2020). As institutions were forced to quickly raise cash for digital infrastructure, student support, and operational changes, sometimes without any prior contingency budgets or financial resilience strategies (Vishnu et al., 2024). Although the South African government played a significant role in supporting institutions to respond to the COVID-19 crisis, the challenges negatively affected universities' budgets and financial abilities (Ndembi et al., 2024). According to Kaeane and Molokomme (2025), the pandemic strained an already limited financial source, particularly in public and historically disadvantaged institutions. Furthermore, Nguyen, Tran and Duong (2023) uncover that the lack of comprehensive and integrated pandemic preparedness policies, which include academic continuity, infrastructure resilience, and risk management, weakened institutional responses. These issues become more severe in regions such as the Eastern Cape Province due to ongoing funding restrictions and governance limitations (Landa, Zhou & Marongwe, 2021), emphasising the importance of proactive financial planning and collaborative policy development to enhance the future readiness of HEIs.

2.4. Human capacity and institutional adaptability in higher education

Human capacity and institutional adaptation had a significant impact on HEIs' resources for responding effectively to pandemic disruptions and continuing academic operations (Krishnannair, Krishnannair & Krishnannair, 2021; Rydzewski, 2025). Pereira et al. (2025) report that a significant shift from traditional to remote and hybrid learning revealed shortfalls in digital literacy, pedagogical preparation, and technical assistance among academic and administrative staff. According to Sporn and Godonoga (2024), academic staff were pressured to adopt new teaching and learning strategies with little training, thereby compromising the quality and consistency of learning delivery across South African universities.

In the Eastern Cape Province, these difficulties were exacerbated by limited resources and unequal access to capacity-building opportunities (Fobosi & Stal, 2026). The flexibility of the institutions was constrained by tight institutional structures and limited change management methods, which reduced HEIs' ability to respond proactively to crises (Sarmento & Riana, 2024). In addition, a lack of comparative studies intensifies the research gap, which consequently results in limited knowledge relative to the COVID-19 pandemic in South African Universities. However, a study by Krishnannair et al. (2021) reveals that the interconnected nature of the world, industrialised for the "fourth time", thus offers higher education a new facet in terms of its affordances and agency to undertake the cause of social transformation on a grand scale. This emphasises the necessity of ongoing skills development, institutional support structures, and adaptable governance to enhance overall preparedness for future pandemics and achieve sustainable educational development (Rydzewski, 2025). The government's COVID-19 Response Fund, a significant AU initiative, demonstrated the role of public-private partnerships (PPPs) in strengthening domestic capacity to reduce the impact of COVID-19. In the South African context, particularly within the Eastern Cape Province, the literature remains limited, with less focus on the impediments to future pandemic readiness of HEIs within the province. Therefore, this study addresses this gap.

3. Research Methodology

This study adopted a qualitative research method to examine the challenges that impede HEIs' ability to prepare for future pandemics, drawing on lessons learned from COVID-19. The qualitative research approach is useful for this study because it enables a thorough knowledge of participants' experiences and perspectives (Saunders et al., 2018). Furthermore, qualitative research is a practical approach to studying authenticity, in which the researcher's source of information is the subject's perspective on reality (Fellows & Liu, 2015). This is captured through behaviours, beliefs, opinions, personal views, and experiences. The study relied on an interpretivist paradigm that focuses on subjective interpretations of their experiences and opinions and allows for a more nuanced examination of institutional preparation (Gelling, 2016). The study's data were collected through semi-structured interviews, a flexible yet focused method for obtaining comprehensive, detailed opinions from the selected sample (Turale, 2020). The study focused on Eastern Cape higher education institutions, including academic staff, institutional management, ICT personnel, and facilities and infrastructure managers, and academic staff. A purposive sampling technique was used to select the participants with relevant knowledge and experience of institutional responses during the COVID-19 pandemic. The sample size comprises 12 participants from two institutions, namely Walter Sisulu University and the University of Fort Hare, which is considered

appropriate for qualitative research data saturation. Data saturation was achieved at 58.33% across 12 participants. According to Naeem et al. (2024) and Saunders et al. (2018), in a qualitative research study, the adequacy of the response rate is achieved when a researcher reaches data saturation, rather than the number of participants, where no new themes or insights emerge from the data.

A thematic analysis was used to analyse the data, as recommended by Saunders *et al*. (2018). To enhance the study's trustworthiness, credibility, dependability, confirmability, and transferability were used. Ethical principles were maintained during the data collection period, including obtaining informed consent, maintaining participant confidentiality and anonymity, and obtaining the required ethical approval from the institution (Sharpley *et al*., 2020). This methodological approach ensured a systematic and contextually grounded research of the difficulties affecting higher education institutions' preparedness for future pandemics in the Eastern Cape province.

4. Findings and Discussion

4.1. Demographics of participants

The demographic information from seven (7) participants who took part in this study established that 71.43% (5) of the participants were working in the operations and ICT departments, followed by 28.57% (2) were working in the built environment. Regarding the participants' current positions, 57.14% (4) were project managers, followed by 28.57% (2) operational managers and 14.29% (1) lecturer. The results underscore that the majority of participants are knowledgeable about the challenges affecting HEIs' ability to prevent future pandemics.

With respect to the experience of participants, 42.85% of participants have relevant experience ranging between >5 ≤10 years, this is closely followed by 28.57% of participants ranging between >2 ≤5 years, and 14.29% of participants have experience ranging between > 0 ≤ 2 years and > 10 years respectively. The results show that the participants have relevant experience in managing cases related to impediments hindering higher education Institutions in readiness for future pandemics.

4.2. Thematic analysis and discussions of findings

This section shows a thematic analysis of qualitative data collected from seven participants (P1–7). The analysis focuses on challenges faced by HEIs' readiness for future pandemics, as informed by COVID-19 experiences. The data were classified and grouped into topics representing governance, operational preparedness, policy frameworks, and institutional capabilities to achieve the study objectives.

Theme 1: Fragmented governance and unclear institutional responsibility

The results from seven participants show the key results pertaining to the lack of a consistent and institutionalised disaster governance structure across HEIs of the Eastern Cape, which negatively affects institutions' ability to prevent future pandemic disruptions. The participants reported a formal Risk and Safety Committee; others indicated either absence or uncertainty regarding responsibility allocation. Evidence shows this fragmentation clearly, as the respondents stated that:

"No, the university does not yet have a formally assigned disaster preparedness team." (P1 and P5)

The findings are consistent with previous research from Van der Berg and Spaull (2020), who posited that the lack of institutionalisation of disaster risk governance inside higher education institutions significantly contributes to the inability of HEIs to manage pandemics, as many HEIs were structurally unprepared for the COVID-19 pandemic, owing mostly to the lack of established disaster risk management units prior to the crisis.

The results show that there is a reliance on transitory task teams during the epidemic, which demonstrates the lack of a long-term disaster management infrastructure.

"I would presume that it is our Facilities Management Department." (P3)

The findings are supported by Legusov et al. (2022), who posited that effective disaster preparedness in HEIs requires institutionalised governance frameworks with clearly defined roles, accountability strategies, and cross-departmental coordination systems, which will enhance a coordinated effort. The uncertainty expressed by participants, such as "I would presume…" reflects the absence of such structured governance, reinforcing the argument that preparedness is not embedded within institutional culture, which all leads to exposure to future pandemics.

"The university has a Risk and Safety Committee and Maintenance management plan." (P2, P6 and P7)

Even where structures exist, they are often functionally reactive, as shown during COVID-19:

"A special COVID-19 Task Team was established to respond to the challenges posed by COVID-19" (P4).

According to the study by Ahmed et al. (2022), HEIs often rely on temporary crisis committees rather than permanent disaster preparedness institutions, leading to inadequate coordination and inconsistent emergency responses when needed.

Theme 2: Inconsistent operational preparedness and training

The results from the interviews show that operational preparedness, particularly disaster drills and training, was found to be inconsistent by the participants and largely reactive across institutions. Evidence includes:

"I have never participated in a disaster tool…" (P7)

"Training, awareness and implementation was done concurrently." (P4, P3, and P1)
"We have participated in a few fire and evacuation drills… inconsistent participation from departments." (P6, P5, and P2)

The findings from this study are consistent with the normative literature by Bama and Nyikana (2021), who report that most institutions shifted to emergency remote operations without prior preparedness frameworks, reflecting a broader absence of institutional readiness planning. Similarly, research conducted by UNESCO (2020) reported that HEIs, not only in the Eastern Cape province but globally, lacked systematic disaster simulation programmes and relied on ad hoc responses rather than routine preparedness training. This finding exposes the absence of regular disaster drills identified in this study, aligning with this observation, indicating that preparedness is not embedded as a continuous institutional practice. However, a study by Alexander and Klein (2020) argues that effective disaster readiness requires repeated simulations, interdepartmental coordination, and scenario-based training, which strengthen institutional response capacity and reduce operational uncertainty during crises.

Theme 3: Weak policy frameworks and emergency planning deficiencies

The results from the qualitative responses reveal two critical governance failures:

- Policy incompleteness (absence of updated pandemic-specific frameworks)
- Policy invisibility (lack of communication and awareness)

The participants noted that, even where emergency plans exist, their effectiveness is undermined by poor dissemination and lack of institutional integration. Evidence from:

"No, the university does not yet have a comprehensive, regularly updated emergency response plan." (P1)

This creates a disconnect between formal policy existence and operational awareness, which is a major barrier to effective crisis response.

According to Bhaskar et al. (2020), while universities were compelled to respond quickly during COVID-19, the majority did so without pre-established emergency response strategies, resulting in inconsistent and fragmented institutional responses. Furthermore, these findings are parallel with those of Wirba (2022), who states that the findings are consistent with the current study, in which participants either were unaware of such plans or stated that they were out of date and not completely operational, indicating a need for the Eastern Cape to review its management strategies.

Alexander (2018) contends that disaster preparedness is only effective when rules are adequately recorded, routinely updated, and effectively communicated at all institutional levels to enable a culture within the universities. Uncertainty indicated by participants ("I cannot conclude that it is there…") indicates a breakdown in policy dissemination and institutional communication channels, limiting effective preparedness, particularly in universities located in rural areas.

Theme 4: Institutional readiness and capacity constraints

The results from this study show that there are differences in responses, which suggests that preparedness is unevenly distributed across institutional units, rather than being uniformly embedded. For instance, some respondents indicated that the institution is not ready, no disaster management awareness since COVID-19.

While HEIs demonstrated adaptive capacity during the COVID-19 pandemic, particularly in digital transformation and continuity of learning, these improvements were largely situational and not institutionalised, which weakens the ability of Eastern Cape universities to respond to future pandemics.

The absence of continuous training, awareness programmes, and structured capacity-building reinforces a fragile preparedness culture, where readiness depends on experience rather than established systems.

The findings are consistent with Louw et al. (2023), who highlight that while universities demonstrated rapid adaptation, long-term preparedness challenges are out of reach for universities located in the Eastern Cape province. Furthermore, the findings from Da Silveira et al. (2025) indicated that HEIs globally were able to successfully deliver teaching and learning through emergency remote teaching and learning delivery; however, this shift was not a planned change but a reactive one, rather than planned, exposing structural weaknesses in institutional readiness systems to respond to future pandemics.

These findings were further strengthened by the findings from Alghamdi (2021), who distinguishes between "emergency remote teaching" and well-planned online learning, arguing that the rapid transition during COVID-19 reflected crisis response rather than institutional preparedness. These findings are similar to those of the current study, in which participants acknowledged operational success (e.g., continuation of online learning) but also identified gaps in training, planning, and preparedness awareness.

5. Conclusion and Further Research

This study investigated the impediments hindering higher education Institutions in readiness for future pandemics, building on lessons learned during COVID-19, particularly in the Eastern Cape Province. The findings from this study indicated that institutional readiness is limited by disjointed governance structures, inconsistent operational preparedness, insufficient policy frameworks, and uneven institutional competence. Although HEIs were able to maintain academic activities during the crisis, this was primarily accomplished through reactive, improvised strategies rather than through planned and established disaster preparedness. As a result, preparedness remains unevenly institutionalised, relying on departmental capacity rather than integrated institutional frameworks.

Overall, the study indicates that the HEIs demonstrate a reactive resilience rather than a proactive preparedness approach used by the Eastern Cape universities. While emergency actions during COVID-19 enabled the continuation of teaching and learning, the lack of ongoing disaster planning, training, and communication mechanisms restricts the sustainability of institutional resilience. This gap between operational response and strategic readiness underscores the need for HEIs to move from crisis-driven adaptation to systematic, continuous risk management. The study recommends that HEIs develop and implement comprehensive emergency risk management frameworks with well-defined roles, responsibilities, and reporting systems. Future research should expand the scope of this study by integrating a larger sample of higher education institutions from various provinces to enhance the generalisability of the findings across the nation and/or in other developing nations. Comparative studies of well-resourced and under-resourced institutions could provide further comprehension of how institutional capability affects pandemic preparedness. Furthermore, quantitative studies could be undertaken to assess the level of readiness among higher education institutions using standardised readiness indexes.

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Supplier relationships and logistics management to reduce material supply disruptions among SME contractors in the Western Cape, South Africa

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Abstract

The purpose of this study is to investigate effective SME contractors' supplier relationship management and logistics strategies to prevent material supply disruptions and enhance construction project performance for SME contractors. This study adopted a quantitative research method. 75 survey questionnaires were distributed to respondents to investigate supplier relationships and logistics management to reduce material supply disruptions. To achieve the objectives of this study, the Statistical Package for the Social Sciences (SPSS) version 31 was used to analyse the data gathered, using both mean ranking and principal component analysis (PCA). To ensure the internal consistency of constructs, this study used Cronbach's Alpha. The findings reveal loyalty agreements with high-performing suppliers, long-term contracts with key suppliers, working closely with suppliers on project requirements, tracking shipments from dispatch to site, planning for alternative delivery routes or vehicles, ensuring that materials are delivered just-in-time, financial stability, logistics capability, and maintaining a database to reduce material supply disruptions. Furthermore, PCA findings reveal that SME contractors adopt supplier logistics coordination and implement strategic supplier and logistics management to reduce material supplier disruptions. This study shows that strengthening collaboration, enhancing logistics coordination, and promoting supplier development can significantly improve project outcomes. The research contributes to both theory and practice by providing a framework that supports SME contractors in achieving more efficient and reliable material supply, aligned with industry expectations and regulatory requirements. This study offers insights by integrating supplier relationship management and logistics strategies in the context of SME contractors.

Keywords: Construction procurement, logistics management, material supply disruptions, supplier relationship management, and Western Cape Province

1. Introduction

Small and medium-sized enterprises (SMEs) play an important role in the delivery of construction projects in South Africa, particularly in provinces such as the Western Cape (Oyegoke *et al*., 2024). This contribution includes infrastructure development, local job opportunities, and Gross Domestic Product (GDP) (Manathunge *et al*., 2021). Despite their role in job creation and infrastructure development, the majority of SME contractors' business performance continues to be affected by recurring material supply delays (Sogaxa & Simpeh, 2022; Chowdhury, Lau & Pittayachawan, 2019). According to research by Ali *et al*. (2021), these disruptions are often associated with poor supplier relationships, inadequate logistical systems, low bargaining power, and financial constraints, which all negatively affect the delivery of construction projects. Manathunge *et al*. (2021) reveal that material availability and timely delivery are critical contributors to SME contractors' ability to meet project schedules, control costs, and maintain quality standards in conformity with regulatory expectations. However, Madhavika et al. (2025) and Bak *et al*. (2021) argue that SME contractors usually operate within limited supply chains with unreliable suppliers, poor coordination, and insufficient integration of logistics planning. Khuan, Shee and See (2023) note that SME contractors are affected by transportation inefficiencies, price volatility, and demand fluctuations, which worsen SMEs' ability to deliver, increasing sensitivity to delays and cost overruns. According to Sogaxa and Simpeh (2022), effective supplier relationship management and logistical coordination are widely acknowledged as critical enablers of supply chain resilience in construction. On the other hand, a robust collaboration with local suppliers may improve procurement planning, increase communication, and secure priority access to construction resources (Wloch, 2023). Similarly, Khuan, Shee and See (2023) reveal that efficient logistics systems can shorten lead times, decrease waste, and enhance on-site material availability during the implementation of construction projects. However, Donyavi (2009) and Kumar *et al*. (2025) claim that these practices remain immature and are inconsistently adopted among SME contractors in the Western Cape. Given that materials can constitute up to 70% of total project costs, any inefficiencies or

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delays in the procurement process can lead to substantial financial ramifications, hampering not only individual projects but also the long-term viability of SMEs within the construction industry (Parisi & Donyavi, 2025). The objectives of this study are stated as follows:

Against this backdrop, this study investigates supplier relationships and logistics management to prevent material supply disruptions and enhance the success of construction projects among SME contractors. The study aims to contribute to the body of knowledge related to the existing literature on supply chain management in developing countries by providing context-specific insights and practices to enhance performance, resilience, and sustainable SME contractors in the Western Cape Province. This study comprises six sections, namely: Section A, the introduction to the study, patterning supply chain disruptions; Section B, the literature review and the underpinning theories; Section C, research methodology; Section D, presentation of results; Section E, discussions of findings; and Section F, conclusions and recommendations.

2. Literature Review

2.1. Material supply disruptions in construction projects

Material supply disruptions are delays, shortages, or irregularities in the delivery of building supplies necessary for project completion (Panova & Hilletofth, 2018). Kissi *et al*. (2021) divulge that these disruptions significantly contribute to project delays, cost overruns, and poor quality, which could negatively affect business success. Heaton *et al*. (2022) reveal that supplier unreliability, inadequate inventory management, transportation delays, and contractor financial instability are all common causes of supply chain disruptions.

The impact on SME contractors is particularly severe due to limited capacity for buffering and limited access to alternative suppliers (Pamidimukkala, Kermanshachi & Karthick, 2020; Duong *et al*., 2026). Disruptions frequently cause work stoppages, activity rescheduling, and increased labour costs (Duong *et al*., 2026). Furthermore, Kisi and Sulbaran (2022) find that inconsistent material delivery may result in noncompliance with building standards, such as NHBRC criteria, thereby compromising project integrity and certification.

2.2. Supplier relationship management in construction

The concept of supplier relationship management in construction has become a pivotal strategic practice in supply chain and procurement, transforming transactional relationships into collaborative, value-oriented partnerships with suppliers (Jones, 2025). SRM entails methodical interaction, lateral tracking, and collaborative issue resolution to achieve efficiency, durability, innovation, and future results (Jones, 2025). As the case in point, the studies in the area of procurement prove the existence of a positive and statistically significant correlation between SRM practices and the supply performance outcomes, including delivery reliability, cost efficiency, and quality improvement, which indicate that effective supplier engagement can advance the wider supply chain objectives (Ofori Issah, Aidoo-Acquah & Boafor, 2025). Likewise, the results from construction supply chains indicate that proactive SRM is associated with improved operational performance. This will involve improved inventory levels, standardised supplier analysis and monitoring of performance, which collectively will improve overall performance (Nakile, Kibuine & Kimemia, 2025).

2.3. Logistics management and its role in material supply

According to Buhaievskyi and Petrenko (2025), logistics planning significantly influences construction productivity, particularly when material flows are complex and time-sensitive. Furthermore, transport disruptions, driver shortages and infrastructure bottlenecks have emerged as major constraints in construction supply chains (AlTalhoni, Ali & Al-Sheikh, 2025). Transportation risk management has therefore gained prominence, especially in post-pandemic contexts characterised by global instability (Nowakowski & Ryczyński, 2025). Machine learning approaches are increasingly used to predict transportation durations and mitigate uncertainty (Emerald, 2024). Moreover, logistics challenges under uncertainty require integrated planning among procurement, scheduling, and transport functions (Papadopoulos, Gunasekaran & Dubey, 2022). In addition, effective logistics management requires real-time monitoring systems, diversified transport strategies, and risk-adjusted planning models to ensure continuity of material flow (Popa *et al*., 2025).

2.4. The link between supplier relationships, logistics, and project performance

The correlation between supplier management and logistics performance is critical for establishing consistent material flow in building projects (Kalubanga & Namagembe, 2022). Effective supplier relationships encourage early participation, open communication, and coordinated planning, all of which significantly contribute to aligning material production, dispatch, and delivery schedules with project requirements (Kalubanga & Namagembe, 2022; Prajogo & Olhager, 2012). Prajogo and Olhager (2012) further identified that when SME contractors maintain constant contact with suppliers, they are better able to anticipate future shortages, negotiate delivery priorities, and procure crucial goods within the required timeframes. Moreover, this alignment decreases

uncertainty while improving overall supply chain responsiveness (Costa et al., 2019). Therefore, in the light of the supply chain integration concept, logistics and
information integration originally reflects two interrelated forms of integration which flow in opposite directions (Mitrega et al., 2017). A study by Kalubanga and Namagembe (2022) highlighted that logistics efficiency is an operational strategy that translates these relationships into project outcomes. However, Emon, Khan and Siam (2024) claim that even with good supplier relationships, poor logistics planning, such as insufficient transport coordination, delivery scheduling, or site storage, leads to ineffective management of construction resources. In contrast, Butt (2019) reveals that well-structured logistics systems enable timely delivery, reduce material handling risks, and ensure the continuity of site activities. Integrating logistics planning with procurement decisions is critical for SME contractors to avoid delays that could lead to idle labour, longer project durations, and higher costs (Vaka, 2024; Schmelzle & Mukandwal, 2023).

3. Research Methodology

This study adopts a quantitative approach, using descriptive and inferential statistics, to investigate supplier relationship management, logistics practices, and material supply disruptions among SME contractors in the Western Cape (Saunders, Lewis, Thornhill & Bristow, 2015). According to Koshy (2008), quantitative research is advantageous for statistically analysing large amounts of information collected through prepared questionnaires and surveys. Quantitative research is a broad approach to studying a desired subgroup (Dawson, 2009). Furthermore, quantitative research was adopted in this research to collect information from the contractors due to its cost-effective nature (Creswell & Clark, 2011). The study focuses on SME contractors working on residential and general building projects, where the constant supply of materials is important for meeting time, cost, and quality targets (Mohajan, 2020).

The target population for this study was the management personnel of SME contractors in the Western Cape province, comprising the operational manager, procurement manager, quantity surveyors, and supply chain manager involved in the supply chain, making it convenient to distribute the questionnaire. SME contractors' management teams play an important role in running the construction business procurement. Management perspectives are critical in understanding the impact of supply chain disruptions in the delivery of construction projects. SME contractors operating under cidb Grade 1 to 4 are more exposed to supply chain interruptions, making them an important focus for examining productivity difficulties. The actual population size was determined using the most recent cidb online database and related industry records. According to the most recent publicly accessible information from the cidb, there are 1369 GB contractors registered in Grades 1 to 4 in the Western Cape Province. These grades are often regarded as established SME contractors with demonstrated financial and operational capacity.

In its public reports for Grade 1, the cidb regards Grade 1 contractors as entry-level. However, to achieve the study objectives, Grade 1 contractors were included. Therefore, the confirmed total for formally graded SME contractors in the General Building category (Grades 1-4) is 1369, comprising 978 Grade 1 contractors, 182 Grade 2 contractors, 94 Grade 3 contractors, and 115 Grade 4 contractors. To ensure representativeness, a probability sampling method using a random. Primary data were obtained using a standardised questionnaire with closed-ended items, assessed on a Likert scale to ensure consistency and ease of analysis. To maximise response rates, the questionnaire was distributed both electronically and in hard copy on construction sites. The minimum sample size for the study is 300 SME contractors in the Western Cape Province. Out of 300 survey questionnaires sent to the respondents using email, 224 emails were successfully delivered to the respondents, and 31 questionnaires were not correctly completed. A total of 75 surveys were correctly completed and returned, which indicates a 25% response rate compared to a 300-sample size.

Descriptive statistics were used to summarise the data using SPSS version 31, while inferential techniques such as PCA were utilised to assess the strength and significance of correlations between variables. This study adopted mean score ranking to analyse the data. Furthermore, Loeb *et al*. (2017) reveal that the variables are ordered in descending order by mean, with the highest mean indicating the most relevant factors influencing supply chain relationships and logistics. Mean ranking offers a clear, methodical strategy for prioritisation and assists the researcher in decision-making, especially when assessing the impact of supply chain relationships and logistics on SME contractors' productivity within a certain demographic (Rücker & Schwarzer, 2015). This study adopted PCA to identify the most significant factors influencing supply chain relationships and logistics; it also assessed whether the data were suitable for factor analysis (Pallant, 2020). This research used the two popular measures that include Bartlett's sphericity test and the Kaiser-Meyer-Olkin (KMO) test (Kim & Mueller, 1978). When the data are suitable, researchers use PCA to extract factors (Pallant, 2020). The factor loading cut-off value for this study was 0.40. The factor loadings, which display the strength and direction of the correlations between the observed variables and the underlying factors, can be used to analyse the factors (Beavers *et al*., 2019).

Cronbach's Alpha was used to assess the instrument's reliability, with an acceptable internal consistency of 0.7. Ethical considerations were carefully followed throughout the investigation. Participation will be voluntary, and respondents will be informed of the research objective. Confidentiality and anonymity were preserved, and all information was collected only for academic purposes.

4. Presentation of Results

4.1. Background information of the respondents

The results from this study present the gender distribution of respondents, and the results indicate a significant gender imbalance, with male respondents accounting for 81.3% (61) and female respondents comprising only 18.7% (14) of the sample. This reflects the continuing male dominance in the construction industry, although the presence of female respondents indicates a gradual but positive shift towards gender inclusion in the sector. The data indicate that 45.3% (34) of respondents were in the >40 ≤ 50 age group, followed by 26.7% (20) in the >25 ≤ 40 age group. Respondents aged >50 ≤ 60 made up 22.7% (17) of the sample, while those aged > 60 and above accounted for only 4% (3). A minimal 1.3% (1) of respondents were within the >18 ≤ 25 age group. These findings suggest that the SME construction workforce in the Western Cape is largely composed of mature professionals in their mid to late careers.

The majority of contractors, 70.7% (53), were graded under grade 2, followed by 17.3% (13) under grade 4; on the other hand, 9.3% (7) under grade 1, and 2.7% (2) under grade 3. These results confirm that the study appropriately targeted SME contractors. The findings show that 37.3% (28) of respondents had > 20 years of experience, followed by 30.7% (23) with >10 ≤ 15 years, 16% (12) with >15 ≤ 20 years, and 13.3% (10) with >5 ≤ 10 years. Only 2.7% (2) had >0 ≤ 5 years of experience. This distribution highlights a highly experienced workforce, suggesting that respondents were well-positioned to provide informed insights into the effects of supply chain disruptions on productivity.

The results show that 58.7% served as Operational Managers, followed by Quantity Surveyors (37.3%). Procurement Managers and Supply Chain Managers represented 2.7% and 1.3%, respectively. This shows that most responses were drawn from professionals with direct oversight of construction operations and procurement activities, key areas affected by supply chain disruptions, thus making their input particularly relevant to the research objectives.

4.2. Effective SME contractors' supplier relationships and logistics management to reduce material supply disruptions

Table 1 (Appendix 1) presents practices pertaining to SME contractors' supplier relationships and logistics to reduce material supply disruptions. The respondents were asked to rate the impact of the following mitigation practices on minimising supply chain disruptions and avoiding delays. Please note: On a scale of 1 (less impact) to 5 (high impact), please evaluate the role of supplier and logistics relationships in minimising supply chain disruptions within your organisation's construction projects. The results present the role of supply chain relationships. High-performing practices included loyalty agreements with suppliers (MV = 4.50), long-term contracts (MV = 4.42), and close collaboration on project requirements (MV = 4.42). This was closely followed by supporting supplier development and capacity building, as well as engaging in joint problem-solving with suppliers sharing the same MV of 4.40. The relatively lower practice involved suppliers in the project planning stages (MV = 4.35). With an average MV of 4.41, supplier collaboration is a very major mitigation practice, reflecting strong emphasis on trust and partnerships, but with less focus on early-stage supplier engagement. It is noticeable that shipment tracking from dispatch to site (MV = 4.42), alternative delivery routes or vehicles (MV = 4.34), and just-in-time deliveries (MV = 4.26) were prioritised as the most effective logistics strategies used by SME contractors. However, regular evaluation of logistics providers (MV = 3.83) was rated lowest. The overall mean of 4.03 indicates a major practice, with SMEs prioritising operational logistics control. Table 1 shows that the most valued criterion was financial stability (MV = 4.26), followed by logistics capability (MV = 3.94) and maintaining a preferred supplier database (MV = 3.85). The least emphasis was on assessing delivery timelines before appointment (MV = 3.00). The average of 3.71 indicates that supplier evaluation is a major practice, though it is weaker than other mitigation measures.

4.3. PCA for supplier relationships and logistics management to reduce material supply disruptions

FA was adopted in this study to identify and classify the most important SME contractors' supplier relationships and logistics, thereby reducing material supply disruptions. Dehkordi *et al*. (2021), Cureton and D'Agostino (2013), and Kline (2014) employed FA to validate the consistency of the quantitative analysis. Additionally, PCA was used to extract the variables. The data analysis for SME contractors' supplier relationship and logistics to reduce material supply disruptions revealed a KMO score of sampling adequacy of 0.746, which is more than 0.60 and indicates a viable sample for factor analysis (Shrestha, 2021). The Bartlett test for sphericity yielded 203.087 with a significance level of 0.001. KMO and Bartlett's

tests propose factor analysis for the data presented in Table 2. Using PCA, 2 latent components with eigenvalues greater than 1.0 were discovered from 21 SME contractors' supplier relationships and logistics to reduce material supply disruptions.

Table 2: KMO and Bartlett's Test

Kaiser-Meyer-Olkin Measure of Sampling Adequacy.		**.746**
Bartlett's Test of Sphericity	Approx. Chi-Square	203.087
	Df	22
	Sig.	<.001

Table 3 reveals that the extracted components have eigenvalues of 2.924 and 1.375, which account for 61.41% of the variance. The findings indicate values more than 0.40, while variables with values less than 0.40 are omitted. Furthermore, the most important components of SME contractors' supplier relationship and logistics to reduce material supply disruptions are Component 1, '*Supplier logistics coordination*', and Component 2 '*Strategic supplier and logistics management '*.

5. Discussion of Findings

As presented in Table 1, the quantitative findings pertain to supplier collaboration, including loyalty agreements with high-performing suppliers, long-term contracts with key suppliers, close collaboration with suppliers on projects, support for supplier development and capacity building, and joint problem-solving with suppliers. Supporting supplier development and capacity building improves supplier performance and long-term reliability, which is critical in the SME setting (Deep, Gajendran & Jefferies, 2021). Furthermore, Costa *et al*. (2019) indicated that engaging in collaborative problem-solving with suppliers enables the effective resolution of issues such as delays and shortages, thereby reducing supply chain-

Table 3: Component Matrix[a] for contractors' supplier relationship and logistics to reduce material supply disruptions

	Component	
	1	**2**
Component 1: Supplier logistics coordination		
Planning delivery schedules in advance with suppliers	.967	
Maintaining a database	.932	
Supporting supplier development and capacity building	.910	
Engaging in joint problem-solving with suppliers	.841	
Storage facilities for critical materials	.732	
Planning for alternative delivery routes or vehicles	.703	
Financial stability	.634	
Tracking shipments from dispatch to site	.611	
Component 2: Strategic supplier and logistics management		
Working closely with suppliers on project requirements		.880
Assessing supplier delivery timelines		.849
Loyalty agreements with high-performing suppliers		.811
Comparing prices, quality, and delivery		.800
Use of logistics companies		.793
Involvement of suppliers in project planning stages		.750
Evaluating logistics providers regularly		.747
Long-term contracts with key suppliers		.689
Reviewing suppliers' past project performance		.631
Logistics capability		.517
Treating suppliers as strategic partners		.461
Ensuring that materials are delivered just-in-time		.406
Terminating relationships with non-performing suppliers		.400
Eigen value	2.924	1.375
Proportion of variance (%)	41.767	19.644
Cumulative variance (%)	41.767	61.411
Extraction Method: Principal Component Analysis.		
a. 2 components extracted.		

related project interruptions. These findings align with those of Nnaemeka and Chijindu (2023), who demonstrate that increased supplier engagement is associated with fewer material supply disruptions and better project performance.

The findings from Table 1 indicate tracking shipments from dispatch to site as the most significant practice used by SME contractors, aligning with the recommendations of Acquah *et al*. (2025). Gatobu and Moronge (2024) support this finding by stating that supplier relationships enhance contractors' confidence, achieved through tracking shipments from dispatch to site, thereby improving the ability to secure construction resources. According to Acquah *et al*. (2025), tracking shipments from dispatch to site increases material planning accuracy, minimises specification errors, and enables the contractor to meet construction deadlines. Furthermore, planning for alternative delivery routes or vehicles is ranked second as the most significant logistics management practice used by SME contractors. This finding is corroborated by the findings from Lasota *et al*. (2024), who posited that planning alternative delivery routes or vehicles is an important logistics risk-mitigation strategy in construction supply chains, especially for SME contractors, who are most affected by transportation disruptions, traffic congestion, and distance to suppliers, all of which can significantly impact material availability.

The quantitative findings revealed that ensuring materials are delivered just-in-time is the third most significant practice among SME contractors. These findings align with the literature from Biswas and Sarker (2020), who pointed out that ensuring that materials are supplied just-in-time (JIT) is an important logistics approach for increasing efficiency and decreasing waste in building projects.

Regarding supplier evaluation and selection, the findings reveal that SME contractors prioritised financial stability, logistics capability, and maintaining a database to reduce material supply chain disruptions. According to Ho, Xu and Dey (2010), suppliers with strong financials are better positioned to buy supplies in bulk, absorb market changes, and fulfil orders consistently, reducing the risk of disruptions. Furthermore, Lopes and Rodriguez-Lopez (2021) reveal that strong logistical capabilities, such as fast transportation, reliable delivery systems, and effective coordination, were found to significantly improve on-time material delivery to the site. Tavana *et al*. (2016) add that suppliers' capacity to maintain continuous quality and delivery performance has also emerged as a vital issue, ensuring the continuation of construction activities and reducing delays. The findings indicate that SME contractors who prioritise financially stable and logistically capable suppliers are more likely to have improved overall material flow (Lammi, 2016).

PCA findings revealed two components, namely supplier logistics coordination and strategic supplier and logistics management, influencing SME contractors' supplier relationships and logistics to reduce material supply disruptions in the Western Cape Province. Component 1 supplier logistics coordination: this principal factor explained the most variance and was defined by eight variables: planning delivery schedules in advance with suppliers (0.8967); maintaining a database (0.932); supporting supplier development and capacity building (0.910); engaging in joint problem-solving with suppliers (0.841); storage facilities for critical materials (0.732), planning for alternative delivery routes or vehicles (0.703), financial stability (0.634), and tracking shipments from dispatch to site (0.611). Notably, each variable's appropriate factor loading has been contained in parentheses. This finding aligns with the findings from Kmiecik (2022) who revealed that supplier logistics coordination leads to enhanced delivery reliability, and the perspective suggests that its effectiveness among SME contractors is mostly restricted by informal and reactive practices used in the construction industry. Furthermore, Ashenbaum and Maltz (2017) reveal that supply chain coordination often relies on manual communication and supplier-driven arrangements to achieve consistency and control. This practice enhances SMEs' capacity to influence supply timetables and prioritisation during moments of strong demand (Vlachos & Dyra, 2020). Furthermore, effective integrated logistics planning during the early stages of a project enhances the overall effectiveness of coordination, as procurement and site operations (Vlachos & Dyra, 2020).

Component 2 Strategic supplier and logistics management: the second component includes 13 features, namely working closely with suppliers on project requirements (0.880), assessing supplier delivery timelines (0.849), loyalty agreements with high-performing suppliers (0.811), comparing prices, quality, and delivery (0.800), use of logistics companies (0.793), involvement of suppliers in project planning stages (0.750, evaluating logistics providers regularly (0.747), long-term contracts with key suppliers (0.689), reviewing suppliers' past project performance (0.631), logistics capability (0.517), treating suppliers as strategic partners (0.461), ensuring that materials are delivered just-in-time (0.406), terminating relationships with non-performing suppliers (0.400) as shown in (Table 3).

The findings align with the existing literature, including Harrison et al. (2019), who strongly support the significance of strategic supplier and logistics management in improving supply chain performance and minimising construction disruptions. Furthermore, Khan and Yu (2019) and Harrison et al. (2019) highlighted that SCM in construction is acknowledged as a significant driver of project efficiency,

incorporating essential areas such as logistical coordination, supplier relationships, and strategic planning to improve overall performance. In this context, supplier relationship management is described as the strategic management of supplier relationships to maximise value, with trust, collaboration, and a long-term focus identified as important drivers of effective partnerships (Gattorna, 2017).

6. Conclusion and Further Research

The purpose of this study was to investigate supply chain relationships and logistics management to reduce material supply disruptions while improving the success of construction projects in the Western Cape. This study employed a quantitative research method to achieve its objectives. The findings demonstrate that SME contractors adopt loyalty agreements with high-performing suppliers, long-term contracts with key suppliers, working closely with suppliers on project requirements, tracking shipments from dispatch to site, planning for alternative delivery routes or vehicles, ensuring that materials are delivered just-in-time, financial stability, logistics capability, and maintaining a database to reduce material supply disruptions.

The study demonstrates that adopting a structured approach to Strategic Supplier and Logistics Management significantly enhances reliability in material flow. Furthermore, this study indicated that SME contractors adopt supplier logistics coordination to effectively manage the material supply chain during the delivery of construction projects. This study recommends that SME contractors actively involve key suppliers during project planning and design to ensure effective delivery of construction materials during the construction stage. Furthermore, this study recommends that contractors should move away from transactional relationships and adopt long-term agreements with high-performing suppliers. SME contractors in the Western Cape province should develop and maintain supplier databases and implement basic material tracking systems.

Future research should explore how digital technologies and lean construction practices can be integrated into SME supply chains to improve supplier coordination, logistics efficiency, and overall project delivery performance within frameworks

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Appendix 1

Table 1: Supplier relationship and logistics management to reduce material supply disruptions

Category	Statement	Mean	Std.	Rank
Supplier collaboration *Cronbach's Alpha* = 0.86 Composite score = 4.41	Loyalty agreements with high-performing suppliers	4.50	.900	1
	Long-term contracts with key suppliers	4.42	.919	2
	Working closely with suppliers on project requirements	4.42	1.015	2
	Supporting supplier development and capacity building	4.40	.834	3
	Engaging in joint problem-solving with suppliers	4.40	1.002	3
	Treating suppliers as strategic partners	4.36	.977	4
	Involvement of suppliers in project planning stages	4.35	.932	5
Logistics management practices *Cronbach's Alpha* = 0.86 Composite score = 4.03	Tracking shipments from dispatch to site	4.42	1.045	1
	Planning for alternative delivery routes or vehicles	4.34	1.025	2
	Ensuring that materials are delivered just-in-time	4.26	1.115	3
	Storage facilities for critical materials	4.23	.990	4
	Use of logistics companies	4.16	1.290	5
	Planning delivery schedules in advance with suppliers	3.99	1.325	6
	Evaluating logistics providers regularly	3.83	0.973	7
Supplier evaluation and selection *Cronbach's Alpha* = 0.86	Financial stability	4.26	1.000	1
	Logistics capability	3.94	1.044	2
	Maintaining a database	3.85	0.984	3
	Comparing prices, quality, and delivery	3.85	1.333	4

Category	**Statement**	**Mean**	**Std.**	**Rank**
Composite score = 3.71	Reviewing suppliers' past project performance	3.78	1.445	5
	Terminating relationships with non-performing suppliers	3.28	1.518	6
	Assessing supplier delivery timelines	3.00	1.546	7

Adoption of Lean Construction Techniques by SMEs in the Western Cape Province, South Africa to Enhance Project Delivery.

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Abstract

Small and Medium Enterprises (SMEs) in Western Cape construction industry face significant challenges in adopting Lean Construction Techniques (LCT). This work examined the challenges and benefits that come with the adoption of LCT to improve the delivery of projects of SMEs in the Western Cape Province of South Africa. The qualitative research methodology was employed, involving six semi-structured interviews with construction professionals from Construction Industry Development Board (cidb) registered SME constructors (grade1-6) operating within the Western Cape province. A thematic analysis was used to determine the existing practices, limitations and performance results. The results reveal that although LCTs are positively perceived among SMEs, its adoption is still informal and project-oriented because of financial limitations, lack of training, resistance to change, and weak commitment of management to embrace change. Despite these challenges, partial adoption of techniques like the Last Planner System (LPS), Just-in-time (JIT), 5S, and Value Stream Mapping (VSM) contributed to improved workflow coordination, time management, decrease in rework, better performance of safety, and client satisfaction. The findings indicate that LC techniques and management commitment may be institutionalised to boost the performance of SMEs. The study established that Lean Construction techniques are a promising solution to enhance project delivery among SMEs in Western Cape if awareness, systematic training, and policy-backed solutions are given priority.

Keywords: Lean construction; Lean construction adoption; Lean construction techniques; Project delivery; SMEs

1. Introduction

Construction is a fundamental economic development engine across the globe that drives infrastructure building and job creation as well as sustaining the economy in the country (Karimulla et al., 2024). The South African construction sector is a vital component for national economic development because it contributes about 3% to the country's GDP according to Ramabitsa (2022). It adds substantial economic value to the national GDP which amounted to 109.5 billion rand in 2023 (Statista, 2024).

However, with all these contributions, the construction industry is facing several challenges which are curbing its ability to successfully complete construction projects. The factors that cause delays in the completion of project, financial running over, low quality, etc, are common factors that results in the disatisfaction of the client and loss of revenue opportunities (Al Balkhy *et al*., 2021). It was suggested by Jacobs (2024) that the lack of financial resources on SMEs in South Africa, coupled with low operational capabilities, is the primary reasons for their poor performance. LCT are structured process improvement mechanisms designed to minimise waste, coordinate more effectively and generate more value in project environments (Salem et al., 2020). However, the adoption of LCT faces many issues for South African SMEs to manage. Poor industry-academia collaboration, opposition to policy changes, cultural differences, and a lack of industry knowledge of LC are some of the obstacles that prevent the adoption of lean techniques by South African SMEs (Salem et al., 2020).

This study aimed to explore the adoption of LC techniques by SMEs in the Western Cape Province, South Africa, to enhance project delivery. A qualitative research design was used where data were collected as structured and in-depth interviews using purposely sampled cidb-registered general building contractors (Grades 1-6) and a thematic analysis. This method was suitable because it allowed the in-depth understanding of professionals' experiences that would have been more difficult if a quantitative approach had been used. The study, although restricted to the Western Cape province, provided context-specific results that should help SME managers, policymakers, and industry stakeholders to become more efficient, competitive, and sustainable in project performance.

2. Adoption of Lean Construction techniques in SMEs

Problems that South African construction SMEs face with project delivery include delays, cost escalation, rework, low productivity, and inconsistent quality deliveries (Sogaxa, 2020). These performance issues

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are usually caused by financial constraints, informal management systems, poor planning systems, lack of skills and disjointed communication among project stakeholders. These limitations lower the competitiveness and limit the long-term sustainability of the SMEs. Process improvement solutions for these inefficiencies are organised and are specific to the SME context (Xing et al, 2021).

According to Akanbi et al., (2019) Lean Construction (LC) is a construction management philosophy based on Lean Manufacturing, which is aimed at increasing the value while minimising waste throughout the construction process. It focuses on continuous improvement, teamwork, effective management of workflow, and doing away with non-value-added activities. The construction industry is in the state of constant advancement and industry players employ a more significant degree of activity towards operational effectiveness, waste elemination, and environmental responsibility (Liong et al, 2024). LC is a disruptive approach that can be utilised to make construction projects more productive in terms of the reduction of their inefficiencies (Akanbi et al., 2019). LC is the adaptation of Lean Manufacturing principles to the construction sector that suggests new delivery solutions to the implementation of a project taking into account its specifics (Xing et al, 2021). Despite the proven effectiveness of lean construction techniques in large construction organisations, their uptake in SME remains unsatisfactory, particularly in developing countries such as South Africa (Makondo, 2021).

The financial ability, skills and informal management structure of SMEs tend to restrict their capacity to undertake formal improvement initiatives, as well as determine the resultant outcome of lean techniques adoption, when the latter is applied. It is therefore important to comprehend both the obstacles that would impede the adoption and the benefits that can be achieved by adopting LC to the project environment of SMEs to establish the practicability in the SME project setting. The current literature is examined on two important levels, namely the challenges hindering the adoption of lean construction techniques and the benefits linked to their use in improving the performance of project delivery.

2.1 Challenges hindering the adoption of lean construction techniques by SMEs to enhance project delivery.

The problems that the construction industry faces are issues of cost overruns, delays, re-work and low productivity, which makes lean construction a strategy that can help reduce waste and maximise value (Al Balkhy *et al*., 2021). Although it has been found to work within large companies, its level of adoption remains low in SMEs, especially in developing economies. SMEs possess scarce resources and unstructured management frameworks constraining the ability to perform structured improvement practices (Jacobs, 2024).

The first barrier has been recognised as resistance to change since managers and workers usually enjoy the routine and perceive LCTs as hard to implement or disrupting (Sarhan *et al.,*2018). Lean initiatives are regarded as another administrative burden, not as a productivity tool, without effective leadership and change management (Al Balkhy *et al*., 2021). Implementation also faces financial and time limitations, as the adoption of LCT involves initial investments in the form of training, planning, and redesigning processes that most SMEs cannot afford (Jacobs, 2024).

According to Huaman-Orosco *et al.,* (2022) the lack of knowledge and poor collaboration among industry, academia, and support institutions lead to decreased awareness and practical knowledge of lean construction techniques. A commitment of poor leadership also compromises long-term implementation as stated by Al Balkhy *et al*., (2021). All these cultural and financial, as well as capability-related barriers, clarify the gradual adoption of LCT among SMEs despite the opportunities it may provide in terms of improving project performance.

Besides the cultural and financial barriers, technical capacity is also limiting as it restricts effective adoption of LCT in SMEs. The most popular are the Last Planner System, Just-In-Time (JIT) delivery, 5S organisation of the workspace, and Value Stream Mapping (VSM) that are expected to enhance the reliability of workflow, efficiency of materials, and coordination (Singh, 2025). The effective application of these techniques however involves disciplined planning, training as well as regular leadership guidance. These enabling conditions are not present in most SMEs, and informal, intermittent and project-specific application is in place as opposed to institutionalisation by the organisation (Singh, 2025).

2.2 Benefits of adopting lean construction techniques by SMEs to enhance project delivery.

Although SMEs have been facing substantial adoption challenges, empirical studies have proved that lean construction can bring substantial benefits to an organisation in terms of operational as well as strategic advantages, especially when it is implemented wisely. LCT can be used to improve project performance through reduction of the non-value-adding activities and maximisation of resources utilisation, which leads to an increase in productivity and competitiveness (Dara *et al.,* 2024). These benefits have a particular relevance to SMEs, because their survival in a variety of situations depends on effective cost control and timely delivery.

One of the main benefits that have been reported in the academic literature is the minimisation of waste of material and the cost implication thereof. Just-in-time (JIT) procurement and enhanced workflow planning are lean tools that ensure the reduction of unnecessary inventory, material damage, and over-ordering (Dara *et al*., 2024). Belhadi et al. (2018) state that the material losses and storage cost are reduced considerably in organisations that use pull-based and JIT systems. In the case of SMEs, which are normally faced with limited financial resources, the cost savings would directly increase profitability, positive cash flow, and financial sustainability. Waste minimisation will help in environmental sustainability, making construction activities in line with the rising client demands and regulation standards (Belhadi *et al*., 2018).

Lean construction techniques are linked to better time management and schedule reliability. Co-operative planning methods, like the Last Planner System, help in coordinating tasks, identifying constraints earlier and stabilising the workflows, thus producing fewer delays and less rework (Sibiya *et al.,*2023). Belhadi *et al.,* (2018) states that companies using formal lean scheduling have a shortened project life and greater predictability of the completion time. Improved performance in schedules builds confidence in clients and allows SMEs to implement more projects during the same time, thereby increasing revenue opportunities.

Another relevant advantage is better collaboration among the stakeholders. LCT also promote frequent communication, joint problem-solving, and shared responsibility between the contractors, subcontractors, and suppliers (Belhadi *et al.,* (2018). The use of the LCT like daily huddles and visual management boards enhances the transparency and the speed of the decision-making process. Dara *et al.,* (2024) note, that it becomes easier to coordinate the work, and the number of disagreements and misunderstandings decreases, resulting in an improved flow of the work. In the case of SMEs, which often rely heavily on the working relationships, this collaboration will improve the efficiency of the operations and lead to long-term partnerships.

The value proposition of LCT adoption is further supported by improving of quality and customer satisfaction. The continuous improvement practices encourage the early identification of flaws, streamline operations, as well as learning about earlier undertakings (Belhadi *et al.,* 2018). This results in better quality of workmanship by minimising rework, reducing the cost of corrective work and more regular performance, also enhances the reputation of the organisation. According to Sibiya *et al., (*2023), small and medium enterprises adopting lean strategies record better repeat business and referral rates, which can be attributed to the high-quality of service delivery. These performance improvements are reflected in increased competitiveness in tendering as clients become more willing to hire contractors who have proven their efficiency, reliability, and cost-effectiveness (Sibiya *et al.,* 2023).

2.3 Synthesis

The existing evidence proves that although lean construction offers unique benefits to the execution of the SME projects, its adoption is hampered by resistance to change, limited resources, lack of competencies, and the lack of leadership support. There is however systematic evidence that demonstrates that SMEs that overcome these hindrances incur fewer costs, better schedule performances, increased teamwork, better quality, and increased competitiveness. The contrast of high potential benefits in the future with the long-term barriers to implementation, highlights the necessity of contextually focused empirical research on ways SMEs, including those in the Western Cape, can effectively apply lean methodology to streamline project results.

3. Research Methodology

A qualitative research design was used to investigate the adoption of Lean Construction Techniques among the Small and Medium Enterprises (SMEs) in the Western Cape Province. An interpretivist research philosophy was adopted since the study was concerned with trying to make sense of the experiences, perceptions, and practicality of LCT adoption by construction professionals. Six semi-structured interviews were conducted with a project manager, quantity surveyor, site supervisor, director, safety officer, and operations manager in different General Building contractors registered with the Construction Industry Development Board (cidb), i.e., SMEs in Grades 1 to 6. These participants were selected using purposely sampling method and are considered a small-scale representation of construction stakeholder with experience ranging between 6 and 18 years in the construction industry, ensuring a range of practical insights from mid-level to senior professionals.

Face-to-face and virtual interviews were scheduled for 30-45 minutes. The interviews were audio-recorded with participant consent to ensure accurate transcription and analysis. The data were analysed using thematic analysis; the data were coded and reclassified into key themes of lean adoption, challenges and benefits. Careful comparison of the results with the literature was used to strengthen the credibility of the study in interpreting the results. Ethical considerations were observed throughout the study. Participation was voluntary, and all participants were informed of the study's purpose before the interviews began. Respondents were anonymised and identified as P1 to P6 to preserve confidentiality.

4. Findings and Discussion

4.1 Challenges hindering the adoption of lean construction techniques by SMEs to enhance project delivery

The analysis established that the biggest issues include knowledge and training deficiencies, financial constraints, resistance to change, limited leadership support, with all of the themes supported by literature and participant responses.

4.1.1 Lack of knowledge and Training

Four participants (P1, P3, P5 and P6) emphasised the lack of awareness and available training opportunities as barriers to the understanding and adoption of lean construction techniques. P1 clearly stated: "Lack of awareness is the greatest challenge. Therefore, a lot of effort is required to train many workers who do not understand lean construction concepts." Similarly, P3 added: "Our artisans are competent but lack exposure to lean construction techniques." This is supported by Huaman-Orosco *et al.,* (2022) who stated that the lack of specific lean education is one of the factors contributing to poor adoption.

4.1.2 Financial Constraints

Many of the participants also highlighted financial constraints as one of the key obstacles. P2 explained: "Financial pressure forces us to cut corners. LCT are regarded as something that is nice to have rather than necessary." P4 further stated: "With no finances we will not have the ability to employ qualified individuals to carry out lean construction in the proper manner." In addition, P3 noted: "We struggle to buy proper software or planning tools, so lean construction remains basic." These assertions prove that cost barriers do not only influence training but also acquisition of proper systems and tools needed to implement formal lean construction techniques. This is consistent with Jacobs (2024) who established that the financial capacity of SMEs is low, and as such, their choices are restricted to whether they invest in the training, technology, or seek consultancy services.

4.1.3 Resistance to Change

Another considerable barrier was identified as the resistance to change, and five of the six respondents cited difficulties with employee attitudes. P2 stated: "My greatest challenge is resistance of older staff. They are stuck to the traditional way of doing things." P5 similarly explained: "Most workers resist change because they want to do things the way they've always done." The findings indicated that not all employees are receptive to change especially employees who are used to doing things using traditional methods of construction and this is a major obstacle towards the successful adoption of lean construction techniques (Sarhan *et al.,*2018).

4.1.4 Lack of Management Commitment

Respondent P4 and P6 cited a lack of management commitment as a restraint. P4 stated: "The support of the management is unequal. There are those who desire LCT and there are those who believe that LCT is a distraction." P6 added: "The management regards lean construction primarily as compliance with safety, rather than as a company-wide strategy." These results imply that construction lean techniques have not yet been fully institutionalised in the SME governance system. In cases where leadership commitment is not steady, implementation activities are often informal and in a disjointed form. Jacobs (2024) has also indicated that inadequate managerial commitment has negative effects on the implementation of LCT. The results indicate that the problems faced by SMEs in Western Cape are similar to those found in international literature and is enhanced by the local contextual challenges of poor funding, inadequate training programmes, and the skills gap.

4.2 Benefits of adopting lean construction techniques by SMEs to enhance project delivery.

All the participants noted concrete gains of partial LC adoption as the process of work improvement, time management, teamwork, work reduction, and client satisfaction. These results are in line with Dara et al. (2024) who concluded that the adoption of LCT can help in the reduction of waste and shortening of the project duration. Quality and safety performance were improved as well, which is in line with Belhadi et al. (2018), who have associated collaborative lean construction techniques with better coordination and increased safety.

4.2.1 Better Workflow and Co-ordination

According to the participants, workflow stability and coordination were significantly better. P3 stated: "With Last Planner, the work is smoother and the subcontractors work together." P1 added: "It minimises the time wastage and enhances inter-team communication." Such responses show that LCT enhance the sequence, communication, and cooperation of project stakeholders. With improved coordination, the project will be executed with ease, and this will reduce the disruptions at the site.

4.2.2 Work Reduction and Time management

Participants also highlighted that LCT were used to eliminate rework and delay of projects. P3 explained: "I have come to know how to have better time management and how to skip unneeded overtime." Similarly, P5 confirmed: "If we eliminated rework and wastage, projects are completed faster and at reduced cost." These results show a higher level of reliability in planning and better prioritisation of tasks, which result in a reduced number of errors and decreased material waste. This is in line with Dara et al. (2024), who

associated the adoption of lean construction techniques to better time performance and reduction of wastage.

4.2.3 Client satisfaction

All six respondents attested that the adoption of LCT had a positive impact on client satisfaction. P4 stated: "Clients are more satisfied as a result of the fact that LCT minimises waste, which is converted into cost savings to them."

4.2.4 Productivity and Profitability

Respondents cited moderate productivity and profitability. P1 stated: "The cost overruns are less, and this is more profitable." P4 noted: "It improves the profitability, but not significantly." P6 clarified: "There is an increase in productivity because of improved organisation and there is limited profitability as dictated by the outside market factors."

The modest profitability improvements achieved by all respondents are in line with Makondo (2021), who reported financial benefits of introducing LCT only after long-term and systematic adoption. The overall evidence holds that partial LC implementation may produce both operational and relationship benefits, but more far-reaching financial benefits will be realised when the institutionalisation process and the commitment of the leadership are sustained. A summary of the challenges, findings and benefits of LCT adoption is presented in Table 1.

SMEs recognise the need and potential benefits of using LCT, their use is still low and informal. The primary obstacles mentioned are lack of awareness, training, financial constraints, resistance to change and management commitment.

Despite these challenges, the findings showed that even partial adoption of LCT contributes positively to project delivery. Some of the improvements that participants mentioned were better workflow coordination, communication, time management, decreased re-work, improved safety performance and client satisfaction. The study highlights that LCT can be effective in enhancing the operational performance and project outcomes of SMEs when they are supported by proper training, leadership commitment and organisational support.

The study contributes to the body of knowledge on LC adoption in the South Africa's SME construction industry, by providing context specific evidence from the Western Cape Province. The results could help SME contractors, industry players and policy makers in formulating strategies that promote the broader use of LCT.

6. Suggestions for further research

Further research could replicate the study in other provinces of South Africa, and could also include interviews with clients and consultants to extend the range of viewpoints regarding the introduction of LC in the construction sector by SMEs. Furthermore, a mixed method or longitudinal method of research can be used to explore the long-term economic impact of LCT implementation of SMEs. Research on the application of digital technologies, such as Building Information

Table 1: Summary of challenges findings and benefits of LC adoption among SMEs

Challenges	Findings	Benefits
Lack of knowledge and training	Limited awareness of lean construction techniques among and insufficient formal training opportunities among SME employees and management	Improved understanding of lean construction techniques, better workflow coordination, and enhanced project planning.
Financial constraints	SMEs experience limited financial capacity to invest in training, software, tools and lean adoption processes.	Minimise material waste, improve cost control and enhance profitability overtime.
Resistance to change	Employees, especially long-serving workers, do not easily embrace new methods and prefer traditional construction methods.	Develop collaboration, streamline workflows and minimise project delays.
Lack of management commitment	Inconsistent leadership support and failure to institutionalise lean construction practices within organisations.	Better use of lean construction techniques, better organisation performance and better sustainable project delivery improvements.
Partial adoption of lean construction techniques (LPS, JIT, 5S, VSM)	SMEs adopt lean construction techniques on a limited scale due to operational and financial challenges.	Less rework, better time management, minimisation of waste and better project delivery results.

5. Conclusion and Further Research

The aim of this study was to explore the adoption of Lean Construction techniques by SMEs in the Western Cape Province, South Africa, specifically to improve project delivery. The results showed that although

Modelling (BIM) for supporting and facilitating LCT among SMEs could also be pursued. Finally, further research is required to investigate the potential of policy instruments, such as tender requirements and government regulations, that would promote and facilitate the adoption of LCT by SMEs.

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ASSESSMENT OF IMPACTS OF POOR PROJECT GOVERNANCE IN A MULTI-STAKEHOLDER PROJECT ENVIRONMENT: STAKEHOLDER INSIGHTS

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Abstract

Good governance in construction projects improves project performance by reducing risks, enhancing transparency and stakeholder trust, preventing disputes and cost overruns, and ensuring timely delivery and quality outcomes. The purpose of this study is to examine how poor project governance affects project performance, relationships, and decision-making within multi-stakeholder project environments from the perspectives of the involved stakeholders. The study used a mixed-method research approach, including both qualitative and quantitative approaches. A total of 83 construction professionals participated in the survey, while 15 additionally took part in the interviews. Quantitative data were analyzed using descriptive analysis, whilst qualitative data were assessed using thematic analysis. The study found that a lack of good project governance negatively impacts the project performance and compromises project objectives. Due to poor communication and inadequate project governance, the projects mostly fall behind on their milestones. The study suggests that enhancing stakeholder collaboration, clarifying roles, and strengthening communication channels can significantly improve governance effectiveness and project outcomes in complex construction environments

Keywords: Project Governance, Stakeholder Engagement, Multi-Stakeholder Environment, Construction Projects, Governance Challenges

1. Introduction

Project governance is a critical aspect of project success, particularly in multi-stakeholder environments where diverse actors, interests, responsibilities, and expectations must be coordinated to achieve common objectives (Woldesenbet 2020). Dick-Sagoe et al. (2023) assert that Ineffective governance structures often lead to weak accountability, poor decision-making, communication breakdowns, stakeholder conflicts, delays, cost overruns, and reduced project performance. In complex project environments, governance provides the framework through which roles are clarified, decisions are made, risks are managed, and stakeholders are aligned (Gamlath et al. 2024). However, dealing with project governance in a multi-stakeholder setting is inherently difficult because projects involve diverse participants such as clients, consultants, contractors, project managers, government bodies, communities, and end-users, each with different priorities and levels of influence. These differences can create power imbalances, fragmented communication, unclear authority structures, and competing interests, making it challenging to maintain transparency, coordination, and accountability throughout the project lifecycle.

Project Governance refers to the frameworks of rules, relationships, systems, and processes through which projects are directed and through which decision-making, accountability, and productivity are controlled (Too and Weaver 2014; Garland 2009; Muller 2017). Kerzner (2025) argues that it guides in terms of how the project objectives are set, responsibilities are allocated, and monitoring is achieved throughout the project lifecycle. In the construction industry, projects are often large, complex, and of high risk, which necessitates effective project governance to ensure that the project becomes a success (Datta et al. 2025; Famoti et al. 2025). Construction projects frequently involve significant investment, tight schedules, regulatory scrutiny, and quality expectations, all of which demand robust governance mechanisms to guide execution, manage risks, and ensure accountability. Ominde et al.

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(2025) state that, since the construction industry involves multiple stakeholders with different backgrounds and interests, governance is vital to ensure all stakeholders are of one mind and one interest, thereby enhancing the achievement of project objectives.

These stakeholders typically include clients, contractors, consultants, suppliers, regulatory bodies, and affected communities (Musonda et al. 2025). Their dynamic interactions influence the success or failure of governance systems. Stakeholder engagement in governance is not merely administrative but strategic, as it fosters transparency, promotes shared decision-making, and enhances trust and legitimacy (Vickneswaran 2025). Anjum (2025) states that poor stakeholder alignment or exclusion from governance processes can lead to conflict, project delays, or even failure. Therefore, understanding stakeholder dynamics is critical to the design and implementation of governance structures in construction projects. Despite the known benefits of governance, there remains a significant gap in implementing effective governance in construction projects. This study seeks to fill that gap by exploring stakeholder insights into impacts of project governance in multi-stakeholder construction environments. By gathering qualitative data from professionals across various roles, such as project managers, quantity surveyors, engineers, and contractors, the study aims to understand how governance is practiced, perceived, and influenced on the ground.

2. Literature review

2.1. Role of stakeholders in project success and governance

Construction projects, like any other projects, involve various stakeholders, including clients, project managers, consultants, contractors, subcontractors, suppliers, regulatory bodies, and community representatives (Olanrewaju 2025; Kadan and Wium 2025). Stakeholders play a very critical role in project success and the effectiveness of project governance in construction projects. The involvement of stakeholders is crucial from the planning phase through subsequent project phases to commissioning and handover (Frommweiler and Poirier 2025). Therefore, stakeholder engagement is not just a good practice but a necessity and a critical element of project governance, ensuring accountability, transparency, and alignment with project objectives. One of the key contributions by the stakeholders in decision-making and governance guidelines often relies on multiple stakeholders' contributions to enhance balanced and informed decisions (Vickneswaran 2025). Clients and sponsors typically provide strategic direction and financial support, while contractors and consultants contribute technical expertise (Sonkar 2025). Furthermore, stakeholders contribute to effective risk management and compliance, which are very critical components of governance. By involving stakeholders early in the project, project stakeholders can identify potential legal, environmental, financial, and operational risks (Osifo et al. 2025).

Moreover, regulatory authorities assist in compliance with safety and environmental standards and zoning laws (Xu et al. 2025). Contractors, on the other hand, as stakeholders, contribute information on project feasibility and resource availability, while the community can highlight potential social and cultural issues (Li et al. 2025). Stakeholder engagement enhances project communication and knowledge sharing. Project governance mainly depends on clear, timely, and structured communication channels that stakeholders help maintain, and when stakeholders are well informed and regularly consulted, misunderstandings are avoided (Wood et al. 2025). According to Enechi and Pattberg (2025), communication with stakeholders helps align expectations and fosters mutual understanding, especially in multi-stakeholder environments where interests may conflict. Transparent communication practices should be embedded in governance frameworks so that they have a positive impact on the project outcomes

3. Research methodology

Research methodology is a systematic approach and strategy for gathering data from respondents (Kumar and Praveenakumar 2025). It includes a philosophical stance, methods of data collection, analytical tools, and steps to validate and assess the reliability of the findings. Furthermore, research design is a guideline that outlines how data will be collected, measured, and analyzed to address the research question and research objectives (Dharavath 2025, Apriani et al. 2025, Ariyandy et al. 2025). Common research designs include qualitative, quantitative, and mixed-methods research, which integrates both qualitative and quantitative approaches. The chosen research methodology for this study was mixed-methods research. This methodology aimed to integrate qualitative and quantitative research methods to leverage the strengths of both approaches and address their limitations, while providing more comprehensive insights into the research problem and questions. The study purposively selected professionals affiliated with construction-related professional bodies, namely the South African Council for the Project and Construction Management Professions (SACPCMP), the Engineering Council of South Africa (ECSA), and the Project Management Institute (PMI). Due to the cross-sectional nature of the study, it involved construction and consulting companies in Bloemfontein, Free State, South Africa. Respondents were from 70 companies that were actively registered with the CIDB and operated in Bloemfontein, Free State, indicating that

they were drawn from formally recognized and geographically concentrated construction firms. Their gradings ranged from Grades 5 to 9 across several construction categories, particularly civil engineering, general building, mechanical engineering, and electrical engineering, reflecting varied levels of capacity, experience, and project execution capability. The questionnaires were distributed electronically via email to enhance accessibility and convenience. The respondents were given a month to complete the dispatched questionnaire, with weekly reminders to enhance participation. Only 83 completed and returned the questionnaire, yielding a response rate of 81%. According to the study conducted by Babbie (2010) and Dillman et al. (2014), states that sample size above 70% is regarded as excellent. Data gathered for the questionnaire were analyzed descriptively. According to the studies by Kaushik and Mathur (2014) and Dong (2023), descriptive analysis helps identify trends, patterns, and the importance of the variables under investigation, providing a clear understanding of their significance. For the qualitative component, data from the semi-structured interviews were analyzed using thematic analysis with the aid of ATLAS.ti software. According to Braun and Clarke (2006), thematic analysis provides a flexible and systematic approach to identifying, analyzing, and reporting patterns within qualitative data, allowing for rich, detailed, and varied perspectives from respondents on the specific topic. Table 1 illustrates the coding of the respondents that were included in the study.

4. Findings

In this section, the study presents findings from the perspectives of the participating construction professionals. These findings are twofold: quantitative, from the questionnaires, and qualitative, from the interviews with the construction professionals. Firstly, under quantitative findings, the section unpacks demographic data on the respondents, and secondly, it delves into barriers to the adoption of Sound project governance in construction projects. Thirdly, it unpacks the impacts of Poor Governance on Construction Projects, and lastly, it outlines the drivers of the adoption of effective project governance in construction projects. The rest of the section will be delineated according to the following themes: Theme 1: Knowledge of Project governance by the respondents; Theme 2: Barriers to the adoption of effective project governance in construction projects; Theme 3: Impacts of Poor Governance on Construction Projects; Theme 4: Drivers to the adoption of effective project governance in construction projects

4.1. Demographic Data of the Respondents

Nature of the organizations

Figure 1 shows the nature of organizations that the 83 respondents in the study belonged to, and among the 83

Table 1: Coding of the interview respondents

No.	Code	Participant
1.	Pr CM 1	Construction Management Professional
2.	Pr QS 1	Quantity Surveying Professional
3.	Pr ENG ELE 1	Electrical Engineer Professional
4.	Pr ENG MECH 1	Mechanical Engineer Professional
5.	Pr PM 1	Project Management Professional
6.	Pr QS 2	Quantity Surveying Professional
7.	Pr QS 3	Quantity Surveying Professional
8.	Pr CM 2	Construction Management Professional
9.	Pr CM 3	Construction Management Professional
10.	Pr PM 2	Project Management Professional
11.	Pr PM 3	Project Management Professional
12.	Pr ENG ELE 2	Electrical Engineer Professional
13.	Pr QS 4	Quantity Surveying Professional
14.	Pr ENG MECH 2	Mechanical Engineer Professional
15.	Pr PM 4	Project Management Professional

Source: Authors

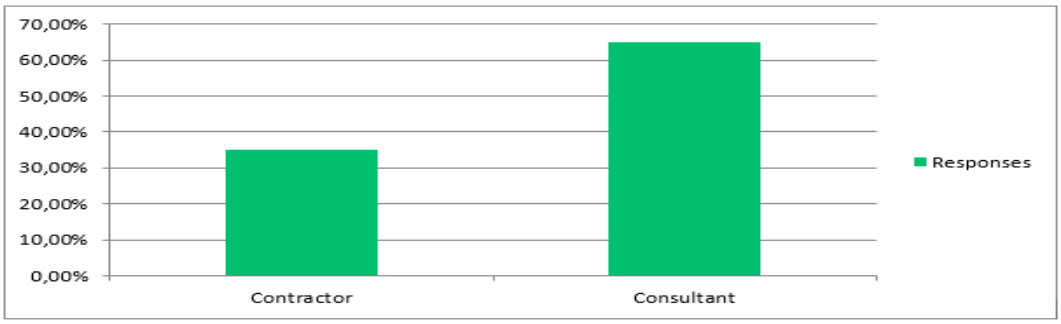

Figure 1: Nature of the organization
Source: Authors

respondents, 54 were from the consulting firms, which accounted for 65.4%, while 29 were from the contracting firms, which amounted to 34.6%. Most of the respondents were from the consulting firms.

Years of organization existence

According to Figure 2, most of the organizations that the respondents were working on, 22 out of 83 (26.9%), were in operation for 5 to 10 years, followed closely by 19 organizations (23.1%) in the 11 to 15 years category. Another 19 organizations (23.1%) existed for 20 years or more, indicating a strong presence of long-established firms. A total of 18 organizations (21.2%) reported having less than 5 years of operational experience, reflecting the participation of newer entrants into the industry. Only 5 organizations (5.8%) had been operating for 16 to 20 years, making this the least represented category.

Qualifications of the respondents

Figure 3 presents the highest qualifications of the 83 respondents, reflecting a well-educated sample of construction professionals. Most respondents, 45 out of 83 (53.8%), held qualifications at NQF Level 7, which typically includes BSc and BTech degrees. This indicates a strong representation of bachelor's degree holders in the sample. Additionally, 19 respondents (23.1%) completed NQF Level 8 qualifications, such as Honours degrees and Postgraduate Diplomas, while 13 respondents (15.5%) possessed NQF Level 9 qualifications, including master's degrees (MSc, MTech, or MCON). A smaller proportion, 6 respondents (7.6%), held qualifications at NQF Level 6 (e.g., National Diploma), and no respondents reported having only Matric or a doctoral-level qualification (NQF Level 10).

4.2. Impacts of Poor Governance on Construction Projects

Based on Table 2 on the impacts of poor governance on construction projects, the highest-ranked impacts were project performance and compromise of project goals, both receiving the highest mean score of 2.60. Although this is not a surprise, a weak governance

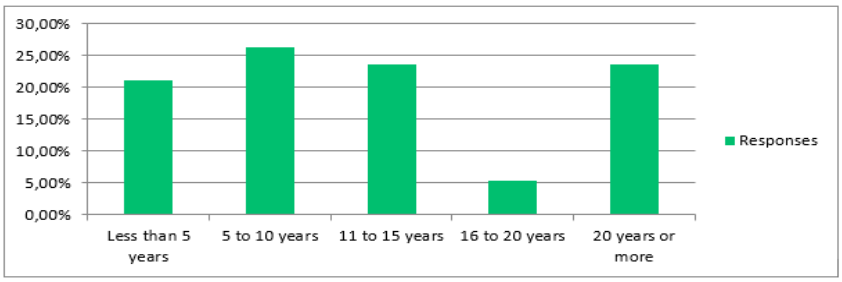

Figure 2: years of organisation's existence
Source: researcher

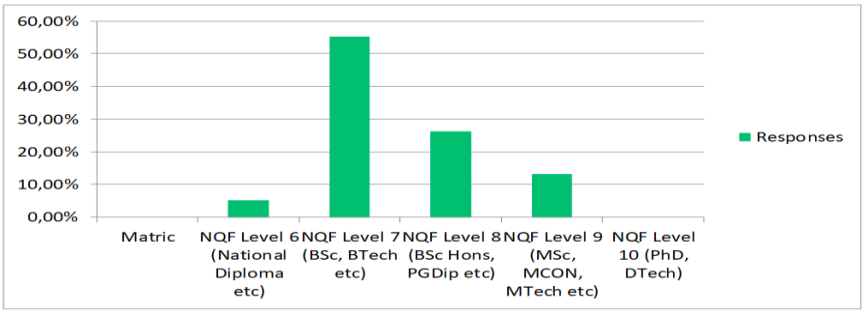

Figure 3: Qualifications of the respondents

Table 2: Impacts of Poor Governance on Construction Projects (source: Researchers)

Descriptive Statistics									
Impacts	**5- Likert Scale**					**No. of Respondents**	**Mean**	**Std. Deviation**	**Rank**
	Strongly Agree (1)	**Agree (2)**	**Neutral (3)**	**Disagree (4)**	**Strongly Disagree (5)**				
Reduces project performance	18	25	20	12	8	83	2.60	1.209	1
Compromise project objectives	17	26	21	11	8	83	2.60	1.257	2
Impacts the project governance	20	27	18	10	8	83	2.50	1.229	3
Compromise project milestones	24	24	16	11	8	83	2.46	1.290	4
Compromises the project communication	26	23	15	11	8	83	2.42	1.226	5

structure contributes to unreasonable decision-making, scope creep, and project delays. Cantarelli et al. (2025) assert that ineffective planning and governance breakdowns contribute to time overruns and cost overruns. Furthermore, Marzouk and Hisham (2020) state that a lack of accountability and unclear leadership contribute highly to the project outcomes. Similarly, the compromise in project governance, with a mean of 2.50, indicates that a lack of guidelines or a framework contributes to project failures. Muller et al. (2021) define this phenomenon as a "governance capacity trap" in which structural and human initiatives are unable to recover from a governance collapse.

Moreover, governance deficiencies with a mean of 2.46 compromise the project milestones and compromise the communication with a mean of 2.42, which are highlighted as the factors for project execution. Delayed milestones are commonly caused by a lack of communication or ineffective communication, which affects decision-making and productivity of the construction projects. Haled et al. (2023*)* found that weak planning and communication frequently cause delays, rework, and cost inflation. Likewise, Hoezen et al. (2022) argue that ineffective communication is a root cause of construction defects, with breakdowns in information flow often stemming from insufficient governance protocols. The respondents' perspectives reinforce these claims, showing that a lack of structured communication channels and governance integration results in fragmented team efforts and weakened project delivery.

Qualitative Data

This section unpacks the data gathered from respondents through interviews on the impacts of poor project governance in construction projects.

Theme 1: Impacts of Poor Governance on Construction Projects

According to the findings, poor project governance mostly leads to inefficiency in coordination and decision-making. Without proper project governance, project role players lack direction, which can lead to delays, conflicts, and confusion in project delivery and ultimately to project failure. *Pr PM 3* highlighted this challenge, stating, *"In some of our projects, decisions are made on the spot without consulting the broader team, and that causes a lot of confusion later."* Too and Weaver (2014) stated that poor governance affects the coordination between the project teams and organizational objectives, which affects the project performance. Furthermore, poor governance contributes to financial mismanagement, which can lead to cost overruns and time overruns. *Pr QS 3* remarked, *"We've had situations where there was no proper control over changes in scope, and that led to major cost escalations."* Similarly, *Pr CM 2* noted, *"Budgets are rarely followed because no one enforces the financial governance properly."* These findings are in line with the study by Owusu et al. (2019), which states that poor project governance leads to inadequate risk management, a lack of financial accountability, and unethical practices in construction projects.

Poor project governance hinders stakeholder collaboration and erodes trust among stakeholders, which in turn affects project productivity. When communication channels and responsibilities are not discussed, stakeholders end up working in silos, leading to more disputes and disagreements among them. *Pr QS 1* explained, *"Sometimes clients and contractors clash because there's no clear governance process outlining who does what." Pr ENG ELE 2* added, *"Without a structured governance plan, everyone ends up blaming each other when issues arise."* These findings are supported by Derakhshan et al. (2019), which state that poor project governance leads to mixed stakeholder expectations and discourages collaboration among stakeholders. Lastly, a lack of governance practices compromises project quality and regulatory compliance. When quality assurance is not integrated into the governance structure, projects are prone to defects, safety risks, and potential legal consequences. *Pr ENG MECH 2* reflected, *"Governance is often overlooked, and that's when mistakes happen, especially on site."* Similarly, *Pr CM 3* stated, *"Quality gets compromised when no one is accountable for overseeing compliance."* To support this finding, Prasanna et al. (2024), state that proper governance is key in safeguarding the quality control of the project and regulatory compliance

This study reveals that poor project governance has a significant negative impact on project performance in multi-stakeholder project environments, particularly through weak coordination, ineffective decision-making, financial mismanagement, poor stakeholder collaboration, and compromised quality control. A unique finding from the study is that governance failure not only affects formal project processes but also creates confusion among project role players, weakens accountability, and causes stakeholders to operate without a shared direction. Participants indicated that decisions are often made without consulting the broader project team, resulting in delays, conflicts, and uncertainty during project delivery. For example, Pr PM 3 noted that decisions made "on the spot without consulting the broader team" often create confusion later in the project. The study further found that poor governance contributes to uncontrolled scope changes, weak budget enforcement, cost escalations, and time overruns, as reflected in the views of Pr QS 3 and Pr CM 2. Another important finding is that poor governance damages stakeholder trust and collaboration, as unclear communication channels and undefined responsibilities cause clients, contractors, and consultants to work in silos and blame one another when problems arise. This was evident in the comments of Pr QS 1 and Pr ENG ELE 2, who highlighted the

absence of clear governance processes and structured governance plans. The study also found that weak governance compromises project quality and regulatory compliance because no single party is clearly accountable for monitoring standards, site practices, and compliance requirements

5. Conclusion

This study concludes that poor project governance has a significant negative impact on project performance in multi-stakeholder project environments, particularly through weak coordination, ineffective decision-making, unclear accountability, financial mismanagement, poor stakeholder collaboration, reduced trust, and compromised quality and regulatory compliance. The findings show that governance is not only an administrative function, but a critical mechanism for aligning stakeholders, controlling project resources, managing risks, and ensuring that project objectives are achieved. A key conclusion is that when governance structures are weak or poorly implemented, project participants often work in silos, decisions are made without sufficient consultation, and responsibilities become unclear, leading to delays, cost overruns, disputes, and reduced project outcomes. An alternative conclusion is that some governance failures may not result from the absence of governance frameworks alone, but from poor enforcement, weak leadership, limited stakeholder commitment, and contextual pressures within the project environment. Theoretically, the study contributes to project governance literature by showing that governance in multi-stakeholder projects should be understood as both a structural and relational process, where formal systems, accountability mechanisms, communication practices, and stakeholder trust interact to influence project success. Practically, the findings imply that project managers, clients, consultants, and contractors should strengthen governance processes by clearly defining roles, improving communication channels, enforcing financial controls, integrating quality assurance into governance systems, and ensuring inclusive decision-making throughout the project lifecycle. However, the findings should be interpreted within the study's parameters, as the data were drawn from stakeholder insights in a specific project environment and may therefore not be fully generalizable across all countries, sectors, professions, or project types. Future research should test these findings across sectors and with larger samples, while practitioners should prioritize governance frameworks that promote accountability, transparency, collaboration, and compliance to improve project delivery in complex, multi-stakeholder environments.

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CSR Implementation Strategies to Achieve Sustainable Business Performance of Large Contractors in the Western Cape Construction Sector

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Abstract

Corporate Social Responsibility (CSR) is becoming a critical constituent in influencing the long-term sustainable business performance of organisations across sectors. Despite CSR being a global driver of sustainable business, large contractors in the Western Cape Province of South Africa continue to face obstacles integrating CSR. In this research, CSR strategies that could be implemented by large contractors in the Western Cape Province, to achieve sustainable business performance were identified. A quantitative methodological approach was utilised with a structured online questionnaire survey. The research data was analysed using descriptive (percentages, mean, standard deviation, etc.) statistics. The sample population comprised of large construction enterprises registered with the Construction Industry Development Board (cidb) between Grade 7 and 9 under the General Building (GB) and/or Civil Engineering (CE) categories. CSR strategies such as promoting energy-efficient product development; Prioritising employee health and safety; Clear reporting on social and environmental performance alongside financial results, and collaborating within supply chains to ensure ethical and environmental standards are maintained throughout the project lifecycle; are among the top strategies that were highlighted. The findings of this study contributes to understanding the interplay between the CSR strategies and how it can strengthen the business resilience of large contractors in the Province, contributing to their sustainability and long-term business growth.

Keywords: Corporate Social Responsibility; Sustainable Business Performance; Large Contractors

1. Introduction

The construction industry is well established, contributing and impacting the economy, environmental development, and society (Zhang *et al.,* 2022). It promotes employment, creates jobs, and supports other organisations' economic endeavours, and influences the standard of living of people by constructing housing and infrastructure (Pearce, 2006). The construction industry is one of the biggest consumers of raw materials and waste generators, accounting for 25% of global CO^2 emissions and 38% when combined with building operations (Ecochain, 2026), including 35% solid waste globally (Balasbaneh *et al.,* 2025). Olanrewaju, (2025) adds that, with the continuous societal expectations, construction firms face a consistent pressure of being more aware of their environment and being socially responsible through their business activities, hence a need for these firms to be more sustainable. It should be noted that CSR, has in recent years begun to attract research interest in the construction industry. However, Ebekozien *et al*., (2024) indicate that there is a paucity of literature regarding the implementation of CSR in the construction sector. The World Business Council for Sustainable Development (2000) defines CSR as: "the commitment of business to contribute to sustainable economic development, working with employees, their families, the local communities and society at large to improve their quality of life".

The International Organisation for Standardisation (ISO) (2010) defines CSR more elaborately as the need for firms to operate ethically, transparently and make a contribution to the health and welfare of society by considering six core dimensions: (1) human rights; (2) environment; (3) labour practices; (4) consumer issues; (5) fair operating practices; and (6) community involvement and development. Considering these definitions the construction industry continues to struggle with a bad reputation for exploitation, and its negative impact on the communities and environments in which it operates, due to many activities causing pollution and environmental degradation (Mokwena, 2020). Notwithstanding the CSR implementation challenges, Nichols (2023) is of the opinion that there is a definite need to develop CSR strategies that can be employed by construction organisations, creating a sense of accountability towards environmental protection, efficient energy practices, use of sustainable materials, waste management and recycling, erosion control, employees' improvement, and community development, all of which can contribute to sustainable business performance. Wentzel *et al*., (2022) stated that

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CSR initiatives among other: Improves an organisations prestige; Increases the organisational ability to attract good and quality staff; Improves the organisations efficiency; Positively contributes to the credibility of the organisation, and improves the organisations corporate image and reputation with various stakeholders (employees, customers/clients, investors, government, suppliers and the community) all of which contributes to sustainable business performance. Despite some research on CSR conducted from a construction perspective in South Africa, very little research focuses on CSR strategies that large contractors can utilise in order to contribute to environmental, societal, and economic sustainability and also to improve their business sustainability trajectory. Hence the following research question and aim:

- What are the CSR strategies that should be implemented by large construction firms in the Western Cape Province of South Africa, to achieve sustainable business performance?

- The aim of this study was to establish CSR strategies that could be implemented by large contractors in the Western Cape Province, to improve their sustainable business performance.

A quantitative research method was adopted, utilising an online structured questionnaire, with the link to the questionnaire emailed to large contractors who are registered on the Construction Industry Development Board (cidb) register of contractors between Grade 7 and 9 under the General Building (GB) and/or Civil Engineering (CE) work categories, in the Western Cape Province. It should be noted that the distribution of the questionnaire was guided by voluntary response sampling McCombes (2023), and that data was analysed using only descriptive (percentages, mean, standard deviation, etc.) statistics. Limitations to the research consisted of the following:

- Time constraint - The study was conducted within the limited time restricting the depth of data collection.
- Sample size - The study was confined to specific numbers of large construction firms in the Western Cape Province.
- Research design limitation - The study adopted only a quantitative approach for the study, and
- Access to Information - Some firms were reluctant to disclose detailed internal CSR data.

The following CSR strategies such as promoting energy-efficient product development; Prioritising employee health and safety; Clear reporting on social and environmental performance alongside financial results and collaborating within supply chains to ensure ethical and environmental standards are maintained throughout the project lifecycle, contribute to closing this research gap. This assists large contractors not only achieve business operational sustainability but also impacts the environment and society where these businesses are housed and in so doing helps these businesses to balance profit and responsibility.

2. Literature review

2.1. Robust Environmental Stewardship and Sustainability Integration

A core element of CSR in the construction industry is its environmental responsibility to reduce resource consumption and waste production (Gurmu *et al*., 2022). Large construction firms need to prioritise strategies that minimise their environmental footprint. This includes the use of cleaner production methods, the development of energy-efficient products, and circular economy practices (Munir *et al.,* 2025). For example, reducing emissions, appropriate disposal of waste, and tapping into energy from renewable sources are important environmental initiatives (Tiganis *et al.,* 2025). Sustainability includes overall waste management and the use of sustainable materials (Munir *et al.,* 2025). Companies should strive to not only meet but surpass environmental regulations and be proactive, looking for innovative solutions to help solve environmental issues to reduce regulatory risks, lower costs, enhance reputation, and ensure resource resilience (Grytskov, 2020).

2.2. Comprehensive Employee Welfare and Development

A responsible attitude towards employees is another fundamental aspect of CSR and includes fair labour practices, safe workplaces, and training opportunities for professional growth (Tiganis *et al*., 2025). The nature of the construction industry, with its often-hazardous workplaces, makes it essential to put a high level of importance on health and safety (Zhang et al. 2022). This includes ensuring non-discriminatory hiring practices, acceptable working hours, and a supportive work culture that promotes peace, wellbeing and loyalty. In addition to basic welfare, investing in employee development, including training and skills enhancement programs, contributes to improved organisational resilience and overall organisational productivity (Ma *et al*., 2024). The higher the employee involvement rate and competency level, the better the quality of the project will be, and the more efficiently the organisation can operate, which is directly linked to sustainable performance (Zhang *et al.,* 2022; Sun *et al*., 2024).

2.3. Ethical Governance and Transparency in Operations.

Transparency and good corporate governance are necessary conditions for increasing the trust between stakeholders and securing accountability (Tyan *et al.,* 2025). Large construction companies should have strong governance in place to manage CSR initiatives

incorporating ethical decision-making processes into all business operations. This includes clear reporting on social and environmental performance alongside financial results (Jamaluddin *et al.*, 2023). This is becoming increasingly relevant within the CSR framework, and within the context of Construction 4.0, which suggests an integration of corporate digital responsibility (CDR) within the CSR (Weber-Lewerenz *et al*. 2025). Effective corporate governance together with a properly aligned organisational structure can have a real impact on an organisation's financial and social performance which strengthens compliance, reduces corruption resulting in overall sustainable business performance (Tyan *et al*., 2025).

2.4. Strategic Stakeholder Engagement and Collaboration.

The construction industry is a complex network involving clients, suppliers, local communities and regulatory bodies (Ma *et al.*, 2024). An effective CSR strategy necessitates the engaged interaction with these diverse groups, building good relationships that are underpinned by trust and working together for project success and sustainable development (Nguyen *et al*., 2025). This involves understanding and responding to the expectations and needs of stakeholders, which can be very different. (Zhang *et al*., 2021). Within the realm of sustainable supply chain management, collaboration is key to upholding ethical and environmental standards throughout the project's life cycle (Munir *et al*., 2025). Firms that engage their stakeholders are likely to have better implementation of CSR and are more aware of society's demands, which can lead to competitive advantages and reduced risks, and thereby enhance their sustainable business performance (Zhang *et al.,* 2023).

2.5. Innovation for Sustainable Development

Innovation is an essential factor for sustainable business performance in the construction sector. This includes promoting both technological and organisational innovation that supports CSR objectives (Hussain *et al.,* 2024). Sustainable innovation may take different forms; these may include the creation of designs that are energy efficient, the adoption of new construction technologies that reduce wastes or coming up with new business models that result in enhanced sustainability (Munir *et al.,* 2025). As an example, companies pursuing innovation as part of CSR initiatives are more likely to respond to changes in the market environment, to improve their competitive position, or overall sustainable business performance of the firm (Zheng *et al.,* 2022; Han *et al*., 2022).

2.6. Community Engagement and Social Contribution

In addition to their internal operations, large contractors have an obligation to get involved in giving back to communities where they conduct their operations. It includes community investment, community employment programs, and social impacts related to the construction process (Melo *et al.,* 2020). Such engagement builds goodwill, improves reputation and may lead to a social licence to operate, which is especially important for projects that may have substantial local impacts. (Nguyen *et al.,* 2025). Companies may undertake different types of philanthropic activities or invest in the development of local infrastructure or take part in social programmes that are beneficial to the population. This builds trust, enhances reputation and social equity, directly reinforcing the firms' sustainable business performance (Al-Swidi *et al*., 2024).

3. Research methodology

A quantitative methodological approach in the form of a structured online questionnaire survey was used, supported by a positivism philosophy and deductive reasoning. The justification for the research philosophy stems from the fact that positivism emphasises research through empirical observations and objective truths, which seeks to find laws and regularities that apply universally using systematic and quantitative methods (Zhang, 2024). The justification for deductive reasoning was that this is commonly used to validate or disapprove propositions according to empirical habits (Bryman, 2021), linking very well with the positivism philosophy and the quantitative methodological approach adopted. Positivism was appropriate for this study as it allowed the researcher, through the online questionnaire survey, to collect structured, quantifiable data that was analysed objectively. Deductive reasoning was employed because variables related to CSR strategies found in the literature were then tested in the context of this study, allowing for achieving of the research aim. The research population was 89 large contractors who are registered on the CIDB register of contractors between Grade 7 and 9 under the General Building (GB) and/or Civil Engineering (CE) work categories, in the Western Cape Province. The 89 questionnaires were distributed utilising the voluntary response sampling method as described by McCombes (2023). Thirty (30) large contractors indicated their willingness to participate and submitted the online questionnaire. Of the 30 who submitted the questionnaire, 3 were incomplete, therefore 27 completed questionnaires were analysed. The descriptive statistics were generated and reported to analyse the respondents' profile (percentiles, frequencies) and rank the CSR strategies that could be implemented by large contractors to achieve sustainable business performance (frequencies, standard deviation, and mean scores (MSs)). To analyse the data, the MS ranges were as follows: 1.00-1.75 (strongly disagree); 1.76-2.50 (disagree); 2.51-3.25 (agree); 3.26-4.00 (strongly agree). Standard deviation was also used to report the variability (how concentrated the data are around the mean) in ranking those items that have the same mean score (Neuman,

2011). Only the mean of the items was used to show the central tendency and to rank the CSR strategies in order of having the most effect to having the least effect.

4. Findings and discussion

The demographic information of the respondents is presented in Table 1 (Appendix 1). The data shows that 52% of the respondents are male, while 48% are female. While males still dominate as workers and business owners, more women are entering the sector and taking on ownership roles (CIDB, 2025). The data also indicates that all respondents occupy senior level positions, and that most of the respondents have obtained higher education training in the construction field.

4.1. CSR Strategies that could be implemented by large construction firms to achieve sustainable business performance

From analysing the descriptive data in Table 2 (Appendix 1), it is evident that 4 variables listed have MS values between 3.26 and 4.00 (strongly agree), and the 16 remaining variables MS values between 2.51 and 3.25 (agree) indicating that large contractors in general agree with the value of the CSR strategies listed. The top two MS values related to "Robust Environmental Stewardship and Sustainability Integration" shows that large contractors strongly agree with the CSR strategy to "Promote energy-efficient product development" as it is ranked the highest (MS = 3.33); followed by the CSR strategy to "Implement circular economy practices" (MS = 3.22) as highlighted by (Munir *et al.,* 2025; Grytskov, 2020) to reduce regulatory risks, lower costs, enhance reputation, and ensure resource resilience. This agrees with the ISO 14001 principle and reflects the standards of global sustainability (KPMG, 2023).

With reference to "Comprehensive Employee Welfare and Development", the results suggest the top ranked CSR strategy in this section is to "Prioritise employee health and safety to a high degree" (MS = 3.37) as stated by Zhang *et al.* (2022); followed by the strategy to "Ensure employee non-discriminatory hiring practices" (MS = 3.22) described by (Zhang *et al*. 2022; Ma *et al*. 2024) that the higher the employee involvement rate and competency level, the better the quality of the project, and the more efficiently the organisation can operate. This is supported by Loosemore and Lim (2018), who stated that social responsibility and transparency improve workforce motivation and a credit to firms.

Data relating to "Ethical Governance and Transparency in Operations" clearly illustrates the CSR strategies to "Include clear reporting on social and environmental performance alongside financial results" and "Building strong relationships with stakeholders based on trust and collaboration for project success and sustainable development" both having the same (MS = 3.22 and SD = 0.58) values, which is supported by Tyan *et al*., (2025) stating that this strengthens compliance, reduces corruption resulting in overall sustainable business performance. Ali (2023) also supports this indicating that there is a need to adopt good governance processes that manage CSR activities and demonstrate the incorporation of ethics in all business practices.

Interpreting the data related to "Strategic Stakeholder Engagement and Collaboration" shows that large contractors regard the CSR strategies to "Collaborate within supply chains to ensure ethical and environmental standards are maintained throughout the project lifecycle" as the highest ranked strategies having a (MS of 3.26). This is supported by Zhang *et al.,* (2023) as leading to competitive advantages and reducing risks thereby enhancing sustainable business performance. Oyewobi *et al*. (2022), concur with this stating that innovation and stakeholders play an important role in achieving sustainable competitiveness in the construction industry.

The top MS score relating to "Innovation for Sustainable Development" shows that large contractors regard the CSR strategies to "Adopt advanced construction technologies that reduce waste" as the highest ranked strategy having a (MS of 3.26) and opined by (Zheng *et al.,* 2022; Han *et al*., 2022) that companies pursuing innovation as part of CSR initiatives are more likely to respond to changes in the market environment, to improve their competitive position, and overall sustainable business performance of the firm.

Lastly when interpreting the data for "Community Engagement and Social Contribution" it is apparent that the top ranked CSR strategy in this section is to "Contribute positively to local employment initiatives where they operate" (MS = 3.22). This finding is supported by Melo *et al*., (2020) who is of the view that large construction firms should get involved in giving back to communities where they conduct their operations. Hence this builds trust, enhances reputation and social equity and directly reinforcing the firms' sustainable business performance (Al-Swidi *et al*., 2024)

5. Conclusion and recommendations for further research

This research set out to establish CSR strategies that could be implemented by large construction firms in the Western Cape Province of South Africa, to improve sustainable business performance. The study was motivated by a continuous struggle in the construction industry related to its bad reputation for exploitation, and its negative impact on the communities and environments due to activities causing pollution and environmental degradation, all of which not just affects

the environment, society, and the economy but also the sustainable business performance of construction organisations. A quantitative methodological approach in the form of a structured online questionnaire was utilised to gather data from large contractors who are registered on the CIDB register of contractors between Grade 7 and 9 under the General Building (GB) and/or Civil Engineering (CE) work categories, in the Western Cape Province.

The main finding in the research indicated the following CSR strategies that could be utilised by large contractors to achieve sustainable business: Promote energy-efficient product development; Prioritise employee health and safety to a high degree; Include clear reporting on social and environmental performance alongside financial results; Collaborate within supply chains to ensure ethical and environmental standards are maintained throughout the project lifecycle; Adopt advanced construction technologies that reduce waste, and Contribute positively to local employment initiatives where they operate. Limitations to the research consist of the following: the study was conducted within the limited time restricting the depth of data collection and confined to specific numbers of large construction firms in the Western Cape Province, only a quantitative approach for the study was used, and the research sample being small.

The following are recommendations of this study in line with the CSR strategies highlighted:

- Strengthen managerial awareness through training mechanisms to minimise resistance and increase CSR literacy across the various levels of the organisation, and
- Develop measurable CSR performance indicators to monitor and continuously improve CSR performance.

Based on the relatively small sample size:

- Future research may be extended to other South African provinces to facilitate comparative analysis of CSR practices and sustainability outcomes in different regional and regulatory contexts.
- A mixed-methods or qualitative research approach can be used to obtain in-depth information, regarding the CSR strategies identified in this study as well as to better understand the attitude of managers, cultural factors, and organisational dynamics affecting CSR integration.
- Future research should examine policy and institutional frameworks, in terms of how government regulations, industry bodies and professional councils influence CSR compliance and outcomes.

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Appendix 1

Table 1: Respondents Demographic Information

S/N	Variable	Category	Frequency	(%)
1	**Gender**	Male	14	52%
		Female	13	48%
	TOTAL		**27**	**100%**
2	**Age Bracket**	20 - 30 years	2	7%
		31 - 40 years	10	37%
		41 - 50 years	6	22%
		51 - 65 years	9	34%
	TOTAL		**27**	**100%**
3	**Designation**	Owner	2	7%
		Chief Executive Officer	5	19%
		Chief Operating Officer	7	26%
		Chief Financial Officer	7	26%
		Director	6	22%
	TOTAL		**27**	**100%**
4		ND in Building & Civil Engineering	4	15%

S/N	Variable	Category	Frequency	(%)
	Construction-related Education & Training	Degree in Civil Engineering	4	15%
		Degree in Construction Management	3	11%
		Degree in Quantity Surveying	3	11%
		Master's in project management	3	11%
		Degree in Architecture	2	7%
		PhD in Construction Management	1	4%
		Others (Business, IT, Electrical & Mechanical)	7	26%
	TOTAL		**27**	**100%**
5	**CIDB Class of Work**	General Building (GB)	15	56%
		Civil Engineering (CE)	9	33%
		Both (GB & CE)	3	11%
	TOTAL		**27**	**100%**
6	**CIDB Grade**	Grade 7	8	30%
		Grade 8	9	33%
		Grade 9	10	37%
	TOTAL		**27**	**100%**

Table 2: CSR Strategies that could be implemented by large construction firms to achieve sustainable business performance.

	Variables	**Response %**				**Mean**	**Std. Dev.**	**Rank**
		Strongly Disagree	**Disagree**	**Agree**	**Strongly Agree**			
		1	**2**	**3**	**4**			
Robust Environmental Stewardship and Sustainability Integration								
1	Promote energy-efficient product development	4%	0%	56%	41%	3.33	0.68	1
2	Implement circular economy practices.	0%	4%	70%	26%	3.22	0.51	2
3	Prioritise adopting cleaner production methods	0%	7%	63%	30%	3.22	0.58	3
4	Firms should aim to seeking innovative solutions to environmental challenges	0%	11%	59%	30%	3.19	0.62	4
Comprehensive Employee Welfare and Development								
1	Prioritise employee health and safety to a high degree	0%	11%	41%	48%	3.37	0.69	1
2	Ensure employee non-discriminatory hiring practices	0%	11%	56%	33%	3.22	0.64	2
3	Employ fair working hours, and create a supportive work culture that fosters employees' well-being and loyalty	0%	15%	48%	37%	3.22	0.70	3
4	Invest in employees' development through training and skill enhancement programs	4%	11%	52%	33%	3.15	0.77	4
Ethical Governance and Transparency in Operations								
1	Include clear reporting on social and	0%	7%	63%	30%	3.22	0.58	1

Variables		Response %				Mean	Std. Dev.	Rank
		Strongly Disagree	Disagree	Agree	Strongly Agree			
		1	2	3	4			
	environmental performance alongside financial results							
2	Building strong relationships with stakeholders based on trust and collaboration for project success and sustainable development	0%	7%	63%	30%	3.22	0.58	1
3	Implement robust governance structures that oversee CSR initiatives and integrate ethical decision-making into all business processes	0%	19%	48%	33%	3.15	0.72	2
4	Integrate corporate digital responsibility (CDR) within the broader CSR framework	4%	7%	59%	30%	3.15	0.72	2
Strategic Stakeholder Engagement and Collaboration								
1	Collaborate within supply chains to ensure ethical and environmental standards are maintained throughout the project lifecycle	0%	4%	67%	30%	3.26	0.53	1
2	Build strong relationships with stakeholders through understanding and responding to their expectations and needs	0%	4%	70%	26%	3.22	0.51	2
Innovation for Sustainable Development								
1	Adopt advanced construction technologies that reduce waste	0%	4%	67%	30%	3.26	0.53	1
2	Pioneer new business models that promote sustainability	0%	11%	59%	30%	3.19	0.62	2
3	Foster both technological and organizational innovation that supports CSR objectives	0%	7%	70%	22%	3.15	0.53	3
4	Foster sustainable innovation through developing energy-efficient designs	4%	7%	59%	30%	3.15	0.72	4
Community Engagement and Social Contribution								
1	Contribute positively to local employment	4%	4%	59%	33%	3.22	0.70	1

Variables		Response %				Mean	Std. Dev.	Rank
		Strongly Disagree	Disagree	Agree	Strongly Agree			
		1	2	3	4			
	initiatives where they operate							
2	Address social impacts arising from construction activities	0%	11%	59%	30%	3.19	0.62	2

Operational, financial and policy constraints limiting emerging property developers' participation in affordable housing delivery in Polokwane Municipality

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Abstract

Robust emerging property developers are an important step towards dealing with housing shortages and promoting more inclusive housing development in secondary cities in South Africa. However, the participation of this sector is limited by ongoing operational, financial and institutional problems. This paper aims to uncover the operational, financial, and policy-related barriers that limit the ability of emerging property developers in Polokwane Municipality from participating effectively in affordable housing delivery. This will make it possible to recommend possible solutions for enhancing their participation. The qualitative research design was adopted, relying on semi-structured interviews with 15 emerging property developers from the Polokwane Municipality. Purposive sampling was used to select information-rich participants with experience of the development of affordable housing and of the regulatory, financial, and operational context under investigation. Thematic analysis was used to analyse the data. The results indicate that there are three sets of challenges: structural and operational, financial exclusion, and weak policy implementation. Major challenges include slow administrative processes, lack of access to serviced land, inadequate infrastructure, high collateral requirements, difficult loan conditions, and uneven application of existing policies. Due to these challenges, project costs and timelines are negatively affected and this limits the competitiveness and sustainability of emerging developers. The qualitative nature of the study and the focus on only one municipality constitute a major limitation in terms of generalisability. This research contributes to literature on the provision of affordable housing by revealing the interconnectedness of operational, financial, and policy constraints, highlighting the need for coordinated policy interventions ass opposed to isolated initiatives.

Keywords: Emerging property deveopers, affordable housing; operational challenges, financial constraints.

1. Introduction

The property development sector is recognised as the centrepiece of national economies as it spurs employment creation, economic growth and the provision of much needed housing and urban infrastructure (Amos et al., 2025; Haagenson, 2025). In this context, new property developers, defined as small to mid-size or historically marginalized firms that are relatively new to the market, are increasingly seen as important players in affordable housing delivery (Lehner & Heiss, 2024). Nonetheless, despite their strategic importance, these developers also face structural, financial, and regulatory barriers that consistently limit their participation and long-term sustainability (Ozigbo et al., 2023).

South Africa is an acute example of these tensions. Decades after the transition to democracy the country still face a huge housing backlog, spatial inequality, and the unresolved legacies of apartheid urban planning (Property Review, 2025). These issues are most acute in secondary cities, where growing urbanisation pressures is occurring at the same time with limited institutional capacity and inadequate investment in infrastructure. The Polokwane Municipality, Limpopo Province's administrative capital, bears the brunt of this challenge. Recently, the municipality has obtained Level 2 housing implementation accreditation which gives it increased delegation to plan, budget, appoint contractors and manage housing projects (Polokwane Municipality, 2025). Nonetheless, systemic challenges continue to plague the city.

Three related domains of constraints that are particularly disadvantageous to emerging developers have been identified in the literature. These are operational and structural barriers, financial access constraints, and policy and governance problems (Buthelezi, 2025; Dlamini, 2022; Githae et al., 2024; Kgaka, 2020; Theodos et al., 2025). While similar constraints have been noted in international scholarship in countries such as the UK, Ghana, and India, empirical research that clarifies specific operational, financial, and policy challenge facing developers in South African secondary cities, and the intersections thereof, is limited. Previous research has generally addressed metropolitan cities, or has seen housing provision via the state's housing programs rather than the perspective of individual emerging private

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developers. This is an important gap in knowledge that the current study seeks to fill. Within this context, this paper seeks to explore the operational, financial and policy challenges that are constraining the involvement by emerging property developers in the provision of affordable housing in the Polokwane Municipality.

2. Literature Review

2.1. Barriers to Entry, Market Structure, and Competitive Disadvantage

The literature consistently identifies barriers to entry as the most persistent structural challenge facing new property developers globally. A key driver is the mismatch between development timelines and holding costs: developers unable to sustain holding costs through extended approval and servicing processes are pushed toward higher-risk, marginal sites (Amos et al., 2025; Theodos et al., 2025). Large and institutional developers maintain their competitive advantage mainly through control of land banks, which enable staged rollout, optimised pricing, and stronger bargaining power with suppliers and municipalities, advantages inaccessible to undercapitalised emerging developers (Mokoele, 2023; Musvoto et al., 2021). In South Africa, this dynamic is compounded by historical land dispossession, which produced racially skewed ownership patterns that continue to disadvantage historically marginalised groups, who make up a significant share of new entrants (Musvoto et al., 2021).

2.2. Institutional and bureaucratic constraints

Institutional and bureaucratic constraints are a prominent theme across both global and South African literature on emerging developers. Municipal approval processes are described as overlapping, sequential, and discretionary systems that produce unpredictable outcomes for applicants (Githae et al., 2024). In South Africa, SPLUMA compounded this by devolving first-instance decision-making power to municipalities without matching institutional resources, producing lengthy, uncertain approval timelines and prolonged holding periods for developers (Heukelman & Cillier, 2025). The HSRC's (2022) municipal capacity assessment confirms severe shortages of urban planners, engineering reviewers, and land-use management specialists within municipal structures nationally. Mabasa et al. (2023) further highlight inconsistent discretionary enforcement as especially damaging: identical development proposals can receive different outcomes from different officials within the same municipality, generating serious regulatory risk and undermining developer confidence in the planning system as a whole.

2.3. Financial Exclusion and Access to Capital

Financial exclusion is presented as the most debilitating, and most widely discussed, constraint facing emerging property developers. Kgaka (2020) identifies high collateral requirements, risk-averse lending policies, and a lack of financial products suited to small-project cash-flow cycles as the primary mechanisms of exclusion, a finding echoed by Chiwetu's (2019) Johannesburg-based research showing that completion-value loan criteria disadvantage developers without existing asset portfolios. At a global scale, the IFC (2024) frames this as a financing gap rooted not only in risk perception but in genuine product-design failures within formal financial markets. Development finance instruments intended to close this gap, such as those offered by the DBSA and government transformation programmes, are undermined in practice by complex application processes, long waiting periods, and eligibility criteria that favour applicants with existing businesses (Theodos et al., 2025; Hassen, 2023). The consequences compound rather than remain isolated: limited financing access pushes developers into fixed-price contracts poorly equipped to absorb rising input costs (Radzi et al., 2022; NAHB, 2024; World Bank, 2024), while resulting cash-flow strain drives quality and schedule failures that further damage credit histories (Kgaka, 2020). This cycle suggests financial exclusion reflects systemic design rather than developer capability or creditworthiness.

2.4. Policy and Regulatory Frameworks: Intent, Implementation, and the Equity Gap

The literature consistently identifies a gap between the intent and implementation of housing and property policy. South Africa's legislative framework, SPLUMA, the Housing Act, NHBRC requirements, and transformation-oriented procurement laws, is regarded as progressive in design but weak in execution, as ambitious national policies are promulgated without corresponding investment in municipal capacity, intergovernmental coordination, or accountability (Dlamini, 2022; Heukelman & Cillier, 2025; Todes & Malaza, 2023). Mokoele (2023) shows this implementation gap plays out locally, where limited capacity combines with political-economy dynamics to produce inconsistent, inequitable policy application. SALGA's (2022) ease-of-doing-business assessments confirm that lower-capacity municipalities apply regulations less consistently, disadvantaging developers who lack the institutional relationships needed to navigate discretionary systems, a pattern echoed internationally by the OECD (2024), which finds regulatory discretion can entrench incumbents in concentrated markets. The literature also debates the effectiveness of transformation-oriented procurement, such as B-BBEE provisions: proponents argue these measures create demand-side market access for marginalised developers (Sebake & Sekese, 2020), while critics contend benefits are often captured by nominally compliant fronts for established capital (Kgaka, 2020; Viljoen, 2025). This tension between supply-side capacity-building and demand-side access

reflects an emerging consensus that neither approach alone is sufficient (Mabasa et al., 2023; Smit, 2022).

2.5. Research gaps

Synthesising the literature reveals three research gaps that this study is positioned to address. First, while individual constraints, financial exclusion, bureaucratic delay, and policy failure, are well documented in isolation, their systemic interdependence remains under-theorised: structural barriers generate holding costs that financial exclusion prevents developers from absorbing, while policy failures simultaneously block access to the support mechanisms that might otherwise compensate. Second, existing research concentrates heavily on metropolitan or international contexts, leaving South Africa's secondary cities, with their distinct combination of governance capacity, market depth, and infrastructure constraints, largely unexamined. Third, most studies foreground government and institutional framings of supply-side housing delivery, leaving the developer's own lived perspective underrepresented. By centring the experiences of emerging developers in a particular secondary city, this study addresses these gaps and aims to inform evidence-based policy and institutional reform.

3. Research Methodology

This research takes an exploratory qualitative case study approach framed within an interpretivist research philosophy. The decision to pursue qualitative research aligns with the desire to gain an understanding of the lived experiences, perceptions, and coping mechanisms of the new property developers, which are all inherently contextual, and not quantifiably measurable (Saunders, Lewis & Thornhill, 2020). The research design employed an inductive logic, with themes and explanations emerging from participants' narratives as opposed to being driven by abstract propositions (Reid, 2024).

The bounded case for this research was the Polokwane Municipality, specifically chosen for being a growing secondary city, with a recent expansion of its housing mandate, an emerging developer community that is active but not effective, and a public discourse on governance and affordability challenges. The primary data was collected through semi-structured interviews with 15 emerging property developers active in the municipality. Purposive sampling was used to ensure participants had direct, relevant experience in the property development process and institutional context under investigation (De Jonckheere & Vaughn, 2019). The sample consisted of 11 male and 4 female developers, and varied experience from very new operators to those who had been active developing for almost 10 years. With permission, interviews were audio-recorded, transcribed verbatim, and complemented by researcher notes.

Data were analysed using thematic analysis, employing the six-phase framework developed by Braun and Clarke (2019). These included getting familiar with the data, generating initial codes, identifying themes, reviewing potential themes, defining and naming themes, and producing the report. Direct quotes from participants were integrated into analyses to support and exemplify themes that emerged.

4. Findings and Discussion

Three overarching themes were identified; structural and operational challenges; financial constraints and access to capital; and effectiveness of the policy, legislative and regulatory framework. A consolidated overview of themes, sub-themes, and key findings is provided in Table 1 (Appendix 1).

4.1. Theme 1: Structural and operational challenges

Structural and operational barriers emerged as the most widespread category of constraint, spanning four compounding sub-themes: bureaucratic delays, limited land access, infrastructure deficits, and shortfalls in technical and managerial capacity. Participants reported that rezoning and building-plan approvals typically took one to three years, creating bottlenecks across multiple departments and accruing holding and financing costs beyond what is economically feasible, consistent with Buthelezi (2025) and Githae et al. (2024), who found South Africa's planning system disproportionately burdens smaller developers with compliance costs. In Polokwane specifically, SPLUMA's devolution of first-instance decision authority was not matched by investment in planning personnel or administrative systems, producing an uncertain, disjointed approval environment; this study extends metropolitan-focused knowledge by evidencing how acutely these dynamics play out in a secondary city.

These delays were compounded by land access and infrastructure constraints. Without proactive municipal land release, emerging developers must compete against better-capitalised incumbents holding portfolios of serviced, consented land, a concentration Anim-Odane (2022) and the IFC (2024) identify as a primary barrier to entry. Infrastructure deficits reinforced this: participants noted that even where permits were secured, development remained impossible without bulk water, electricity, or road access, reflecting the reactive, demand-responsive infrastructure planning documented by Todes and Malaza (2023), which disadvantages developers unable to wait for municipal service extension.

A lack of managerial expertise was a further structural challenge, as developers could not afford professional experts such as quantity surveyors, legal counsel, urban

planners, undermining financial modelling, regulatory compliance, and project oversight. Hassen (2023) and Kgaka (2020) attribute this to a structural feedback loop in which capacity gaps limit access to formal finance, which in turn prevents developers from retaining the professional expertise needed to produce the credible feasibility documentation lenders require.

4.2. Theme 2: Financial constraints and access to capital

Financial exclusion was identified as the single most debilitating theme, and operates as both a separate barrier as well as an amplifier of structural constraints. Commercial banks consistently classify emerging developers as high-risk borrowers who require collateral, track record, and documentation that new entrants would structurally never be able to provide. This has resulted in a financing paradox whereby institutions will only fund bulk infrastructure on serviced land and developers cannot service any land without capital up front. This challenge was highlighted by participants as one of the most flagrant product design failures in the development finance market in South Africa. While this dynamic has been theorized by Theodos et al. (2025) and the IFC (2024), this study provides primary empirical evidence of how it plays out in a secondary city context, a rarity. Viruly and Karam (2022) also point out that the reliance on collateral has the effect of systematically excluding previously disadvantaged developers who do not have a portfolio of assets to inherit. This dynamic has particular relevance in Polokwane where the racially produced inequality of wealth continues to have a direct bearing on people's ability to access development finance.

Government-supported funding instruments like the National Housing Finance Corporation (NHFC), DBSA and Human Settlements Development Grant (HSDG) were perceived by participants as not offering better solutions. Application processes were described as prohibitively difficult, processing times as lengthy and opaque, and selection outcomes as tending to favour those with political connections or established developers and projects rather than genuinely emergent ones. These results align with the work of Musvoto et al. (2021) and the Centre for Affordable Housing Finance in Africa (CAHF, 2023) which report on systematic underutilisation of formal development financing instruments by early stage developers throughout South Africa. The overall impact is a dependence on individual savings and informal financing, a condition that not only limits the scale and profitability of projects but also places developers at great personal financial risk. Importantly, this reframes financial exclusion not as a borrower-capability problem that developer training would solve, but rather a structural market failure that is based on the design of financial products that serve the needs of large, asset-rich borrowers rather than small project-based developers.

4.3. Theme 3: Effectiveness of Policy, Legislative, and Regulatory Frameworks

The policy and governance findings present what emerges as the most analytically significant pattern of the study; that South Africa's progressive legal framework is being effectively neutralised at the level of implementation. SPLUMA and policies related to human settlements were described by participants as being persistently disconnected from what they were intended to achieve. This experience is a direct manifestation of the structural implementation gap. This gap was also noted by Heukelman and Cillier (2025) and Dlamini (2022) who described it as being rooted in fragmented cooperative governance arrangements where expanded national-level commitments are devolved to municipalities without the requisite administrative capacity, inter-governmental coordination, or accountability mechanisms. According to participants, the municipality and COGHSTA consistently blame each other for problems faced. This results in applications being held indefinitely. The finding is consistent with those of Moffat et al. (2021) who found the persistent overlap of mandates in multiple spheres as a significant factor in delaying development approvals in South African local government.

Corruption and lack of transparency in procurement was another form of policy failure that is particularly damaging. Participants described politically awarded tenders, awards that do not comply with procurement rules, bribery, and evaluation criteria that are not clearly laid out as a norm in the municipality. These issues have the effect of leading development contracts in the public sector toward incumbents with political contacts rather than other worthy developers. These accounts are substantiated by Auditor General reports 2020-2023 detailing persistent MFMA contraventions and irregular expenditure within South African municipalities. Furthermore, Heukelman and Cillier (2025) argued that this sort of governance failure results in conditions that actively discourage rightful, legitimate market participation by creating spaces where compliance with the rules and merit are not reliable markers of success. For emerging developers, already facing the double bind of administering complex processes and being financially excluded from public sector support, procurement processes being seen as captured is another structural barrier that undermines any confidence in the public sector as an institutional supporter.

4.4. Systemic Interdependence: The Central Analytical Contribution

The main contribution of this study's findings is in asserting that the three constraint themes are not autonomous but represent a network of cumulative disadvantage. The structural and operational barriers create costs and delays that financially excluded developers cannot absorb. Financial barriers prevent

developers from retaining the professional capacity and accessing the serviced land needed to navigate structural constraints. Policies and governance failures withhold access to the regulatory streamlining, institutionally-derived finance, and equitable procurement that may otherwise offset these disadvantages. This systemic reliance has a direct implication for policy design: single-domain interventions-regulatory reform without financial support, financial instruments without capacity building, or governance reform without administrative resourcing-are insufficient. It is critical for interventions to deal with all three constraint domains simultaneously and in an integrated fashion, targeting the feedback loops between them rather than each barrier in isolation. his integrated framing is the principal conceptual contribution of the present study, and departs from existing literature, which has treated operational, financial, and governance constraints as separate rather than structurally interconnected constraints.

5. Conclusion and Further Research

This study explored the operational, financial, and policy constraints that restrict emerging property developers' involvement in the production of affordable housing in Polokwane Municipality. It uncovered three linked sets of constraints: structural and operational impediments financial obstacles and governance issues. The study also reveals the interconnected nature of these barriers. This means that interventions in one single area in isolation will not yield significant progress. Future studies should employ mixed-method approaches and should include a number of secondary cities. In these studies, alternative financing instruments and long-term developer support mechanisms should be explored.

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Appendix 1

Table 1: Themes, sub-themes, and summary of findings

Theme	Sub-theme	Key Findings
Theme 1: Structural and operational challenges	1.1 Bureaucratic delays and regulatory bottlenecks	Rezoning and building-plan approvals take months to years, and multi-department review sequences create bottlenecks on a schedule. Respondents indicated that even simple decisions took 1-3 years, increasing both holding and financing costs and negatively impacting investor confidence.
	1.2 Limited access to land and tenure security	The overall cost of serviced land in a desirable location was repeatedly cited by participants as a disincentive. The limited supply of small sites through municipal releases coupled with insecurity of tenure pushes the new developers onto less viable development sites.
	1.3 Infrastructure deficits	Poor bulk infrastructure, including intermittent water supply, electricity shortages and poor road access also emerged as a key driver of development costs. Participants shared examples of obtaining land and use approvals, but being unable to develop because of missing infrastructure.
	1.4 Lack of technical and managerial capacity	Emerging developers reported significant deficits in project management, development feasibility assessment, financial modelling, and regulatory compliance skills. The inability to afford professional support services (legal advisors, quantity surveyors, urban planners) compounds these gaps and limits access to formal finance, as lenders require credible feasibility studies and risk management plans.
Theme 2: Financial constraints and access to capital	2.1 Limited access to affordable credit and unfavourable loan terms	Participants reported that formal financial institutions categorised emerging developers as high-risk borrowers, demanding collateral and track records that most new entrants do not possess. High interest rates, short repayment periods, and the absence of grace periods make loan servicing unaffordable during early project phases when no income is yet generated; a 'chicken-and-egg' financing constraint.
	2.2 Inadequate institutional support	Government financing instruments such as the NHFC, DBSA, and the Human Settlements Development Grant (HSDG) were widely seen as inaccessible due to complicated application procedures, long processing times, and criteria that favoured established or politically connected developers. The majority cited reliance on personal savings or informal finance, which severely limited both the scale of projects and increased personal financial risk.
Theme 3: Effectiveness of policy, legislative, and regulatory frameworks	3.1 Weak implementation and poor institutional coordination	Although the legislative structure is purported to be progressive (SPLUMA, Housing Act, municipal by-laws), respondents detailed a disconnect between legislative intention and practice. The municipality's lack of effective coordination with other tiers of government (primarily COGHSTA) resulted in jurisdictional ambiguity, blame-shifting, and indefinitely stalled applications. Regulatory bias toward established developers was a common concern.
	3.2 Corruption and lack of transparency in tendering	Among the narratives participants shared were politically compromised tender awards, procurement procedure noncompliance, bribery, and the opaque nature of project evaluation in Polokwane's built environment procurement landscape. If municipal contracts are perceived to have been captured by politically connected developers, then legitimate emerging developers will avoid public- sector opportunities and lose confidence in institutional backing.

Source: Primary Data

Improving skills deployment in mega or large complex projects

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Abstract

This study examines how skilled project resources are deployed on mega- and large-scale complex infrastructure projects, with a focus on South African state-owned entities (SOEs). It seeks to assess the contribution of skilled resources to project performance in large, complex infrastructure utility projects. Although existing project management frameworks offer guidance on processes and leadership competencies, they provide limited direction on how skills, competencies, and roles should be configured within temporary project organisations. To address this gap, the study employs a structured content analysis of secondary data, including recent peer-reviewed literature and industry reports, using both deductive and inductive coding techniques. The findings reveal recurring challenges, notably skills misalignment, unclear role definition, and inadequate resource planning. These insights inform the development of a conceptual competency-based framework that links project classification with required capabilities, competencies, roles, and organisational structures. The study contributes to theory by advancing the operationalisation of resource configuration in complex project environments, and to practice by offering a structured approach for aligning skilled resources to improve project performance in South African SOEs.

Keywords: Mega projects, Large Complex projects, Competence, Capabilities, Skills, Project structures.

1. Introduction

There is an extensive body of literature on project management and organisational design in projects. Despite this breadth, many project-oriented organisations tend to adopt similar approaches in practice. In both South Africa and internationally, a significant number of organisations align their methodologies with the Project Management Body of Knowledge (PMBOK), which represents the dominant framework advocated by the Project Management Institute (PMI). This widespread alignment reflects the influence of standardised project management practices. Despite the widespread use of frameworks such as PMBOK, current approaches focus on high-level organisational structures (functional, matrix, projectised) and do not provide sufficient guidance on how to configure project teams in terms of roles, competencies, and skills. When dealing with mega or large complex infrastructure projects, a project manager alone cannot execute them. This raises the question of what support resources a project manager needs to successfully manage and integrate such projects.

Mega projects are typically defined as large-scale, complex projects exceeding US$1 billion, involving multiple stakeholders and extended timeframes. Large complex infrastructure projects are characterised by scale, interdependencies, and organisational complexity. Project management literature primarily focuses on the project manager's skills and explains when resource planning should occur, but it does not explain how to determine the optimal configuration of project teams in terms of roles, skills, and competencies.

2. Literature Review

A structured synthesis of the literature reveals four key themes, namely, resource configuration, skills alignment, capability requirements and organisational structure. The literature consistently highlights that while skills and competencies are recognised as critical, there is limited guidance on how they should be structured and deployed within project organisations.

2.1. Theoretical Foundations

- HCT positions knowledge and education as assets that will ensure contribution to project performance but does not specify how skills should be configured into project roles within temporary organisations.
- RBV explains the competitive advantage of skills at organisational level but does not allude to project team structures, which are inherently temporary.
- PMBOK is used internationally for process standards and guidance on good practice in project management but does not provide structured design or competency modelling.
- Systems theory provides a lens for interconnection and complexity but does not support a skill or competency-based staffing model.
- SMT provides detail on labour market inefficiencies and shortages concerned with

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economic supply and demand of skills in a country but does not support any form of organisational design.

Collectively, these theories highlight the importance of skills but do not provide mechanisms for translating competencies into project roles.

2.2. Determine the optimum number and type of resources required to execute a mega or large complex infrastructure projects.

Traditional resource planning methods include expert judgement, bottom-up estimation, and analytical techniques. However, these methods often lack reliability due to the uniqueness and scale of such projects (Watt, 2014). Front-end planning (FEP) is widely recognised as a critical phase where resource decisions must be made. Poor planning during this phase often leads to inadequate skill deployment, resulting in project delays or failure (Babaei, Locatelli & Sainati, 2021). Approximately 39% of project failures are attributable to insufficient or misallocated resources (Bhika, 2017), and only 16% of crisis-managed projects succeed (Merrow, 2024).

Mega projects operate as complex systems that require the integration of multiple stakeholders, disciplines, and contracting arrangements, such as EPC and EPCM models, each of which demands distinct skill sets and resource configurations (Winch, Sergeeva & Lowe, 2023). The inability to plan for these variations results in frequent project disruptions, including suspensions to secure additional resources (Juarez Cornelio, Sainati & Locatelli, 2023). "Projectification" is an approach that has led to many new projects being assigned to teams rather than individuals, and therefore, specific skilled resources are required to support this shift. (Wagner, Huemann & Radujkovic, 2021). Additionally, resource planning is often influenced by organisational and portfolio-level decisions rather than project-specific requirements, leading to suboptimal allocation within individual projects (Stordy, Zerjav & Kanjanabootra, 2021). This highlights a critical gap in the linkage between macro-level resource planning and micro-level project execution needs. Part of the observations was also that skills shortages exacerbate the problem due to a poor educational system in South Africa. State-Owned Enterprises (SOEs) in South Africa are also experiencing brain drain and loss of tacit knowledge, leading to skills shortages and high staff turnover (Bhika, 2017).

2.3. Examine the alignment of specific skills required to execute mega or large complex infrastructure utility projects

The alignment between skills, roles, and project requirements is widely recognised as a key determinant of project success. Mega or large complex projects require a combination of technical, managerial, and behavioural competencies, all of which must be aligned with specific project roles (Khan, 2018). A clear understanding of the various activities and capabilities that need to be managed is necessary. This should then be supported entirely by a specifically designed organisational structure for the project rather than focused on project complexity, team cooperation and communication (Cristóbal, Fernández & Diaz, 2018). The complexity of these projects necessitates interdisciplinary teams in which technical expertise is integrated with communication, collaboration, and leadership skills (Daniel et al., 2023). However, literature indicates that while competencies are frequently identified, they are rarely mapped to specific roles within project organisations (Moradi, Kähkönen & Aaltonen, 2020). Skills mismatches are particularly prevalent in developing countries, where shortages of critical engineering and management skills result in misaligned project teams and reduced performance (Bhika, 2017). Furthermore, project managers often lack competencies across technical, socio-economic, and adaptive domains, which significantly impacts project outcomes (Damayanti, Hartono & Wijaya, 2021).

Leadership and organisational culture also play a crucial role in aligning skills within project teams. Poor role definition, ineffective communication, and lack of team cohesion are identified as major contributors to project failure (Denicol, Davies & Pryke, 2021). Project-oriented organisations must develop the capability to respond to instability, adapt to change, and realign structures and processes while maintaining effective skill deployment. This is referred to as organisational resilience (Wang, Zhao & Zhang, 2022). The literature also highlights the increasing importance of organisational resilience, where project teams must adapt to dynamic changes while maintaining alignment of skills and capabilities (Wang, Zhao & Zhang, 2022).

Despite strong agreement on the importance of skills alignment, there remains limited guidance on how to operationalise the alignment between skills, roles, and competencies within project structures. Skills development and alignment must be built into the fabric of the project organisation and the project team members (Desjardins, Jean & Bredillet, 2022).

2.4. Examine critical skills and capability requirements for the successful execution of a mega or large complex project.

Mega and large complex projects require a broad range of capabilities that extend beyond traditional project management skills. These include technical expertise in engineering and construction, as well as critical soft skills such as communication, leadership, and stakeholder management (Pieterse et al., 2022). The literature emphasises that competencies should not be limited to project managers but should extend across entire project teams. However, research indicates that most studies focus predominantly on leadership

competencies, neglecting the broader team capabilities required for project execution (Ram, 2023). Organisational capability is defined as the ability to integrate skills, processes, and resources to achieve project objectives. This highlights the importance of viewing skills not in isolation but as part of a broader system of capabilities that enable project performance. Many project organisations still treat project capabilities and skills as secondary considerations and are not concerned with the critical need for the use of a combination of skills and capabilities (Zhang & Leiringer, 2023).

Projects are uncertain, non-linear, interdependent, and often ambiguous; they require extensive experience and knowledge to manage teams within these parameters (Nachbagauer, 2021). A balance is required between expertise and experience in mega projects (Bhika, 2017). There are no dedicated systems for managing mega projects, and historically, they have been executed by traditional project managers using traditional processes and systems. This leads to a lack of skills in many of the capabilities required to execute projects effectively. Examples such as procurement, construction, quality, material management, communication, and stakeholder management are key (Aiyetan & Das, 2022). Leadership qualities are directly related to project success in most industries, and these leaders need to possess interpersonal skills, effective communication, and a governance-oriented approach (Faisal, Al Subaie, Sabir & Sharif, 2022). Emerging trends such as digitalisation, agile methodologies, and hybrid project management approaches are also influencing skill requirements, requiring organisations to continuously adapt and develop new competencies (Cabeças & Marques da Silva, 2021). Furthermore, collaboration across multiple stakeholders, including contractors and external partners, requires strong cross-functional capabilities and integrated team performance (Yin et al., 2023).

2.5. Develop a framework for the alignment of skilled resources to execute mega or large complex infrastructure utility projects.

Projects utilise core teams and key performance indicators from a construction stakeholder perspective, which includes clients, contractors, and consultants. It is suggested that the traditional triangular measure framework, time, cost, and quality, is no longer the only measure that can be used to determine the success of a project. A systematic framework should be implemented in the early stages of mega or large complex projects to address various project requirements and performance measurements (Ashkanani & Franzoi, 2022).

Across all reviewed literature, a consistent gap emerges:

- Skills and competencies are identified but not structured
- Roles are defined but not linked to required skills
- Frameworks exist but remain high-level and non-operational

Most importantly, there is a lack of a systematic approach to configuring project teams based on competencies and roles within mega or large complex projects.

This gap forms the basis for the development of the conceptual framework proposed in this study.

3. Research Methodology

This study employs a qualitative content analysis of secondary data, using a systematic and transparent analytical procedure. The dataset comprises peer-reviewed journal articles, industry reports, and scholarly literature on mega and large complex projects. Sources were identified through structured database searches (e.g., Scopus, Web of Science, and Google Scholar) using predefined keywords related to project complexity, skilled resources, competencies, and infrastructure delivery. Inclusion and exclusion criteria were applied based on relevance, publication quality, and recency.

The analysis followed a multi-stage coding process. First, an initial open coding phase was conducted to extract key concepts related to skills, competencies, and resource deployment. This was followed by axial coding, where codes were grouped into higher-order categories reflecting patterns of convergence and divergence in the literature. Finally, selective coding was used to synthesise these categories into core themes that inform the proposed framework for aligning skilled resources in mega projects.

To enhance analytical depth, both manifest and latent content were examined, allowing not only the identification of explicit concepts but also the interpretation of underlying assumptions and relationships within the literature. The analysis was iterative and comparative, enabling the identification of conceptual gaps and tensions across sources.

Trustworthiness was ensured through established qualitative criteria. Credibility was strengthened through systematic source selection and iterative coding; dependability was supported by maintaining an audit trail of coding decisions; confirmability was enhanced through transparent documentation of analytical procedures; and transferability was addressed by providing thick descriptions of the context and scope of the literature reviewed. This rigorous approach improves the transparency, replicability, and overall methodological robustness of the study.

4. Findings and Discussion

The findings presented in this section are primarily based on thematic content analysis of the existing literature. The analysis reflects established knowledge, dominant debates, and identified gaps within the current body of research on skills and resource planning in mega or large complex projects. A key observation is that, despite a substantial body of literature addressing resource types and availability, there is limited information on how to determine the appropriate number, configuration, and alignment of resources within a mega or large complex project. While organisations may have access to sufficient resources, these are frequently misaligned in terms of competency or incorrectly allocated to project roles (Moradi, Kähkönen & Aaltonen, 2020; Pieterse et al., 2022).

Mega or large complex projects require a combination of technical, behavioural, and managerial capabilities. However, there is no consensus on how these should be combined or structured within project teams. A further key observation is that existing frameworks largely operate at a high level, focusing on competencies, governance structures, or leadership capabilities, without translating these into clearly defined roles and responsibilities within project teams. As a result, there is a disconnect between competency models and their practical application in project environments, leading to inefficiencies in team design and execution (Turner, 2021; Daniel et al., 2023). This gap is also evident in the portfolio management literature, which emphasises allocating resources across multiple projects rather than within a single mega or large complex project (Stordy, Zerjav & Kanjanabootra, 2021). In addition, there is limited research indicating specific links between project scale and complexity and the specific competencies and skills required (Desjardins, Jean & Bredillet, 2022; Zhang & Leiringer, 2023). Collectively, these findings highlight the absence of an integrated approach that connects project characteristics with resources at an operational level.

There is strong agreement amongst authors that successful project delivery depends on the alignment of skills, competencies, and capabilities with clearly defined roles, organisational structures, and project activities (Khan, 2018; Pieterse et al., 2022). Project complexity intensifies this requirement, as a broad range of technical, managerial, and interpersonal capabilities, along with coordinated and integrated teams, is crucial for project success (Damayanti, Hartono & Wijaya, 2021; Nachbagauer, 2021; Denicol, Davies & Pryke, 2021).

There is no clear consensus on the core competencies required for project managers and project teams (Moradi, Kähkönen & Aaltonen, 2020; Faisal et al., 2022), nor on the most appropriate organisational structures for project execution. While some studies advocate agile, flexible, adaptive structures to manage complexity, others highlight the risks associated with matrix structures, including role conflict between functional and project priorities (Cristóbal, Fernández & Diaz, 2018; George, 2020). Existing theoretical and conceptual frameworks tend to emphasise specific areas of project management, particularly leadership and governance, without sufficiently integrating technical skill requirements into project team design (Faisal et al., 2022; Denicol, Davies & Pryke, 2021). Although these frameworks provide insight into management and control mechanisms, they do not adequately explain how project outcomes are achieved through effective project structures. Organisational design and governance structures are recognised as critical enablers of project execution, with models highlighting the need for integrated roles of owners, sponsors, suppliers, and operational teams in mega or large complex project delivery (Winch, Sergeeva & Lowe, 2023; Galvin, Tywoniak & Sutherland, 2021). There is limited agreement on how project success should be defined and assessed. Traditional metrics based on cost, time, and quality are increasingly challenged by broader evaluation criteria, including sustainability, stakeholder value, and team well-being (Ashkanani & Franzoi, 2022; Lingard & Turner, 2023). In addition, there are also differing opinions regarding the main drivers of project success, with some studies emphasising human competencies and leadership (Ahmed & Philbin, 2022; Irfan et al., 2021), while others prioritise organisational drive during front-end planning and governance structures for execution (Babaei, Locatelli & Sainati, 2021; Merrow, 2024). As the findings are conceptual in nature and serve to synthesise and structure existing knowledge, the proposed framework provides a basis rather than representing empirically tested relationships. These findings collectively inform the development of a conceptual framework (Figure 1) designed to address

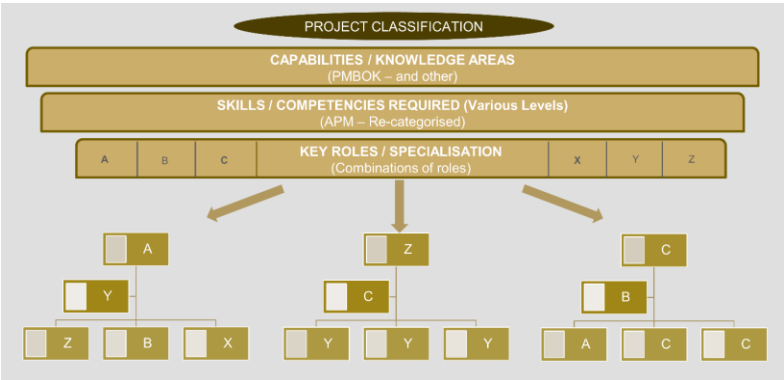

Figure 1: Proposed Conceptual Framework: Mega/Large Complex Project Resource Planning Framework

gaps in translating competencies into structured project team configurations.

The framework addresses the disconnect between high-level competency models and operational team configuration by providing a structured progression from project classification to resource deployment. Project complexity informs the identification of relevant knowledge areas, which define required organisational capabilities. These capabilities are translated into specific competencies and skills, which are then mapped to clearly defined roles and specialised skills. These roles are subsequently presented in a project organisational structure designed to support effective execution. By explicitly linking project capabilities, competencies, skills, roles, and organisational structure, the framework provides a structured approach to resource planning. It therefore addresses the gap identified in the literature and contributes a practical method for aligning skills with project delivery requirements.

5. Conclusion and Further Research

This study highlights a critical gap in the existing project management literature: limited guidance on how to systematically configure project teams in mega and large complex project environments. Although the importance of skills and competencies is well established, their structured integration into project roles and organisational arrangements remains insufficiently conceptualised. This gap has implications for resource deployment and contributes to ongoing challenges in project performance.

In response, the study proposes a framework for aligning skills, roles, and organisational structures in complex project settings. The framework contributes to theory by advancing a more integrated understanding of resource alignment, and to practice by offering a structured approach to improving resource planning and project execution, particularly within state-owned entities.

However, the study is constrained by its reliance on secondary data and its contextual focus on South African SOEs, which may limit the generalisability of the findings. Accordingly, further research is required to empirically validate the proposed framework through case-based or mixed-method studies. Future research should also examine its applicability across different industries and organisational contexts and refine the framework to accommodate varying institutional and project conditions.

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Narrative Infrastructure Under Disruption: Reconfiguring Resilience Narratives in Large South African Construction Contractors

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Abstract

Large South African construction contractors operate in conditions of recurring disruption shaped by market volatility, project fragmentation, and competing stakeholder demands. Construction strategy research has largely focused on formal plans and tools, with limited attention to how resilience is sustained through the everyday narrative processes that make strategy intelligible and actionable in practice. This paper examines how narrative infrastructure shapes the reconfiguration of resilience narratives under disruption. The study adopted an interpretivist multiple case design across four large South African construction contractors. Data was generated through 18 narrative interviews and supported by organisational artefacts, including planning documents, risk registers, reporting packs, meeting minutes, and internal guidance notes. Analysis combined thematic coding with structural narrative analysis. The findings suggest that narrative infrastructure does more than support communication. Recurring strategic forums, documentary routines, and learning practices help stabilise strategic direction during uncertainty, legitimise shifts in priorities, and convert disruption experience into shared strategic reference points. The paper contributes a practice-based account of resilience by showing how continuity under disruption is accomplished through the ongoing reworking of narrative infrastructure rather than through formal strategy alone.

Keywords: construction contractors, disruption, narrative infrastructure, organisational resilience, strategy-as-practice

1. Introduction

The construction contracting sector remains strategically important to economic development while also being acutely exposed to disruption. Economic recessions, epidemics, supply chain shocks, labour shortages, and geopolitical instability have undermined predictable project pipelines and challenged linear planning assumptions, contributing to rising financial distress, insolvencies, and liquidity pressures across the sector (Bolomope *et al*., 2025). Organisational resilience has therefore gained prominence as a strategic concern for firms operating in high-risk environments (Su and Junge, 2023).

These concerns are particularly acute in the South African construction sector. The industry has undergone consecutive contractions from 2016 to 2023 and has struggled to sustain momentum amid economic volatility and structural challenges (Mashegoana, 2023). The downturn has been compounded by declining public investment, procurement delays, governance failures, and community related disruption (Nyangiwe et al., 2023). In such a context, the issue is not simply whether contractors face disruption, but how resilience is sustained under prolonged uncertainty.

Existing scholarship offers only a partial answer to this question. Resilience research has advanced understanding of adaptation and continuity, while construction strategy research has produced valuable insight into planning and competitive response (Zungu *et al*., 2025). However, this literature has tended to privilege structural explanations, formal planning, and managerial tools over the practical and discursive processes through which resilience is sustained in volatile project-based settings (Zungu, 2025). A strategy-as-practice perspective helps address this limitation because it shifts attention from strategy as something organisations possess to strategy as something organisational members do through situated practices and interactions (Whittington, 2006). Within this perspective, narrative becomes important because it provides meaning, coherence, and direction under conditions of uncertainty (Vaara et al., 2016).

The current research focuses specifically on narrative infrastructure. Drawing on Deuten and Rip (2000), narrative infrastructure is understood here as the recurring communicative spaces, routines, and documentary artefacts through which particular accounts of disruption and response are carried, reinforced, challenged, and revised over time. In large construction firms, such infrastructure shapes how disruption is interpreted, how responsibility is assigned, and how strategic responses are rendered discussable across organisational settings (Zungu, 2025). However, limited attention has been paid to how narrative

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infrastructure evolves in project-based construction organisations facing ongoing disruption, particularly in relation to the construction, contestation, and reconfiguration of resilience narratives. This paper addresses this gap by examining how narrative infrastructure shapes the reconfiguration of resilience narratives in large South African construction contractors.

The study draws on four large South African construction contractors to develop a contextually grounded account of resilience narration under disruption. The paper offers a contextually grounded explanation of how resilience is narrated and sustained in a volatile project-based industry. The paper contributes to construction strategy research by extending practice-based understandings of strategizing under disruption, and contributes to resilience scholarship by showing that continuity is sustained not through formal strategy alone, but through evolving narrative work that stabilises meaning, legitimises strategic adjustment, and converts disruption experience into shared reference points for future action.

2. Literature Review

2.1. Resilience research and the problem of enactment

Recent resilience research increasingly presents organisational resilience as dynamic, relational, and processual rather than as a fixed organisational attribute. Recent reviews and conceptual studies emphasise anticipation, adaptation, continuity, and cross level interaction under conditions of disruption, thereby moving beyond earlier recovery centred formulations (Su and Junge, 2023). This development is important. However, a substantial part of this literature still derives its conclusions from conceptual synthesis, review based analysis, and capability-oriented framing. Consequently, resilience continues to be explained largely through the presence of routines, systems, capabilities, and enabling conditions, rather than through the situated work by which continuity is actually sustained. For the present study, this is significant because such literature is more effective in specifying what resilience is assumed to require than in explaining how resilience becomes meaningful, credible, and actionable in organisational practice.

This limitation is especially evident in recent construction research. Zhang *et al*. (2023), for instance, conceptualise project resilience through anticipation, coping, and adaptation by drawing on literature review, expert interviews, questionnaire data, and factor analysis. Hua et al. (2025) likewise explain resilience in construction project organisations through data governance capabilities, combining literature review, expert interviews, and partial least squares structural equation modelling. Even where more qualitative work is undertaken, the explanatory emphasis on capability remains pronounced. Mitansha and Potangaroa (2025), using semi structured interviews with construction professionals in New Zealand, move closer to lived organisational experience and demonstrate that resilience in project-based construction is mediated through the relationship between individual and organisational resilience. Nevertheless, the central concern remains resilience as an enabling condition or mediated outcome, rather than resilience as something narrated and defended in the ordinary flow of organisational life.

A related critique has already emerged within construction specific scholarship. Zungu et al. (2025) argue that existing resilience frameworks remain insufficient for contracting firms because they do not adequately capture the fragmented, project-based, and disruption-prone conditions under which contractors operate. This intervention is significant because it does not merely add another framework. Rather, it questions whether prevailing resilience models, many of which are abstracted from broader management contexts, are sufficiently sensitive to the practical realities of construction contracting. This opens the way for a more interpretive and practice-oriented understanding of resilience, one less concerned with resilience as a stock of capabilities and more with its continual sustenance in context.

2.2. Enacted strategizing in construction

A similar issue arises in strategy research. Much of the construction strategy literature, drawing on broader strategic management traditions, has historically privileged planning, positioning, and performance-oriented explanation (Green et al., 2008). Such scholarship has been useful in explaining strategic intent and competitive posture, but it offers less explanatory power when strategic direction must be sustained under unstable conditions and when plans are repeatedly unsettled in practice. This is precisely the problem that practice-based strategy scholarship seeks to address. Rather than treating strategy as something organisations possess, this literature examines the situated activities, routines, and interactions through which strategy is accomplished and adjusted over time (Whittington, 2006).

Recent work relevant to construction supports this development. Duman and Green (2025), for example, examine epic plot structures in international contracting and show how strategy narratives are mobilised in practice through narrative infrastructure rather than existing merely as formal strategic statements. This is especially important for the present paper because it demonstrates that strategic direction in contracting firms is not only articulated but narratively organised and performed. Recent project research also reinforces this point. Sergeeva (2024) argues that narratives matter because they are translated into commitment and

collective action through projects, stakeholder engagement, and shared identity formation. Such studies move beyond formal accounts of strategy by showing that strategic coherence is actively produced rather than simply implemented. However, they still leave unresolved the question of how resilience specifically is carried through recurring organisational arrangements over time.

2.3. Narrative, legitimacy, and continuity

Narrative research is valuable because it explains how organisational actors render uncertainty intelligible, connect events into plausible sequences, and justify preferred responses (Vaara et al., 2016). Narrative is therefore not a decorative supplement to strategy. It forms part of the work through which strategy becomes meaningful, legitimate, and actionable. Recent studies continue to reinforce this point. Audrin et al. (2024), in their study of flexible work projects, show how project managers build legitimacy through narratives that operate simultaneously across institutional, organisational, and individual levels. Reissner (2025) similarly demonstrates that strategy texts are not only outward facing communication devices, but also forms of auto communication through which organisations explain themselves to themselves during periods of strategic change. These studies are highly relevant because they show that strategic continuity depends on communicative work that stabilises interpretation and legitimacy across multiple audiences.

In construction, this line of thought has become more explicit in recent work by Zungu et al. (2024), who argue that persuasive narratives of strategy can function as resilience enabling resources in construction firms. Their conceptual framework is directly relevant to the present study because it identifies narrative infrastructure as the contextual canvas upon which strategic narratives are crafted and enacted. The value of that contribution lies in shifting the discussion from resilience as a technical response to disruption to resilience as something shaped by strategic discourse, narrative building blocks, and persuasive organisational storytelling. However, because that study is conceptual, the empirical question of how such narrative infrastructure operates in practice remains open.

2.4. Narrative infrastructure and the unresolved issue

The concept of narrative infrastructure remains essential because it directs attention to the recurring organisational conditions that enable some narratives to endure, travel, and be revised. Deuten and Rip (2000) remain foundational in this regard because they define narrative infrastructure as the evolving aggregation of actors and narratives in material and social settings that enables and constrains possible stories, actions, and interactions. What recent scholarship adds is stronger evidence that narratives matter for collective action, legitimacy, internal strategic communication, and project identity. What remains underexplained, however, is how resilience narratives in large construction firms are sustained through repeated meetings, reporting routines, dashboards, guidance texts, and other organisational sites where disruption is interpreted and strategic responses rendered discussable. In other words, recent work has strengthened the case for resilience as dynamic and for narrative as constitutive, but it has not yet adequately explained the infrastructural conditions through which resilience narratives are stabilised, contested, and reconfigured over time in project-based contracting organisations. Accordingly, this study is grounded in the strategy as practice perspective and narrative theory. Strategy as practice is used to examine resilience as situated strategizing work and narrative theory to explain how meanings of disruption are constructed, stabilised, and revised.

3. Research Methodology

The current study adopted an interpretivist qualitative multiple case design because the research sought to understand how resilience narratives are constructed, sustained, contested, and reconfigured within specific organisational contexts, rather than to test predetermined causal relationships (Saunders et al., 2019). Four large South African construction contractors were selected purposively as bounded cases. Selection was based on four criteria: independent operation, primary operation within the South African construction industry, Grade 9 CIDB registration, and an established trading history. These criteria ensured that the cases were comparable in scale and complexity and had sufficient organisational maturity and disruption experience to generate meaningful insight. The final four cases were drawn from 21 eligible Grade 9 firms identified from the CIDB register, reflecting common access constraints in organisational research.

Data were generated through narrative interviews and documentary material. Narrative interviewing was appropriate because the study was concerned not only with what participants reported, but also with how they structured experience, attributed significance to disruption, and linked events to strategic response over time (Holstein and Gubrium, 2012). Data collection proceeded in three stages: pilot interviews, main interviews, and document review. The interview guide was developed from the conceptual framework and refined through pilot interviews to improve clarity and sharpen follow up prompts. The main dataset comprised 18 interviews with executives, directors, and senior managers across the four case organisations. Participants were selected purposively on the basis of their strategic roles and direct experience of disruption and organisational response. Interviews lasted between 30 and 100 minutes, were recorded, transcribed, and supplemented by field notes. Documentary material

from internal and public sources, including company profiles, annual reports, websites, speeches, reporting packs, guidance notes, and selected organisational records, was used to contextualise the interviews and compare participant accounts with organisational texts.

Data analysis combined thematic analysis with structural narrative analysis. Thematic analysis enabled identification of recurrent patterns across interviews and documents, while structural narrative analysis examined how resilience and strategizing were narratively organised through temporality, sequencing, plot movement, evaluation, and character positioning (Riessman, 2008). This was necessary because the study sought to analyse not only what participants emphasised, but also how disruption, adaptation, and strategic response were made sensible and credible through narrative form.

The trustworthiness of the study was addressed through credibility, dependability, confirmability, and transferability (Lincoln and Guba, 1985). Credibility was strengthened through sustained engagement with narrative and documentary data, a crystallisation logic across interviews and archival documents, member reflection where feasible, and peer debriefing. Dependability was supported through an audit trail, a structured case database, and documentation of interview guide development, sampling decisions, coding rules, and analytic memos. Confirmability was enhanced through grounded interpretation, reflexive memoing, and transparent links between evidence and claims, while transferability was supported through rich contextual description and multi case comparison. Although the study is bounded to surviving large contractors within one national context and does not capture collapse trajectories directly, the design is appropriate for generating a contextually grounded explanation of how narrative infrastructure shapes resilience narratives in practice.

4. Findings and Discussion

The analysis indicates that narrative infrastructure in large South African construction contractors evolves through three closely related processes. First, recurring strategic forums and documentary routines keep organisational life sensible under ongoing disruption. Second, prior crises and earlier responses are retained and reused as narrative resources for present judgement. Third, existing resilience narratives are revised when changing conditions place strain on settled accounts of viability, exposure, and strategic direction. Collectively, these findings suggest that narrative infrastructure does not operate as a static background to strategizing.

4.1. Narrative infrastructure as continuity work

Across the cases, recurring strategic forums emerged as central sites through which continuity was narratively maintained. Participants did not describe strategy as something fixed in formal plans and then simply executed. Instead, strategic direction was repeatedly assembled in meetings, reviews, planning sessions, and performance discussions through which actors made sense of uncertainty and reaffirmed what counted as a sensible organisational response. In Case A, one participant explained that *"a big focus for us is on doing rigorous forecasting and budgeting exercises … then we'll have our annual planning workshop … a lot of this is about structured planning systems we've put in place and making sure it runs like clockwork*" (Case A – P5). This account is significant not merely because it refers to planning systems, but because it narrates strategic continuity as something that must be repeatedly enacted through disciplined organisational rhythms. The significance of the quotation lies in its presentation of continuity as an ongoing accomplishment rather than a settled state.

A similar pattern is visible in Case D, where routine review mechanisms were narrated as anticipatory rather than reactive. One participant stated that *"we also have dashboards for programme performance, quality, safety, and contract risk. These show leading indicators so we can intervene before things become major issues. We do not want to be reactive. We want to spot the red flags early and act"* (Case D – P1). The significance of this account lies in the way dashboards and reporting are positioned not as passive information systems, but as practical narrative devices through which volatility is translated into timely and legitimate intervention. Organisational actors are not simply reading risk. They are participating in a repeated sensemaking routine that keeps disruption narratable as something that can still be governed. In interpretive terms, this is continuity work. It is the everyday labour of maintaining a coherent sense of what is happening, what matters, and what can still be acted upon when project conditions remain unstable.

This finding develops the literature in two ways. First, it supports recent resilience scholarship by Su and Junge (2023), Zhang et al. (2023), Hua et al. (2025), and Mitansha and Potangaroa (2025), which treats continuity as a dynamic and ongoing process rather than as post shock recovery. However, the present material suggests that continuity is not sustained only through routines and systems in a structural sense. Continuity is sustained through the recurrent interpretive work by which those routines and systems become meaningful to actors in context. Second, the finding reinforces the strategy as practice literature, particularly Whittington (2006), Vaara et al. (2016), and Duman and Green (2025), by showing that strategic coherence in large contractors is held together through

repeated situated encounters rather than formal intent alone. The evidence therefore aligns with the argument that strategy is accomplished in practice and further shows that recurring strategic forums function as narrative infrastructure by providing regular spaces in which resilience can be retold, clarified, and made actionable under strain.

4.2. Narrative sedimentation and organisational memory

A second finding concerns the way resilience narratives gain durability through accumulation and reuse. Across the cases, prior disruptions were not narrated as closed episodes left behind once immediate pressures subsided. Instead, earlier events were repeatedly re-activated as reference points for present judgement. In Case A, one participant stated that *"we conduct postmortems on all projects … once a project is completed, we do a full postmortem … these help guide future strategy and prevent repeating past mistakes"* (Case A – P4). In Case C, a similar logic appeared in the use of close out processes to review *"what went well, what did not, where we lost money, what caused delays"* (Case C – P1). These accounts indicate that resilience narratives endure through sedimentation. What is carried forward is not simply information, but an interpretive repertoire through which present uncertainty can be understood in the light of prior experience.

The significance of these quotations lies in the way they frame organisational memory as active rather than archival. Postmortems and close out routines do not merely capture lessons. They make prior disruption reusable. This is important because the current paper is not concerned only with whether firms learn. The concern is with how prior disruption becomes narratively portable across time and organisational settings. The interviews suggest that resilience narratives acquire durability because earlier experiences are folded into recurring strategic routines that allow actors to say, in effect, this has happened before, this is what it meant, and this is how response should now be oriented. In this sense, narrative infrastructure carries the past into the present by embedding memory in repeatable organisational forms.

This finding sharpens the existing literature. Recent construction resilience studies have moved toward more dynamic and project sensitive accounts of adaptation, but they remain more focused on capabilities, mediation, and enabling mechanisms than on how experience becomes narratively reusable over time (Zhang et al., 2023; Hua et al., 2025; Mitansha and Potangaroa, 2025). The present findings add that organisational memory becomes strategically consequential through narrative sedimentation. This is also consistent with the notion that continuity is explained through repeated story patterns, regular spaces for retelling, and organisational documents that keep preferred ways of talking about risk and competent action in circulation. The contribution of the present paper, therefore, lies not simply in showing that memory matters but in showing that memory is infrastructurally organised through routines that render prior disruption available as a present strategic resource.

4.3. Reconfiguration under strain

The third finding is that narrative infrastructure does not only stabilise resilience narratives. It also becomes the medium through which those narratives are revised when existing accounts no longer fit unfolding conditions. This is particularly visible in the way participants narrated diversification, selectivity, partnership, and risk reframing. In Case B, one participant explained that *"we changed our strategy to target clients and sectors we know are stable and have favourable payment terms … we do not just chase tenders"* (Case B – P3). The quotation is important because it does not narrate resilience as endurance within an unchanged strategic frame. It narrates resilience as selective repositioning. Viability is sustained through reframing what counts as desirable work, trustworthy clients, and prudent growth. The account is therefore a narrative of revision as much as one of continuity.

A related pattern appears in Case D, where diversification is framed as a condition of continued survival: *"if you are a one trick pony, you are vulnerable"* (Case D – P1). Similarly, in Case A the movement into the renewables sector is narrated in terms of seeing emerging signals and adapting before conditions harden against the firm. What matters in these accounts is that resilience is not presented as the ability to preserve an unchanged strategic identity under pressure. Rather, resilience is narrated through the reworking of what the firm is, where it should compete, and how risk should be interpreted. This is where narrative infrastructure appears not simply as a stabilising arrangement, but as a site of friction and re-authorisation. Existing accounts of competence and direction remain usable only for as long as they continue to fit changing conditions. Once that fit weakens, recurring strategic spaces become arenas for narrative repair, reinterpretation, and sometimes selective abandonment of earlier priorities.

This finding allows a deeper engagement with the literature. Recent narrative studies have shown that organisational narratives matter for legitimacy, collective action, and internal strategic communication (Audrin et al., 2024; Sergeeva, 2024; Reissner, 2025). Recent conceptual work in construction has similarly argued that persuasive strategic narratives can function as resilience-enabling resources (Zungu et al., 2024). The present findings extend those arguments by showing that revision itself is infrastructurally organised. Reconfiguration does not happen outside the

routines, reports, reviews, and strategic discussions that already stabilise continuity. It happens through them. This is consistent the notion that narrative infrastructure both stabilises and strains as fresh disruptions introduce new interpretive demands, identity threats, and pressures to defend legitimacy. The implication is that resilience narratives endure less because they become fixed truths and more because their plausibility is repeatedly produced, tested, and revised across time and audiences.

4.4. Interpretive contribution of the findings

The findings show that narrative infrastructure provides recurring organisational conditions through which resilience narratives are maintained, reused, and revised. The study does not claim that narrative infrastructure causes resilience in a direct sense. Rather, narrative infrastructure shapes the organisational work through which resilience becomes durable, discussable, and reconfigurable in practice. This addresses the central gap identified in the literature. While recent resilience, strategy, and narrative research has shown that continuity and coherence are dynamically and communicatively produced, less attention has been given to the infrastructural conditions that sustain this process in project based contracting organisations. By showing how forums, documentary routines, and memory practices hold resilience narratives together under disruption, the study advances a practice based and interpretive account of resilience in large South African construction contractors.

5. Conclusion and Further Research

This paper examined how resilience is sustained in large South African construction contractors operating under prolonged disruption. The study responded to the need for a practice-based understanding of resilience in construction and adopted an interpretivist multiple case design to explore how resilience is constructed and maintained in organisational practice. The findings show that resilience is sustained not through formal strategy alone, but through narrative infrastructure embedded in recurring meetings, reporting routines, strategic discussions, and organisational texts. This narrative infrastructure supports continuity, enables organisational memory to be retained and drawn upon, and allows resilience narratives to be revised as conditions change. The paper therefore shows that resilience is continually maintained and reworked in practice rather than existing as a fixed organisational property. These findings contribute to construction management and resilience research and may also be useful to managers and practitioners seeking to sustain strategic coherence under uncertain and disruptive conditions. Further research could examine whether similar dynamics are evident in smaller firms, in other national contexts, or over longer periods through longitudinal research.

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Compliance and Implementation Challenges of DHET Minimum Norms and Standards in Off-Campus Student Accommodation in South Africa: A Systematic Literature Review

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Abstract

This study examines the compliance and implementation challenges associated with the Department of Higher Education and Training (DHET) Minimum Norms and Standards for off-campus student accommodation in South Africa. The growing demand for student housing and increasing reliance on privately managed accommodation have raised concerns regarding accommodation quality, safety, and regulatory compliance. A systematic literature review (SLR) guided by the PRISMA framework was conducted to identify, evaluate, and synthesise existing literature published between 2015 and 2025. The review synthesised evidence from 20 eligible studies. The review analysed studies relating to student accommodation conditions, governance, compliance, and student experiences within the South African higher education sector. The findings indicate that compliance with DHET standards remains inconsistent across several areas, particularly safety and security, infrastructure maintenance, facilities and service provision, and accessibility. The review further identified weak governance and regulatory oversight, financial constraints, accommodation shortages, and the prevalence of unregulated accommodation providers as key implementation challenges affecting compliance. The findings also reveal that non-compliance has implications for student well-being, academic performance, and overall accommodation satisfaction. By consolidating existing evidence, this study contributes to the understanding of policy implementation challenges within the student accommodation sector and provides insights that may assist universities, accommodation providers, and policymakers in strengthening compliance and improving the quality of off-campus student housing in South Africa.

Keywords: Challenges, DHET Minimum Norms and Standards, off-campus student accommodation, South Africa, student housing

1. Introduction

Across the world, there has been a significant increase in student enrolment in higher education institutions. Globally, student enrolment growth has outpaced universities' capacity to provide accommodation, resulting in housing shortages and higher costs (du Plessis & Amoah, 2021). Similarly, the student housing sector has transformed rapidly, with growing student populations exceeding institutions' ability to supply accommodation (Edwards, 2019). In Sub-Saharan Africa, rapid population growth and rising demand for higher education have intensified this challenge, with South Africa becoming a key destination for students in the region (Edwards, 2019). In South Africa, the expansion of higher education can be traced back to the 1994 democratic transition, which opened access to institutions for all population groups. This process of deracialisation led to the massification of the tertiary education system, resulting in a significant massification in student enrolment, particularly among students from previously disadvantaged backgrounds (Mzileni, 2018). As a result, private off-campus student housing facilities (SHFs) have emerged as an important alternative for students who are unable to secure on-campus accommodation (Masha & Agyeman, 2024). However, despite their growing role in student housing provision, evidence suggests that many off-campus accommodation providers do not fully comply with the DHET minimum norms and standards for student housing (Masha & Agyeman, 2024). This study provides a critical synthesis of existing literature on student accommodation in South Africa, focusing on off-campus housing. It examines the gap between policy expectations and practical implementation, highlighting systemic and structural factors that undermine effective compliance with DHET standards.

2. Literature Review

2.1. DHET Policy on the Minimum Norms and Standards for Student Housing at Public Universities

The DHET Minimum Norms and Standards apply to all public higher education institutions and university-accredited private student accommodation providers (DHET, 2015). The policy sets minimum requirements for the provision, management, and maintenance of

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student accommodation. The key provisions are summarised below.

The DHET standards require student accommodation providers to comply with requirements relating to physical infrastructure, health and safety, furnishings and fittings, maintenance, student well-being, and financial management. Accommodation must be located within a radius of no more than 20 kilometres from campus, and transport must be provided at regular intervals for residences situated more than 5 kilometres away. The standards prescribe a maximum of two students per room, with single rooms being no smaller than 8m² and double rooms no smaller than 14m². They also specify minimum ablution facilities, including one washbasin per 4 students, 1 shower cubicle per 7 students, and 1 lavatory per 5 students. In addition, accommodation must provide social and study spaces such as television rooms, communal lounges, meeting rooms, dedicated group study spaces, games rooms, gymnasia, computer centres, and reliable internet access in student rooms, study areas, and communal spaces. Providers must comply with relevant health and safety legislation, obtain annual compliance certificates, maintain secure and hygienic living environments, and conduct regular cleaning and safety inspections. Furnishings and fittings must meet minimum requirements, be properly maintained, and be replaced when beyond repair. All construction, refurbishment, repair, and maintenance work must comply with relevant legislation and be carried out by qualified personnel. Universities are also required to provide welfare support services, including first aid resources and emergency assistance, while financial management measures must ensure accountability and transparency through separate residence budgets, financial reporting, and compliance with NSFAS accommodation funding requirements.

2.2. Compliance with DHET Minimum Norms and Standards

2.2.1. Safety and Security Compliance

Krishna et al. (2021) in their study found that over half of respondents reported feeling unsafe, citing ineffective security personnel and inadequate access control measures. A study by (du Plessis & Amoah, 2021) reported limited availability of safety infrastructure such as alarm systems. According to Gbadegesin et al. (2021), a significant proportion of students reside in unregulated accommodation characterised by overcrowding, crime, and poor living conditions. Rammbuda & Mudau (2025) emphasised that the student housing crisis has resulted in unsafe living environments for many students. Collectively, the literature highlights persistent shortcomings in security measures, access control, and student safety within many off-campus accommodation facilities. Security and access control remain ongoing challenges in shared student accommodation (Gregory & Rogerson, 2019).

2.2.2. Physical Infrastructure and Maintenance Compliance

Studies by (Ndlovu & Pophiwa, 2023; Edwards, 2019) highlight the prevalence of ageing and poorly maintained buildings. Khosa et al. (2025) demonstrate that poor housing conditions contribute to physical illness, stress, and mental health challenges among students. Mampuru & Aigbavboa (2019) found that accommodation conditions significantly influence student satisfaction, well-being, and overall academic experience. Masha & Agyeman (2024) identified dissatisfaction with infrastructure and maintenance, while (Gbadegesin et al., 2022) argue that housing satisfaction is influenced by maintenance quality, privacy, and environmental conditions.

2.2.3. Facilities and Service Provision Compliance

The DHET standards require accommodation providers to provide adequate facilities and services, including access to utilities, internet connectivity, study spaces, and supporting infrastructure. Basic services such as water and electricity are generally available across many off-campus accommodation facilities (du Plessis & Amoah, 2021). However, access to academic-support facilities and essential services remains inconsistent. Authors (Masha & Agyeman, 2024; Musundire, 2023) report dissatisfaction with internet access, plumbing systems, and drainage infrastructure. Makhoahle et al. (2025) further note that student satisfaction is influenced by the quality of facilities and services provided within accommodation environments.

2.2.4. Accessibility and Location Compliance

The DHET standards require off-campus accommodation to be located within a reasonable distance from campus and supported by appropriate transport services where necessary. The reviewed literature indicates that proximity to campus remains a key factor influencing accommodation choice and students' access to academic facilities and support services. Limited transport services, including inadequate shuttle systems, increase transportation burdens for students who rely on public or private transport (du Plessis & Amoah, 2021).

2.3. Implementation Challenges Affecting Compliance

2.3.1. Management, Governance and Regulatory Compliance

Several studies highlight governance and regulatory challenges within the off-campus student accommodation sector. Ndlovu & Pophiwa (2023) report that many accommodation facilities operate outside the DHET regulatory framework, limiting oversight and compliance monitoring. Musundire (2023) further notes that many providers lack full-time management structures and adequate tenant management practices. Khosa et al. (2025) identify

poor monitoring, weak stakeholder coordination, and limited accountability as barriers to improving accommodation conditions. Concerns regarding the implementation of DHET standards are also reflected in the discussion by (Ncame, 2016) of inconsistencies in policy implementation. As the student accommodation sector continues to expand, providers are increasingly required to comply with accreditation requirements and municipal bylaws governing student housing operations (Musundire, 2023).

2.3.2. Financial and Structural Constraints

Financial and structural constraints play a significant role in limiting compliance with DHET standards. According to Oladeji et al. (2024), government funding remains insufficient to satisfy growing accommodation demand, resulting in an increased reliance on private sector investment. This challenge is compounded by limitations in financial support mechanisms such as NSFAS, which often fail to meet the full accommodation needs of students (Mabuse, 2023). Mugume & Luescher (2015) further argue that public-private partnership models frequently create tensions between affordability, profitability, and student needs. In addition, accommodation shortages continue to place pressure on the student housing sector. Krishna et al. (2021) identify significant difficulties experienced by students in securing accommodation, reflecting a broader mismatch between accommodation supply and demand. Consequently, many students are forced to accept substandard accommodation due to limited alternatives.

2.3.3. Unregulated Accommodation Providers

The prevalence of unregulated accommodation providers emerged as a significant challenge affecting the implementation of DHET standards. The NSFAS standardisation initiative was introduced to strengthen the accreditation, monitoring, and quality assurance of student accommodation against DHET norms and standards, highlighting the continued need for improved regulatory oversight within the sector (NSFAS, 2023).Studies indicate that a substantial proportion of students reside in accommodation that operates outside formal accreditation and regulatory systems (Gbadegesin et al., 2021). Similarly, Ndlovu & Pophiwa (2023) report that many off-campus accommodation facilities function outside formal regulatory frameworks, limiting oversight and accountability. The existence of unregulated accommodation weakens the effectiveness of DHET standards, as providers are often not subjected to regular inspections, monitoring, or compliance assessments. Issues relating to safety, maintenance, service provision, and student well-being frequently persist.

2.4. Theoretical Framework: Institutional Theory and DHET Regulatory Compliance

This study is theoretically underpinned by Institutional Theory, with a particular focus on regulatory compliance and governance in complex policy environments. Institutional Theory is widely used to explain how organisations respond to formal rules, professional norms, and taken-for-granted practices within their institutional environments (Scott, 2014; DiMaggio & Powell, 1983). The theory is especially appropriate for analysing policy–practice gaps, where regulations exist but are unevenly implemented, as observed in off-campus student accommodation in South Africa (Ncame, 2016; Khosa et al., 2025). The DHET Minimum Norms and Standards for Student Accommodation constitute a formal policy instrument intended to regulate the quality, safety, and management of student housing. However, the persistence of non-compliance—particularly in privately managed off-campus accommodation—suggests that regulation alone is insufficient. Institutional Theory explains this by conceptualising institutions as comprising three interrelated pillars: regulative, normative, and cultural-cognitive (Scott, 2014).

2.4.1. Regulative Pillar

The regulative pillar encompasses formal rules, policies, enforcement mechanisms, and sanctions that compel organisational compliance (Scott, 2014). In this study, the DHET Minimum Norms and Standards represent the primary regulative framework governing student accommodation provision in South Africa. These standards outline minimum requirements relating to safety and security, infrastructure conditions, service provision, accessibility, and management practices (DHET, 2015). However, prior research demonstrates that the effectiveness of regulative institutions is contingent on consistent monitoring, enforcement capacity, and credible sanctions (Parker & Nielsen, 2011). The literature reviewed in this study reveals persistent weaknesses in these areas, particularly in relation to off-campus accommodation. Several studies report that many private accommodation providers operate outside formal accreditation systems or are inadequately monitored by universities and regulatory bodies (Ndlovu & Pophiwa, 2023; Musundire, 2023). As a result, compliance is often superficial, limited to easily verifiable provisions such as water and electricity, while broader regulatory requirements relating to safety, maintenance, and management are neglected (du Plessis & Amoah, 2021; Gbadegesin et al., 2022).

2.4.2. Normative Pillar

The normative pillar refers to professional standards, social obligations, and stakeholder expectations that define appropriate organisational behaviour (Scott, 2014; Suchman, 1995). In the context of student

accommodation, normative pressures arise from universities, students, parents, and society, all of whom expect student housing to support well-being, dignity, safety, and academic performance (Gopal & Van Niekerk, 2018; Mampuru & Aigbavboa, 2019). Findings from the reviewed literature highlight a consistent misalignment between regulatory compliance and student expectations. While some accommodation providers may meet minimum regulatory criteria, students frequently report dissatisfaction with privacy, security, maintenance quality, and service reliability (Krishna et al., 2021; Masha & Agyeman, 2024). This suggests that compliance is interpreted narrowly, focusing on regulatory checklists rather than on normative expectations relating to the student living experience. Institutional Theory explains this as a form of decoupling, where formal compliance is claimed without substantive adherence to underlying norms (Meyer & Rowan, 1977).

2.4.3. Cultural-Cognitive Pillar

The cultural-cognitive pillar comprises shared beliefs, routines, and taken-for-granted assumptions that shape how actors perceive problems and solutions (Scott, 2014). In South Africa, the chronic shortage of student accommodation, coupled with financial constraints and massification of higher education, has contributed to the normalisation of substandard off-campus housing (Mzileni, 2018; Oladeji et al., 2024). Several studies indicate that overcrowding, poor maintenance, and inadequate security have become widely accepted as unavoidable consequences of accommodation scarcity (Gbadegesin et al., 2021; Rammbuda & Mudau, 2025). This acceptance reduces pressure on accommodation providers and weakens regulatory urgency, reinforcing cycles of non-compliance. From an institutional perspective, these cultural-cognitive conditions undermine both regulative enforcement and normative expectations, allowing substandard practices to persist with limited resistance (Scott, 2014).

2.4.4. Institutional Theory and Policy–Practice Gaps in DHET Standards

By integrating the regulative, normative, and cultural-cognitive pillars, Institutional Theory provides a comprehensive framework for understanding the persistent policy–practice gap in the implementation of DHET Minimum Norms and Standards. The findings of this study illustrate that non-compliance is not merely a technical or financial issue, but an institutional outcome shaped by weak enforcement mechanisms, competing market logics, and normalised acceptance of inadequate housing conditions (Mugume & Luescher, 2015; Khosa et al., 2025). Consequently, improving compliance requires institutional reform that addresses governance structures, accountability mechanisms, and stakeholder engagement alongside regulatory requirements.

3. Research Methodology

This study adopted a systematic literature review (SLR) to identify, evaluate, and synthesise existing research on compliance and implementation challenges relating to the DHET Minimum Norms and Standards for off-campus student accommodation in South Africa. An SLR was considered appropriate because it allows for the systematic identification, evaluation, and synthesis of existing evidence relating to compliance and implementation challenges within a defined research context. The review was guided by the PRISMA framework, which provides a structured process for identifying, screening, and selecting relevant studies.

3.1. Search Strategy

Relevant studies were identified through Google Scholar, supplemented by selected government reports, policy documents, and sector publications relevant to student accommodation and DHET compliance. Google Scholar was selected as the primary database due to its broad coverage of journal articles, conference papers, theses, dissertations, and government publications relevant to student accommodation research. Search terms included combinations of “off-campus student accommodation”, “private student housing”, “student accommodation challenges”, “DHET minimum norms and standards”, “student housing compliance”, and “South Africa”. The search was limited to studies published between 2015 and 2025.

3.2. Selection of Studies

Studies were screened using predefined inclusion and exclusion criteria. Included studies focused on student accommodation in South Africa, particularly off-campus accommodation, housing conditions, governance, compliance, and student well-being. Studies conducted outside South Africa, focusing exclusively on on-campus accommodation, or unrelated to student accommodation compliance and challenges were excluded. The screening process followed the PRISMA framework. A total of 41 records were identified, 2 duplicates were removed, and 39 studies were screened. 13 studies were excluded because they did not meet the inclusion criteria, while 6 studies could not be retrieved. Consequently, 20 studies were included in the final review.

3.3. Data Extraction and Analysis

Relevant information relating to compliance with DHET standards and implementation challenges was extracted from the selected studies. The extracted data were analysed using thematic analysis, whereby recurring issues and patterns were coded and grouped into broader themes. These themes formed the basis of the findings and discussion section.

3.4. Ethical Considerations

The study relied solely on publicly available secondary sources and did not involve human participants. Therefore, ethical clearance was not required. Figure 1 presents the PRISMA flow diagram illustrating the study selection process.

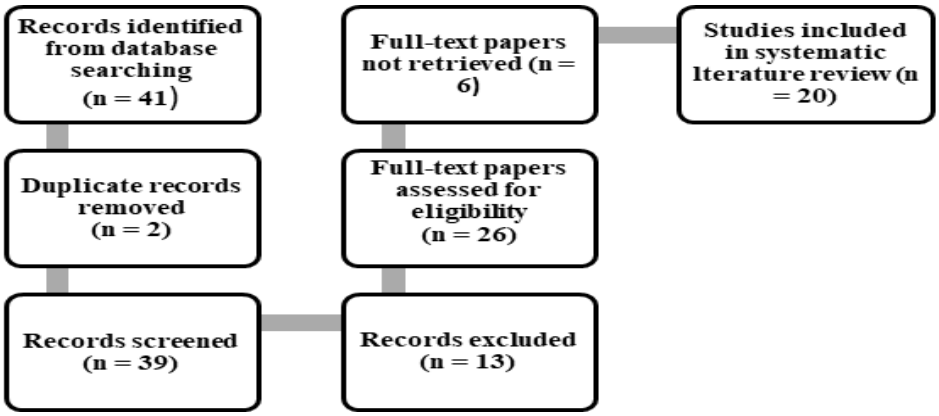

Figure 1: PRISMA flow diagram

4. Findings and Discussion

4.1. Overview of Key Findings

The final review included 20 studies published between 2015 and 2025, supplemented by selected policy reports and sector publications. The reviewed studies comprised journal articles, conference papers, theses, and dissertations, with most focusing on student accommodation conditions, governance, housing provision, and student experiences within South African higher education institutions. Table 1 summarises the main compliance issues identified in the literature.

4.2. Compliance Issues with DHET Standards

The literature indicates that compliance with DHET standards remains inconsistent across several areas. Safety and security emerged as one of the most frequently reported concerns, with students reporting inadequate security measures, ineffective access control, and exposure to crime (Krishna et al., 2021; Gbadegesin et al., 2021). Similar shortcomings were identified in relation to infrastructure and maintenance, where ageing buildings and poor maintenance practices negatively affected student living conditions (Edwards, 2019; Ndlovu & Pophiwa, 2023). Compliance challenges (Table 2) were also evident in facilities and

Table 1: Compliance Issues Identified in the Literature

DHET Area	Key Issues Identified	Studies
Safety and Security	Inadequate access control, ineffective security personnel, crime, overcrowding	Krishna et al. (2021); Gbadegesin et al. (2021); Rammbuda & Mudau (2025); Gregory (2022)
Infrastructure and Maintenance	Ageing buildings, poor maintenance, inadequate living conditions	Edwards (2019); Ndlovu & Pophiwa (2023); Khosa et al. (2025)
Facilities and Services	Poor internet access, plumbing and drainage issues	Masha & Agyeman (2024); Musundire (2023); Makhoahle et al. (2025)
Accessibility and Location	Transport challenges, distance from campus	Krishna et al. (2021); du Plessis & Amoah (2021)

Table 2: Implementation Challenges Affecting Compliance

Challenge	Key Issues Identified	Studies
Governance and Regulation	Weak monitoring, poor enforcement, limited accountability	Khosa et al. (2025); Musundire (2023); Ncame (2016); NSFAS (2023)
Financial Constraints	Funding shortages, NSFAS limitations	Oladeji et al. (2024); Mabuse (2023); World Bank (2021)
Accommodation Shortages	Demand exceeding supply	Krishna et al. (2021); Mzileni (2018)
Unregulated Providers	Non-accredited accommodation	Gbadegesin et al. (2021); Ndlovu & Pophiwa (2023)

service provision, particularly regarding internet access, plumbing, and drainage systems (Masha & Agyeman, 2024; Musundire, 2023). Accessibility concerns centred on transport availability and the location of accommodation facilities relative to campuses.

4.3. Implementation Challenges Affecting Compliance

The literature indicates that compliance with DHET standards is influenced by several implementation challenges. Weak governance structures, inadequate monitoring, and inconsistent regulatory enforcement were identified as major barriers to compliance (Khosa et al., 2025; Musundire, 2023; Ncame, 2016). In addition, financial constraints continue to affect the provision of quality student accommodation, with insufficient government funding and limitations in NSFAS support contributing to increased reliance on private accommodation providers (Oladeji et al., 2024; Mabuse, 2023). The growing demand for student accommodation has further intensified accommodation shortages, resulting in a mismatch between supply and demand and forcing many students to occupy substandard accommodation (Krishna et al., 2021; Mzileni, 2018). Another recurring challenge is the prevalence of unregulated accommodation providers operating outside formal accreditation systems, which limits oversight and weakens the implementation of DHET standards (Gbadegesin et al., 2021; Ndlovu & Pophiwa, 2023).

4.4. Implications of Non-Compliance

The literature highlights several consequences associated with non-compliance with DHET standards. Poor accommodation conditions have been linked to increased stress, illness, and mental health challenges among students (Khosa et al., 2025; Rammbuda & Mudau, 2025). Similarly, Sibanda (2022) found that accommodation-related challenges contribute to academic, emotional, social, and financial difficulties among students residing off campus. Nyangiwe et al. (2020) similarly found that living environments influence student behaviour and overall well-being. Inadequate accommodation also affects academic performance, with poor living environments contributing to reduced concentration, lower academic achievement, and diminished student engagement (Masha & Agyeman, 2024; Khosa et al., 2025). Furthermore, dissatisfaction with maintenance, privacy, safety, and service quality negatively affects students' overall accommodation experiences (Mampuru & Aigbavboa, 2019; Masha & Agyeman, 2024; Gbadegesin et al., 2022). These findings demonstrate that compliance with DHET standards extends beyond regulatory requirements and plays an important role in supporting student well-being, academic success, and overall satisfaction.

5. Conclusion and Recommendations

5.1. Conclusion

This study examined the compliance and implementation challenges associated with the DHET Minimum Norms and Standards for off-campus student accommodation in South Africa through a systematic literature review. The findings reveal a persistent gap between policy requirements and their implementation within the off-campus student accommodation sector. While some providers comply with basic requirements such as water and electricity provision, challenges remain in relation to safety and security, infrastructure maintenance, service provision, accessibility, and governance. The review further identified weak regulatory oversight, accommodation shortages, financial constraints, and the prevalence of unregulated accommodation providers as key barriers to compliance. The findings also demonstrate that non-compliance has important implications for student well-being, academic performance, and overall accommodation satisfaction. Addressing these challenges is essential to improving the quality of student accommodation and ensuring that the objectives of the DHET standards are achieved.

5.2. Recommendations

Based on the findings, stronger enforcement of the DHET Minimum Norms and Standards is required, particularly within off-campus student accommodation. Universities and regulatory bodies should strengthen monitoring and accreditation processes through regular inspections and appropriate measures for non-compliance. Accommodation providers should establish formal management structures and improve accountability through responsive maintenance systems and effective mechanisms for addressing student complaints. Greater attention should also be given to safety and security measures, including access control, surveillance systems, and emergency preparedness. Furthermore, stronger collaboration between universities, accommodation providers, government departments, NSFAS, and student representatives is necessary to improve compliance and enhance the quality of student accommodation.

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Stakeholder Participation Patterns Across Construction Project Stages in the Niger Delta: Archival Evidence from Public Sector Projects in Nigeria

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Abstract

Construction project underperformance in Nigeria's Niger Delta region are long-standing challenges in governance and delivery concern but the significance of stakeholder participation throughout the entire project lifecycle has received little empirical attention, especially in riverine public sector contexts. This study rooted in Freeman's Stakeholder Theory, aims to document and analyse active stakeholder participation patterns across the different stages in lifecycle of completed public sector construction projects in Ondo State, Niger Delta, Nigeria. It also to assess the implications of identified participation deficits for project performance. The study used an archival document analysis of records from 48 projects performed by OPADEC and UBEB between 2016 and 2024 to apply a systematic 18 roles of participation assessment framework across four life cycle stages. The findings show that involvement rates remained below 60% throughout the conception, design and planning and construction phases with 100% participation only noted at the commissioning stage. This pattern is interpreted as evidence of performative rather than substantive engagement in which public participation is concentrated at project completion events while the most crucial decision-making phases to project quality and community alignment receive little stakeholder input. The report advocates mandatory participatory governance protocols from project conception to commissioning, institutional accountability reforms for OPADEC and UBEB and the implementation of participatory monitoring frameworks that empower host communities throughout the project's lifespan.

Keywords: Archival document report, Construction project performance, Niger Delta, Project governance, Stakeholder participation.

1. Introduction

The Niger Delta region is Nigeria's primary center for oil extraction and serves as a source of national wealth, however it endures ongoing underdevelopment despite its economic significance. The scarcity of resources has been recognized as a primary catalyst for the violent conflicts that have disrupted the region, undermining Nigeria's national unity. This has also heightened demands for resource control and terrorist activities (Odusanya, *et al*.,2025). In this fragile socio-political climate, the provision of infrastructure encounters considerable obstacles. Studies conducted by Amadi and Higham (2018) and Amadi (2023) indicate persistent delays and the cessation of construction and highway projects across the Niger Delta. These problems are associated with the region's intricate riverine wetland topography, geotechnical difficulties, and deficiencies in governance and procurement frameworks. The technical difficulties of constructing on unstable, saturated soil are exacerbated by systemic problems in project governance, procurement deficiencies, and inadequate risk management, resulting in much poorer cost and time efficiency for riverine projects relative to those in upland regions. Subsequent analyses, encompassing regression and cognitive mapping, substantiate that non-compliance with best geotechnical practices and inadequate procurement processes are substantial determinants of suboptimal cost performance (Amadi and Higham, 2018; Amadi, 2023). Research underscores the prospective benefits of enhanced cost management, strategic planning, and superior technical oversight; however, persistent governance and procurement challenges inherent in the region's riverine project delivery system impede significant advancement (Okereke, *et al.,*2022; Iroha*, et al*., 2024).Ejiba, *et al.* (2016) analyse the Niger Delta, revealing that riverine populations have traditionally relied on fishing and agriculture, but oil and gas production continues to be a primary economic activity. Despite ample resources, many communities continue to face poverty, environmental degradation, and the disintegration of traditional livelihoods, consequently undermining local economies (Ejiba, *et al.,* 2016). Elisha (2023) study on the environmental and socioeconomic impacts in Niger Delta riverine communities indicates that significant infrastructure deficiencies, such as deteriorated transport networks, water system pollution, and inadequate access to essential services, considerably undermine community resilience. These factors lead to project delays,

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increased implementation costs, and sluggish public sector/community growth (Elisha, 2023). Abosede (2010) determined that numerous governmental intervention agencies, including NDDC, OPADEC, MDGs, ETF, and UBEB, had initiated hundreds of infrastructure projects throughout the years, encompassing schools, healthcare centers, administrative buildings, roads, bridges, and jetties. Project abandonment and delays adversely affect project value, stakeholder confidence, community stability, and prospects for sustainable growth. This study, grounded in stakeholder theory, reveals that inadequate involvement of essential actors—such as government agencies, contractors, consultants, community leaders, and regulatory bodies—typically results in conflict, scope modifications, negotiation delays, and community disturbances, thereby adversely impacting cost and time performance (Tor, *et al*., 2025; Maurer, *et al*., 2022). However, current existing Nigerian construction studies have predominantly relied on surveys and perception-based evidence. Consequently, limited empirical evidence documents actual stakeholder participation across the lifecycle of completed public-sector projects in riverine settings. Moreover, previous research has rarely quantified stage-specific participation or examined the governance implications of concentrating engagement at project completion rather than during conception, planning, and construction. This evidence gap constrains the development of context-responsive stakeholder governance mechanisms for Niger Delta infrastructure delivery.

Accordingly, this study pursues three objectives: (1) to identify and categories the principal stakeholder groups involved in public sector riverine construction projects implemented by OPADEC and UBEB in Ondo State between 2016 and 2024; (2) to document and measure active stakeholder participation across conception, design and planning, construction and commissioning using archival records; and (3) to analyze the implications of the observed participation patterns for construction project performance and formulate governance recommendations for public sector agencies operating in Niger Delta riverine communities.

2. Literature review

Subsequent Nigerian administrations have established various development intervention agencies to tackle the persistent underdevelopment of the Niger Delta. Obiam, *et al.,* (2022) contended that these initiatives have persistently failed, leading to profound frustration among local populations whose expectations have been continually elevated and subsequently dashed. Notwithstanding decades of government initiatives, the region persists in facing widespread poverty, environmental degradation and insufficient infrastructure which researchers characterise as structural violence inflicted through systematic neglect, particularly in this riverine area of the Niger Delta. Deprivation has consistently fuelled youth radicalism and intensified grievances against both state and federal authorities, as well as multinational oil firms (Onoyemeakpo, 2023; Ebeku, 2020). The origins of the Niger Delta's developmental crisis may be traced back to the pro-independence era. Abayomi, *et al*. (2021) assert that the Henry Willink Commission of 1958 identified the region as neglected, topographically difficult and characterized by major developmental disparities. Subsequent institutions, including the Niger Delta Development Board, Niger Delta Basin and Rural Development Authority, Oil Mineral Producing Areas Development Commission, and Niger Delta Development Commission, encountered limited institutional capacity, governance failures, corruption, and inadequate community engagement. Despite substantial project portfolios, many interventions have been abandoned, poorly implemented or misaligned with community priorities (Abosede, 2010; Ebeku, 2020; Owisi and Ikenga, 2025). Political interference, weak accountability and marginalization of local stakeholders during planning and execution have reduced institutional effectiveness and public trust (Isidiho and Sabran, 2015; Owisi and Ikenga, 2025). Furthermore, interventions frequently overlook the region's riverine geography and communities lived experiences, producing projects that appear visible but are insufficiently transformative (Onoyemeakpo, 2023; Ebeku, 2020). The Universal Basic Education framework seeks to promote equitable and compulsory basic education through UBEC and State Universal Basic Education Boards. However, infrastructural deterioration, underfunding and regional inequality constrain educational access in oil-producing riverine areas (Joy, 2025; Monday and University, 2024). Although large investments have supported classroom construction, rehabilitation, e-learning centers, sanitation facilities, workshops, libraries, clinics, playgrounds and boreholes (Idoko, 2024), evidence indicates that some intervention projects remain inadequately aligned with community needs (Onoyemeakpo, 2023; Owisi and Ikenga, 2025).

2.1 Stakeholder Participation in Construction Projects

In construction management, stakeholders are individuals or groups that can affect or are affected by the achievement of project objectives (Preble, 2005; Kivits and Sawang, 2021). Lin, *et al*., (2019); Tor, *et al.,* (2025) highlighted the internal stakeholders include clients, contractors, designers and suppliers, whereas external stakeholders include host communities, regulators, non-governmental organizations and the media. Primary stakeholders are directly involved in project execution while secondary stakeholders may lack contractual roles but can materially influence or be affected by project outcomes (Maddaloni and Davis, 2017). Stakeholder salience is shaped by power,

legitimacy and urgency. Accordingly, stakeholder identification, mapping, communication and impact assessment should be embedded in project planning. Excluding relevant stakeholders, particularly host communities has been associated with conflict, delay, cost inefficiency and project abandonment (Maddaloni and Davis, 2017; Tor, *et al.,* 2025; Adepoju and Obademi, 2023). The stakeholder environment in Nigeria's riverine regions includes clients, contractors, consultants, community groups, youth organizations, traditional leaders, regulators, financial institutions, and environmental organizations (Ali, 2025; Maliki and Ogedengbe, 2025; Ogunsanya, *et al*., 2019). Community actors can exercise substantial influence through their control of waterways, access routes and local security. Consequently, project success depends not only on technical competence but also on the management of stakeholder expectations, competing claims, communication and negotiation (Agbi, *et al*., 2023; Tor, *et al.,* 2025). Poor communication and weak collaboration remain important contributors to construction underperformance in Nigeria (Unegbu, *et al*., 2024; Igbokwe, *et al.,* 2025).

2.2 Theoretical Framework of the Stakeholder Theory

This study is anchored in Freeman's Stakeholder Theory which maintains that organizations and projects should account for the interests of parties who can affect or are affected by their objectives (Preble, 2005; Kivits and Sawang, 2021). Applied to construction, the theory suggests that systematic identification, meaningful engagement and balanced management of stakeholder interests enhance legitimacy, information quality, accountability and the likelihood of achieving project objectives. The framework is particularly relevant to riverine public sector construction where host communities, traditional institutions, regulators and intervention agencies possess different forms of power, legitimacy and urgency. It therefore provides the analytical lens for interpreting whether participation is substantive across the project lifecycle or merely visible at ceremonial completion.

3. Research Methodology

This study adopts an archival document analysis technique using a mixed methods design where qualitative archival records are the main data source and quantitative participation frequency counts are obtained through systematic coding of those records. This design was chosen because the research objectives require access to historical project records that capture actual stakeholder behaviour over the entire project lifecycles rather than retrospective opinions or intentions which would be capture through surveys or interviews. The two source organisations (OPADEC and UBEB) were purposefully chosen because they represent the primary government intervention agencies responsible for most of the public sector construction in Ondo State's oil-producing communities providing a representative cross section of Niger Delta public sector construction governance. OPADEC concentrates on infrastructure in oil-producing regions, whereas UBEB focuses on educational facility construction to ensuring that the sample includes both social infrastructure and community development projects. A total number of 48 completed projects undertaken from 2016 to 2024 were examined; all projects for which complete archival documents were available were included, resulting in a census of the accessible project population rather than a deliberate subset. Documents analyzed comprised project inception reports, stakeholder meeting minutes, site supervision records, progress reports, and project completion and commissioning certificates. Active participation was described as documented evidence of a stakeholder group's involvement in a designated project role at a specified lifecycle stage as recorded in official project documentation. Participation rates were computed as the proportion of the 57 total stakeholders (Divided into four categories: NGOs/activists, community members, government and pressure groups) that were actively involved in each function. A structured participation assessment framework was used based on construction project management literature with 18 discrete stakeholder roles distributed across four project stages: conception (4 roles), design and planning (5 roles), construction (8 roles) and commissioning (1 role). To ensure the validity of the participation rate figures was checked across various document types for each project that where accessible. The identified stakeholder population comprised of 57 actors classified as non-governmental organizations/activists, community members, government representatives, and pressure groups. For each role, the participation frequency was the number of stakeholders for whom documentary evidence of active involvement was identified. The participation rate was calculated as the frequency divided by the total stakeholder population (n=57), multiplied by 100. Evidence was cross-checked across available document types within each project to improve consistency. Descriptive frequencies and percentages established the participation pattern while qualitative thematic interpretation examined its governance and performance implications. The records did not contain uniform cost and schedule outcome measures for every project; the study interprets performance implications through documented participation patterns and relevant literature rather than claiming direct causal effects.

4. Findings and Discussion

Table 1 presents the distribution of the 57 stakeholders identified in the archival records. Community members constituted the largest category (63.2%), followed by government representatives (17.6%), pressure groups (12.2%) and non-governmental organizations/activists (7.0%).

Table 1: Nature of the Stakeholders

Stakeholders	Frequency	Percentage
Non-governmental organization/ Activists	4	7.0
Communities' members	36	63.2
Government	10	17.6
Pressure Group	7	12.2
Total	**57**	**100**

Source: Authors (2026)

The 48 projects comprised 3 commercial projects, 36 educational projects, 8 hospitals and 1 skills-acquisition center. Table 2 reports stakeholder participation across the 18 assessed roles and four lifecycle stages.

Table 2 (Appendix 1) presented the active stakeholder participation across project lifecycle stages which revealed the participation of stakeholders did not exceed 60% in any conception, design and planning, or construction role. The highest rates were recorded for needs analysis, identification of roles and responsibilities, and corrective action (58.8% each). Stakeholder analysis reached 56.9%, while identification of activities required to complete deliverables reached 54.9%. The lowest rate was recorded for influence over factors that could circumvent integrated change control (19.6%), followed by design and redesign of drawings (23.5%) and resource estimation (29.4%). The pattern indicates limited stakeholder involvement in activities that shape scope, design suitability, resource allocation, risk control and performance monitoring. Such deficits can weaken information sharing, project legitimacy, community ownership and the early identification of delivery risks. By contrast, participation reached 100% at commissioning, when all four stakeholder categories were represented.

4.1 Discussion of findings

The findings indicate that the stage specific pattern demonstrates that stakeholder involvement was uneven and generally low during the phases in which project objectives, design choices, resource requirements, risk responses and corrective actions were determined. Although this study does not establish a direct causal relationship between participation rates and measured cost or schedule outcomes, the observed deficits are consistent with literature linking inadequate engagement to misalignment, conflict, delay, cost inefficiency and weak service delivery (Ebekozien, *et al.,* 2024; Nguyen and Mohamed, 2021; Figueiredo-Filho. *et al.,* 2021; Gupta, *et al*., 2019). Stakeholder Theory gives these findings analytical significance. Projects that systematically identify and engage legitimate, powerful and urgent stakeholders are more likely to align decisions with user needs and manage risk effectively (Preble, 2005; Kivits and Sawang, 2021). In the present study, host communities formed the largest stakeholder category, yet participation remained restricted during the stages where their knowledge could most directly shape project relevance, design quality, constructability, access arrangements and implementation acceptance. This supports Maddaloni and Davis's (2017) argument that marginalizing local communities can increase conflict, delay and cost exposure.

The Niger Delta context intensifies this risk because community stakeholders can influence access routes, waterways, local security, and the social license to operate (Agbi, *et al.,* 2023; Tor, *et al.,* 2025). Their limited participation during project development is therefore not merely a procedural weakness but a governance and delivery risk. The most striking result is the contrast between sub 60% participation in all earlier roles and universal participation at commissioning. This pattern indicates performative participation: engagement becomes most visible at project completion, while the substantive decisions affecting project relevance, quality and sustainability occur with limited stakeholder input. The finding echoes evidence that formal participation mechanisms in Niger Delta interventions may function as instruments of legitimacy rather than genuine stakeholder empowerment (Isidiho and Sabran, 2015). Addressing this structural deficit requires participatory project inception, documented community representation on project oversight committees, stage-gate consultation requirements, accessible grievance and feedback mechanisms, and participatory monitoring throughout implementation. These requirements should be incorporated into the contracting, reporting, and accountability systems of OPADEC, UBEB and comparable public sector agencies. A stakeholder register, regularly updated throughout the lifecycle, would also support systematic identification and engagement of affected actors (PMI, 2017).

5. Conclusion and further research

This study examined documented stakeholder participation across 48 completed OPADEC and UBEB projects in Ondo State's Niger Delta riverine context. Participation remained below 60% across all assessed roles during conception, design and planning and construction but reached 100% at commissioning. The evidence therefore reveals a lifecycle imbalance in which stakeholder visibility at project completion is not

matched by meaningful involvement in earlier decision making and delivery activities. The findings indicate that effective riverine construction delivery depends not only on technical and environmental competence but also on inclusive governance across the project lifecycle. OPADEC, UBEB and comparable agencies should institutionalize mandatory stakeholder engagement plans, stakeholder registers, community representation on oversight committees, participatory monitoring, stage specific consultation records and independent feedback mechanisms. These measures would improve transparency, project legitimacy, risk identification and alignment with community priorities.

The study contributes methodologically by demonstrating the value of archival document analysis for examining recorded participation behaviour, thereby complementing the survey and interview approaches that dominate Nigerian construction management research. Empirically, it provides stage level participation data across 18 roles and four lifecycle stages for 48 completed public sector projects. Practically, it identifies the project stages and functions in which participation deficits are most pronounced, enabling agencies to target governance reform at conception, design, planning, risk management, monitoring, and change control activities. The study is limited to completed projects for which accessible archival records were available from two agencies in Ondo State. Documentary absence may not always indicate the complete absence of informal participation and consistent project level cost and schedule performance data were unavailable for causal testing. Further research should combine archival evidence with interviews, community-based inquiry and standardized cost, time, quality, utilization and maintenance indicators. Comparative studies across Niger Delta states and intervention agencies would also test the transferability of the participation pattern identified in the study area

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Appendix 1

Table 2: Active Stakeholder Participation Across Project Lifecycle Stages.

	Frequency of stakeholders				**Percentage of members participation**
	Non-governmental Organization/ Activists	**Communities/ General Public**	**Government**	**Pressure group**	
Roles of the Stakeholders in Projects Conception Stage					
Analyzing the needs in measurable goals	2	13	10	5	58.8
Review of the current operations	3	2	10	5	39.2
Financial analysis of the costs and time benefits including budgets.	0	10	10	2	43.1
Stakeholder analysis, including users and support personnel	4	10	10	5	56.9
Role of the Stakeholders in Projects Design and planning stage					
Design and re-design of the drawing in accordance	0	2	10	0	23.5
Identifying the activities needed to complete the deliverables	1	15	10	2	54.9
Estimating the resource requirements for the activities	0	10	5	0	29.4
Risk planning	2	8	10	0	39.2
Identifying roles and responsibilities of others	2	15	10	3	58.8
Roles of the stakeholders in projects Construction Stage					
Procurement of materials and equipment	0	16	0	3	37.3
Coordinating people and resource	0	17	0	0	33.3
Performing activities of project in accordance with project management plan	0	20	0	2	45.1
Update of risk analysis	0	15	5	0	39.2
Measuring the ongoing activities	0	11	5	0	31.4
Monitoring project variable (cost, time and others) against the project management plan and performance baseline	0	12	10	0	43.1

	Frequency of stakeholders				**Percentage of members participation**
	Non-governmental Organization/ Activists	**Communities/ General Public**	**Government**	**Pressure group**	
Identify corrective actions to address issues and risks properly	4	11	10	5	58.8
Influencing the factors that could circumvent integrated change control	2	3	2	3	19.6
Commissioning of the projects	4	36	10	7	100.0

Source: Author (2026)

Strategies to Enhance Public-Private Partnerships (PPPs) Effectiveness in Managing Infrastructure Project Delays in the Western Cape, South Africa

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Abstract

The delivery of public sector infrastructure projects is characterized by poor performance consistently, with persisting delays that lead to budget overruns in the South African construction industry. While causes of delays in infrastructure projects have been widely demonstrated in previous studies, the use of Public Private Partnerships as a strategic mechanism to deliver infrastructure projects has been highlighted with benefits of minimizing delays through private sector innovative operational excellence. This study investigates causes of delays in Western Cape infrastructure projects and reports their minimization strategies through PPPs. Through a qualitative research design and purposive sampling method, semi-structured interviews were conducted with four experienced professionals who actively participated in Public-Private Partnership infrastructure projects delivery. The data was analyzed using thematic analysis. The findings reveal that delays are multidimensional and systemic, mostly caused by bureaucratic inefficiency, socio-political interference, fragmented interdepartmental coordination, and scope mismanagement. Results further suggest that strategies to improve PPP projects can be strengthened through institutionalization of social facilitation mechanisms, enhanced interdepartmental coordination and accountability via structures, such as the "*stage gate process*", capacity building and knowledge transfer within government institutions, improved communication and transparency among all the project stakeholders. These insights can be applied in improving the PPPs frameworks to achieve timely, inclusive, and sustainable infrastructure provision in the Western Cape.

Keywords: construction project delays, infrastructure development projects, public-private partnerships

1. Introduction

Long-standing research considers infrastructure development as a critical driver of socio-economic growth, improved service delivery, and sustainable development in developing economies (Srinivasu and Rao, 2014; Windapo and Umeokafor, 2023). To achieve these objectives, the construction sector plays a strategic role through the development of economic and social infrastructure (Thacker *et al*., 2019). Consequently, the construction industry is recognized for its substantial contribution to socio-economic development, employment creation, and Growth Domestic Product (GDP) (Ofori, 1997; CIDB, 2025). However, apart from socio-political disruptions, such as community protests and construction site invasions, which have increasingly contributed toward delays in infrastructure delivery (Aigbavboa *et al*., 2022), public infrastructure projects are reported with substantial cost overruns, implementation inefficiencies, and project delays in South Africa (Cosa, 2020). Existing studies attributed these delays to factors such as bureaucratic inefficiencies, resource constraints, limited technical resources, institution fragmentation, inadequate planning, procurement challenges, political interference, and weak stakeholder coordination (Nwafor *et al*., 2019; Ekwuno & Nel, 2022).

Public-Private Partnerships (PPPs) have emerged globally as an alternative infrastructure procurement and delivery approach aimed at leveraging private sector expertise, financing, innovation, and management efficiency in the provision of public infrastructure (Delmon, 2021). Research exists that explored the delivery of infrastructure projects through PPP in South Africa (Aigbavboa, Liphadzi and Thwala, 2014; Dlamini and Botes, 2022). However, there is limited research that examined their in strategies in managing infrastructure project delays within the Western Cape public sector context. To address this gap, the study investigates the role of PPPs in managing infrastructure project delays in the Western Cape, South Africa. The study specifically aims to identify the major causes of delays and explore strategies that can strengthen the role of PPPs in improving infrastructure project delivery.

2. Literature Review

Public infrastructure projects are inherently complex due to the magnitude of each project, its exposure to the surrounding community, and social-political implications (Radujkovic and Sjekavica, 2017), which complicates their successful delivery. As a result, these

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projects are known for exceeding budget and time, poor quality and service delivery, owing to higher levels of infrastructure project delays (Ahmad *et al.* 2020). According to Ekwuno and Nel (2022), delays have become a common challenge in all areas of government, with problems in payment delays and inefficiencies in procurement and planning processes affecting project schedules. Ekwuno and Nel (2022) further suggested that various delays in public sector projects involve critical and non-excusable delays that are linked to delayed payments, procurement irregularity, and ineffective interdepartmental communication. Critical delays are those that have an impact on the project's completion, such as milestone dates, while non-excusable delays are those that are predictable or within the contractor's control, such as poor planning, among others (Gajare *et al,* 2015). To address these delays, Public-Private Partnerships (PPPs) have been proposed as a mechanism to address infrastructure delivery challenges (Memari, Ogunmakinde and Skulmoski, 2025).

2.1 Causes of Infrastructure Project Delays in the Western Cape

The completion of infrastructure projects on time, under budget, with the best quality, and safely, are all shared objectives among contract parties. However, it is well known that delays pose a serious threat towards the success of projects (Ahmad *et al* 2020). For example, in Hong Kong, Chan and Kumaraswamy (1997) found that insufficient risk management and supervision, unanticipated site conditions, slow decision-making, variations initiated by the client, and work variations were major causes of delay in construction projects. While in Norway, Zidane *et al*. (2018) found that poor planning and scheduling, slow decision making, bureaucracy within project organizations, shortage of resources, poor communication and coordination between parties, slow inspections by consultant, design changes during construction and lack of commitment of owner, Gebrehiwet *et al*. (2017) reported that corruption, missing utilities at site, inflation in materials prices, lack of material quality, late issue of design documents, delayed delivery of materials, poor site management and performance in Ethiopia. Similarly, studies found that causes of delays in infrastructural delivery were lack of capacity, poor planning and oversight, budgetary limitations, corruption, and lack of public participation from provincial governments, construction site invasions from construction mafias and violent protests in South Africa (Ekwuno and Nel, 2022; Alamu *et al*.,2024). While these studies show similar persisting problems in internationally, some studies suggested that public-private partnerships possess the opportunity to enhance the delivery of infrastructure projects (Abdel Aziz, 2007). In the construction project context, other empirical studies have demonstrated the benefits of PPP, such as increased project success rates through effective risk management, private-sector knowledge, improved communication processes, improved flexibility and leadership, reduced delays, innovative funding options and good governance practices in Canada and Ghana (Zhang *et al.,* 2019). Liu *et al*., (2015) conceptualized a dynamic life-cycle performance measurement framework for PPP infrastructure projects. This framework involves five dimensions, such as stakeholder satisfaction, strategies, processes, capabilities and stakeholder contribution, which were empirically validated in (Liu et al. 2016). However, the framework does not address issues like delays and their management.

2.3 Strategies to strengthen the role of PPPs for managing infrastructure project delays

While the global growth of PPPs may be evidence that conventional approaches to infrastructure development are insufficient, shifting risks to the private sector, increasing transparency, and providing access to private resources and experience are recognized to offer benefits over traditional project delivery methods (Nguyen, 2017). Nevertheless, the prospects of PPPs in minimizing delays need to be exploited by adopting frameworks that are anchored in value-creation, joint governance, and alignment of stakeholders (Ndevu, 2021). Harris (2023) suggested that PPPs overall and infrastructure projects specifically must be more robust, guarantee equitable distribution of risk, cost, and resources among the stakeholders to achieve financial objectives. In Nigeria, Alamu *et al.,* (2024) found that strengthening the legal and regulatory framework within which PPPs are executed, increasing the skills and capacity of the public and private sectors, contributed to the success of PPP in delivering infrastructure projects. Alamu *et al.,* (2024) further reported that extending access projects and long-term financing, facilitating responsibility and transparency in the process of acquiring and executing PPP projects, and encouraging stakeholder involvement in the success of PPP projects are crucial. These findings are in line with the general international guidelines that encourage infrastructure project delay reduction efforts, including structured risk sharing, in which delay-related risks are distributed among the parties most capable of addressing them and performance-based contracting (Krishandutt, 2021). Such strategies promote a proactive approach to timely project performance and accountability within the PPP, which is relevant for developing countries where the institutional and financial constraints often delay project implementation. Although these strategies have been studied in various global settings, more research is necessary to determine whether they are applicable in the Western Cape, especially in view of the region's unique capacity and regulatory issues.

3. Research Methodology

A qualitative research design underpinned by an interpretivist paradigm was utilized to explore the role of Public Private Partnership in managing delays during infrastructure projects delivery. The main objectives of this study were to identify causes of delays in infrastructure projects and PPP strategies that can be used to manage the delays in the Western Cape. Prior to data collection, ethical considerations were strictly followed, including informed consent received from participants, agreement on confidentiality and voluntary participation of respondents. The purposive sampling method was used to select respondents from a large established contractor and the Department of Public Works to ensure the relevance of their responses to this research.

Semi-structured interviews were conducted with four professionals and stakeholders in the Western Cape, who were involved in the delivery of infrastructure projects using PPPs. While the sample of participants may seem small, Boddy (2016) argues that a small and well-chosen sample can be sufficient for a qualitative study so long as it is fit-to-purpose. Further, Mason (2010) argued that the sample size in qualitative research becomes irrelevant because the value of the study is based on the quality of the data. Lim (2025; p225) concurs with this view by suggesting that "*sample size in qualitative research is best treated as an analytical judgment about adequacy rather than a number derived from a statistical formula*". Hence, this research offers analytical and contextual insights that are relevant for infrastructure project delivery and PPPs despite the small sample. Moreover, the extensive experience of the participants in both infrastructure project delivery and PPPs contributes to the relevance and validity of the data collected. This is also supported by Chileshe, Rameezdeen and Hosseini (2015) in their study, which involved a small sample of eight interviews within the construction management research discipline.

The data was analyzed using thematic analysis, where themes were identified, categorized, and patterns were recognized. Supporting this, Ahmed *et al*., (2025) suggested that thematic analysis is good at identifying, analyzing and reporting patterns and themes in qualitative datasets. The analysis highlighted various common themes that were indicative of the systemic causes of delays, institutional weaknesses and potential reforms to improve the performance of PPPs. These themes emerged inductively through the narratives of the participants that were validated by their recurrence in the various interviews, as compared to the literature, to ascertain the validity and conceptual comparison. This analytical process enabled the study to correlate empirical evidence with its theoretical background.

4. Findings and Discussion

4.1 Profile of Interviewees

Table 1 provides the demographic profile of the participants who contributed to this study. The data emanating from the four structured face-to-face interviews are presented and coded as participant A, B, C and D to protect the privacy of each participant. This involved 2 Contracts Managers from the private sector, the Deputy Director and the Project Manager from the public sector. The selection of these participants was purposive with the aim of guaranteeing diversity of views within the two sectors (public and private) of the construction and infrastructure ecosystem in the Western Cape. This diversity is supported by Chileshe, Rameezdeen and Hosseini (2015) who argue that it is a fair representation of construction organizations involved in a range of construction activities, from strategic to overall construction project delivery.

All participants possessed more than 15 years of pertinent experience, which reflects a seasoned level of knowledge regarding policy level and operational

Table 1: Profile of Interviewees

Participant Code	Sector	Position / Role	Years of Experience	Primary Area of Work	PPP Experience Level
A	Private	Contracts Manager (Infrastructure Projects)	25 years	Project management and delivery of infrastructure in housing and municipal developments.	High
B	Private	Contracts Manager (Civil Works Division)	24 years	Infrastructure project management, residential and civil works	Moderate
C	Public	Deputy Director (Provincial Department)	25 years	Community development, intergovernmental coordination	Moderate
D	Public	Project Manager (State Owned Enterprise – Energy Sector)	17 years	Technical project management and coordination in renewable energy, transmission projects and maintenance works.	High

Source: Researchers

realities in the South African construction industry. The inclusion of both private and public participants guaranteed that the study recorded various aspects of PPP implementation, including contract formulation and technical execution (private sector) and social facilitation and governance oversight (public sector.

4.2 Key Factors Contributing to Infrastructure Project Delays

The findings show that even though PPPs have a high potential to promote speedy infrastructure project delivery and enhance accountability within the Western Cape public sector, the key challenges in their implementation include bureaucratic inefficiency, poor coordination and fragmented governance and socio-political interference which significantly contributes to project delays.

4.2.1 Bureaucratic and institutional inefficiencies

Most of the participants described major causes of PPP infrastructure project delays as bureaucratic inefficiencies and procedural complexity. This was mainly associated with the procedural inflexibility of government structures in which rigid approval regimes within governments and delays in administrative responses are more likely to increase project durations. The respondents, especially those employed in the public sector, focused on the rigid administrative procedures of the Public Finance Management Act (PFMA) and Municipal Finance Management Act (MFMA) models that often require multiple stages of approval before projects can be implemented. Participant C reported that "*Even with approved funding we still have to go through internal committees, supply chain management, and then Treasury and all of that takes weeks or months*."

According to Participant D "…*the long procurement procedures and unnecessarily complex compliance requirements are stalling the project schedule even before the commencement of work*." However, Participant A suggested that "*by the time the paperwork is done, the contractor prices and material costs are already outdated*". This highlights the time-consuming aspect of tender adjudication and contract closing to frequently creates cost uncertainty and cost inflation.

These findings reveal how "bad policy" is not a cause of administrative inefficiency but rather the outcome of over-regulation and lack of process integration that undermines the timeliness of infrastructure delivery. The responses from the participants note that excessive procedural compliance, which is intended to be accountability-facilitating, may frequently lead to stagnation in schedules. These findings are linked to Zidane *et al*.'s (2018) study that found that bureaucracy within project organizations, as well as poor planning and scheduling, are contributing factors that lead to delays in infrastructure projects, even within the PPP project delivery framework. Research by Ekwuno and Nel (2022), also discovered that the fundamental obstacles to timely infrastructure delivery in South Africa are inefficiencies in governance and inefficient administrative planning.

4.2.2 Poor coordination and fragmented governance

The issue of a lack of coordinated efforts within the government departments involved in delivering infrastructure was a consistent theme among all participants. This fragmented approach was widely regarded as a key contributor to project delays. Participant D noted that the line departments tend to handle projects in a silo, which translates to inconsistent communication, duplication of efforts, and slow decision-making. The participant described an energy project that was halted because there was no collaboration between the utility company responsible, the provincial roads department and the local municipality, which resulted in significant scheduling conflicts and the delay of project completion.

Participant A also added that multi-agency dependencies (e.g., environmental approvals, land use permits and funding transfers) are not handled simultaneously but in a sequence, which results in duplication and loss of time. Participant B further noted that there is no single entity that assumes ownership of the entire timeline, thus accountability is compromised. This fragmentation highlights a structural governance challenge of limited policy coherence and cross-sector collaboration despite robust frameworks in theory. It further highlights poor interdepartmental coordination and inclusion of private stakeholders as a structural challenge of governance. Kwofie, Ellis and Opoku's (2021) study found that when good communication processes exist between PPP parties, governmental support exists, activities among stakeholders are efficiently coordinated, and flexibility in contractual arrangements exists, this contributes positively to improving PPP performance.

4.2.3 Socio – political interference

Socio-political interference was identified as one of the major sources of delays in infrastructure projects. According to both the private and public sector participants, local labor conflicts, community unrest, and political influences are some of the factors that tend to derail project schedules. Participant C said that "…*protests or political leveraging can halt project progress despite technical and financial preparations being completed*." Moreover, various studies have highlighted construction site invasions from construction mafias and violent protests in South Africa as a recurring phenomenon causing challenges in the successful delivery of infrastructure projects (Ekwuno and Nel, 2022; Alamu *et al*.,2024), which is confirmed by Participant A, reporting that "construction mafias,"

are some of the reasons that delayed projects or impose costly suspensions of work. However, Participant D noted that political conflicts had held up approvals for months. Among most of the participants, weak stakeholder engagement was a symptom and a cause of socio-political interference, in which the lack of communication and inclusion in the decision-making process creates mistrust and opposition. This is supported by Zidane et al.'s (2018) study which identified poor communication and coordination between parties as a contributing factor for delays.

4.3 Strategies to Enhance PPP Effectiveness in Infrastructure Delay Management

The analysis showed that there are various interrelated strategies that can enhance PPP effectiveness in infrastructure project delay management: improved coordination and accountability, enhanced communication and stakeholder alignment and integration of social facilitation mechanisms.

4.3.1 Improved Coordination and Accountability

Fragmented accountability is a structural weakness that was noted multiple times by participants. Participant D suggested the implementation of "*Stage-Gate Project Management*" in all government agencies to introduce accountability and impose deadlines. Matha (2021) defines the stage-gate process as a project management method where a project is broken down into stages that are separated by "gates", which are strict project reviews conducted between each stage in the project that determines, whether the project team is ready to proceed to the next stage of the project. Participant D reported that "…*had each department been obliged to sign off within a definite time, and the progress reviewed on record, we would not have so many open-ended delays. Stage-gate reviews hold each individual accountable*." While both Participant D and Participant C shared similar sentiments, Participant D further stated that even the most effective private partner could not fully undo the indecisiveness of the public sector in the absence of rigid coordination. Hence, participants from the private sector urged that joint monitoring structures should be established, where both sectors are jointly responsible for enhancing discipline and predictability in project execution. This is further supported empirically by Zhang et al. (2019) who found that PPP projects with project control mechanisms demonstrated better schedule performance compared to projects delivered through the traditional procurement methods. Further, Bwanali and Rwelamila (2015) observed that properly structured PPPs with improved leadership and flexible contractual relationships, result in fewer delays. Collectively, these studies suggest that embedding formal coordination and accountability mechanisms, such as the stage-gate process into PPP governance structures could potentially contribute to reducing project delays in the Western Cape.

4.3.2 Enhanced Communication and Transparency

Improved communication and transparency were considered critical towards ensuring trust, alignment, and dispute avoidance among all stakeholders in a project. Both public and private sector participants indicated that accessibility to open communication channels and transparent reporting systems would reduce the level of misinterpretations and help to promote accountability. While Participant B indicated that "…*clear communication prevents local conflicts from escalating as disputes usually arise as a result of misunderstandings between contractors, consultants and officials*," Participant A reported "…*that effective alignment between consulting engineers, contractors, and government officials avoids duplication and rework. We require regular updates on the progress in real-time and open lines of communication between departments. When we all understand what is going on, there are less surprises*." In line with these findings, Kwofie, Ellis and Opoku's (2021) study found that when good communication processes exist between PPP parties, governmental support exists, activities among stakeholders are efficiently coordinated, and flexibility in contractual arrangements exists, this contributes positively to improving PPP performance.

The value of joint progress meetings and transparent reporting was also emphasized by both participant C and D. This reinforces the view that communication is a direct determinant of project schedule performance. These findings collectively suggest that formalizing communication protocols and transparency mechanisms within the PPP frameworks in the Western Cape could serve as a practical strategy for reducing project delays.

4.3.3 Integration of social facilitation mechanisms

The participants highlighted that social facilitation must be institutionalized in the context of PPPs to avoid community-based disruption. They contended that social facilitation was to be applied as a risk management tool rather than a compliance checkbox. According to Participant C, "…*social facilitation should not be a secondary consideration; it should form part of the PPP design*". The participant further explained that" *by having community development workers on board early, you will identify tensions early enough and resolve them before they rise. Social facilitation must be functional rather than symbolic*."

Participant C further emphasized the need to incorporate social facilitation units, like the Community Development Workers Programme (CDWP), as part of the PPP governance frameworks. The participant gave an example that protests and site disturbances can often be avoided by early intervention by community development workers, citing a transport project where the local conflict was removed through

co-operation between community development workers, councilors, and contractors.

5. Conclusion and Further Research

The purpose of the study was to establish the ability of PPPs as a practical mechanism to govern and reduce delays in the delivery of infrastructure by the government in the Western Cape. The findings show that causes of delays have complex and multidimensional aspects, including administrative, social and governance aspects. Issues of bureaucratic inefficiency and fragmented coordination continue to be problematic, and socio-political risks continue to be a constant threat to the sustainability of infrastructure projects. The findings suggest that application of PPPs incorporates innovation, accountability, and performance management of the private sector with social inclusion and management control of the public sector. Community liaison structures, and improved governance mechanisms are very critical in achieving this balance. This study reveals that PPPs can be viewed as instruments of collaborative governance that can increase the institutional responsiveness, correspondence of stakeholders and public value creation in South Africa in the context of infrastructure provision.

Future research should consider expanding the participant base to include local municipalities, National Treasury PPP unit representatives, and community organizations, to capture a broader range of stakeholder perspectives. Comparative studies conducted across different provinces and countries would further assist in determining whether the patterns identified in this study are specific to the Western Cape or reflect wider national and international trends in PPP implementation. Given the findings of this study regarding the importance of community engagement and socio-political risk, future research should also investigate the cost-efficiency of incorporating social facilitation units into PPP frameworks. Finally, the potential of digital project management systems to enhance transparency and real-time monitoring of PPP performance represents a relevant and underexplored area that warrants further investigation.

6. Disclosure

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Geo-Spatial Territorial Conflict Among Residents in Sub-Saharan Africa – A Perspective from Oyo State, Nigeria

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Abstract

Geospatial territorial dispute is an emerging spatial planning issue in most states and countries in sub-Saharan Africa (SSA) and Nigeria inclusive. This study conducts a thematic review of existing literature to examine the geospatial foundations of territorial conflicts in Oyo State, Nigeria. Synthesis involves data from peer-reviewed articles, GIS-based studies, government documents, and case-study studies. Analysis indicates that the absence of coordinated spatial data systems and poor institutional coordination are contributing factors to the persistent conflicts in Peri-urban areas of Oyo State. Research findings indicate the exploitation of authority by local elites, violations of customary land rights, and the ineffectiveness of dispute resolution systems. The evidence suggests that Geographic Information Systems (GIS) used in participatory boundary demarcation and tenure regularization can reduce conflict by enhancing the transparency and accuracy of planning. Customary authorities, including family heads and traditional rulers, persist in exerting influence over land allocation and utilisation. The disparity among professionals regarding the Nigeria Land Use Act of 1978 should be visited to align with the advocacy for the adoption of modern technology (GIS tools) in order to reduce conflict. The study recommended policy for spatial reforms, multi-stakeholder engagement, and inclusive land registration programs that will mitigate territorial disputes, spatial justice and geospatial governance for a sustainable urbanization in Oyo State and Nigeria in general and other similar urbanizing contexts.

Keywords: Geo-spatial analysis, Land governance, Oyo State, Territorial conflict

1. Introduction

Territorial and spatial conflicts are a defining characteristic of Nigeria's changing urban environment, particularly in areas experiencing accelerated demographic and infrastructural change, with growing urbanisation in Sub-Saharan Africa Countries. Land is used more and more as a resource and source of conflict, representing identity, power, and economic opportunity. Oyo State in South-western Nigeria serves as a notable example. Oyo's population surpasses 7.8 million, with an annual urban growth rate of about 4.5%. This rapid urban expansion is generating considerable land-related tensions, particularly as it intrudes upon historically rural and peri-urban communities (National Population Commission 2023; World Bank, 2022). In cities such as the capital city of Ibadan, land has ceased to be defined classically as space. The land is defined by vying interests, vague tenures, and ineffective institutions. Nigeria's dual land tenure system is a source of the root cause of regional conflict because it combines statutory land titles as regulated by national law and traditional ones as regulated by tradition, held by family lineages and local chiefs. This duality makes room for contradictory claims and the very same piece of land "sold" multiple times under different jurisdictions. Olajide, et el (2021) clarify that the system creates a space of grey where legality intersects with legitimacy. In peri-urban areas like Lagelu and Akinyele, these encounters are not only bureaucratic problems but materialize as physical confrontation, eviction, and long-drawn-out legal conflicts. Locals usually maintain that they bought the land legally but are confronted by new "owners" or traditional leaders challenging the legitimacy of their possession. The grave lack of integrated spatial data systems exacerbates the issue. Cadastral records, where they do exist, are stale or maintained inconsistently (Adegun, 2023). Most stay in paper format, circulated among ministries with little or no interlinking. Electronic ventures such as the Oyo State Geographic Information System (OYOGIS) are attempting to map this challenge by mapping geospatial and placing it in electronic format; however, the platform is incomplete and lacks proper resources (Adegun, 2023; Fabiyi, 2020). The absence of real-time data integration makes planning decisions tend to rely on unverifiable or disputed information for noble purposes. Besides that, planners and users must navigate border areas without access to

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contemporary cartographic techniques, something that undermines trust in land administration.

Grey and Amadasun (2023) posit that without transparent and enforceable spatial governance, the land ends up being a locus of informal bargaining, patronage, and exploitation. The vulnerability is particularly evident in peri-urban areas, where the intersection of urban and rural dynamics results in communities facing legal and administrative uncertainty. This context prompts critical enquiries regarding spatial justice within Nigerian urbanism. Who possesses the entitlement to urban space? Which claims to land are acknowledged, and which are rejected? Addressing these questions necessitates not only policy reforms but also a fundamental re-evaluation of land administration, integrating geospatial technologies, participatory mapping, and transparent land registries. Fabiyi (2022) supports the integration of GIS tools into local governance systems to enhance conflict detection, clarify spatial boundaries and promote inclusive decision-making processes Adegun, 2023). The situation in Oyo State exemplifies broader national challenges in land governance rather than being an isolated regional issue. This serves as a case study for the entrenchment of spatial conflict within the narrative of urbanisation in Nigeria.

2. Literature review

Analysing geospatial territorial conflict among residents in Oyo State necessitates a solid foundation in pertinent theoretical frameworks. Human territoriality, as articulated by Sack (1986), refers to the efforts of individuals or groups to influence, affect, or control people, phenomena, and relationships through the delineation and assertion of control over a specific geographic area. In rapidly urbanising contexts such as South-western Nigeria, land serves as a fundamental component of identity, social power, and economic leverage. Territorial claims over land represent not only economic interests but also socio-political actions rooted in cultural norms and historical relationships.

Land tenure theory serves as an essential theoretical basis for this study. This analysis elucidates the definitions, holdings, and transfer mechanisms of land rights within a society. Nigeria's land governance exhibits a dual system that includes both statutory and customary tenure regimes. The Land Use Act of 1978 instituted statutory control by assigning ownership of all land to state governors; however, customary authorities, including family heads and traditional rulers, persist in exerting influence over land allocation and utilisation. This duality resulted in overlapping claims, frequently leading to extended disputes (Agunbiade et al 2021). The lack of harmonisation among these systems has resulted in legal ambiguity and intensified territorial disputes.

Spatial conflict theory provides a framework for analysing the unequal distribution of space and the resultant competition and confrontation that arises from this distribution (Agunbiade et al. 2021). In Oyo State, territoriality is frequently manifested by families or community groups aiming to preserve control over ancestral land despite urban encroachment and state interventions. Expressions of territoriality intensify in peri-urban areas, where rural and urban dynamics converge. Boundary disputes represent a notable form of geo-spatial conflict, disputes frequently occur as a result of ambiguous land parcel boundaries, obsolete cadastral records, and conflicting claims from both statutory and customary systems. Residents in Akinyele and Lagelu Local Government Areas frequently report on-going disputes concerning land that was previously used for agriculture but now designated for residential development (Fabiyi, 2020) (Figure 1 and 2).

Zoning serves as a planning instrument that allocates land for designated purposes, including residential, commercial, agricultural, or industrial uses. Zoning in Oyo State is subject to inconsistent enforcement. In many cases, land zoned for one purpose is repurposed informally for another (Olaniyan, 2017). Developers and speculators frequently collaborate with local

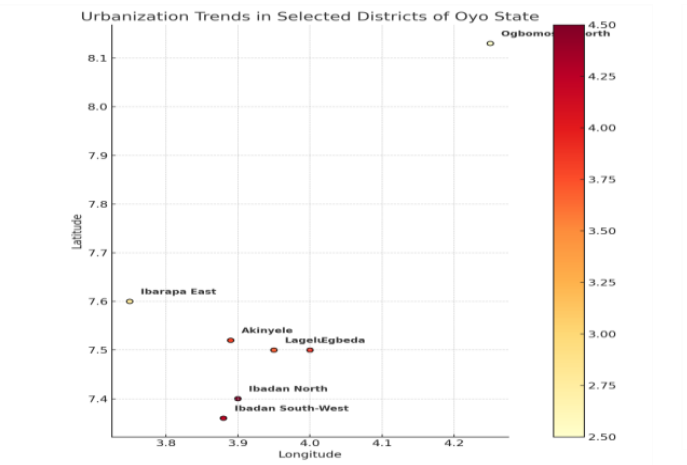

Figure 1: Urbanization trend in Oyo State

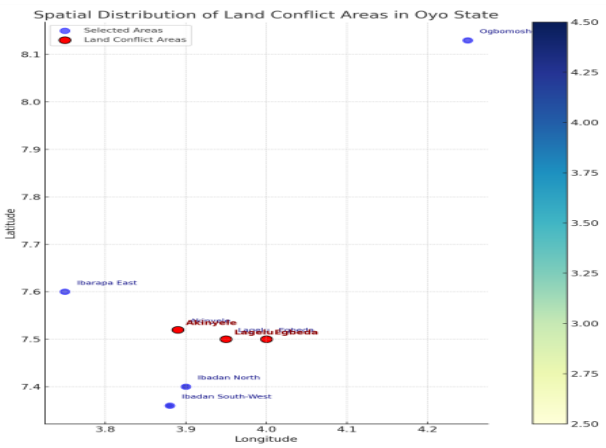

Figure 2: Spatial Distribution of Conflict Area in Oyo State

Source: Generated using Python programming, 2025

officials to secure unauthorised permits, thereby evading established zoning regulations, these compromise planning objectives and frequently results in land use conflicts.

Many studies have investigated geo-spatial conflicts in Nigeria, identifying Lagos and Ibadan as major areas due to their accelerated urban development. Afinowi, (2022) noted that in Lagos, Nigeria, conflicts often stem from the growth of informal settlements, discrepancies in land titles, and inadequate enforcement of planning regulations. Fabiyi (2020) illustrated that inadequate spatial data infrastructure in Ibadan obstructs efficient land administration. The lack of integrated GIS systems results in planners frequently depending on out-dated paper maps, which are insufficient for addressing boundary issues in evolving urban settings. The Oyo State Geographic Information System (OYOGIS) was created to tackle this issue; however, its implementation has been inconsistent and inadequately coordinated. In Nairobi, informal settlements have developed on state and communal land (Andoh, 2024), resulting in recurrent conflicts between residents and authorities. De Satgé & Watson (2018) illustrates that spatial conflict in Johannesburg, South Africa is fundamentally linked to the historical context of apartheid-era land policies, further exacerbated by contemporary governance deficiencies and market-oriented development practices. The global cases illustrate the universality of spatial conflict in the contexts of rapid urbanisation and institutional duality.

The literature offers important insights into land and spatial conflict; however, notable gaps remain. Most Nigerian studies primarily address land conflict as a legal or administrative matter, with minimal involvement in geospatial analysis. This research addresses the gap by using GIS tools to delineate the spatial aspects of territorial conflict in Oyo State. This approach enhances the comprehension of geographic patterns and hotspots of disputes, providing data-driven solutions. Secondly, current research predominantly emphasises urban centres, overlooking peri-urban and transitional zones where conflict occurs. Finally, there is insufficient discourse on spatial justice in the context of Nigerian planning, spatial justice as a framework that examines the distribution of benefits and costs associated with land development, equitable planning, conflict resolution, promoting participatory land governance that encompasses all stakeholders, particularly the most vulnerable populations. This research offers a detailed analysis of geospatial territorial conflict and suggests practical solutions for resolving land disputes and improving planning practices in South-western, Nigeria.

2.1. Study Area

Oyo State is situated in South-western Nigeria, ranks among the most urbanised regions of the country and serves as a significant socio-economic centre within the Yoruba-speaking population. The population was estimated at over 7.8 million in 2023 (National Population Commission 2023), with urban growth rates between 2.5% and 4.5% in its central districts, Ibadan, the capital of the state, ranks as the third most populous city in Nigeria and serves as a cultural, political, and administrative hub characterised by a growing peri-urban landscape. The socio-spatial structure of Oyo State demonstrates a complex relationship between urban growth and established rural communities. The land conversion process frequently lacks regulation, resulting in disputes regarding zoning, resettlement, and resource allocation. The territorial conflict in Oyo State has a historical foundation, particularly in regions where urban and customary land claims converge. In Yoruba societies, land was traditionally held communally and managed by family heads or representatives of lineages. The transition to statutory land administration systems during the colonial and post-independence periods disrupted this pattern. After the enactment of the 1978 Land Use Act, governors were granted authority over land management. In practice, customary authorities maintained de facto ownership, particularly in peri-urban areas; this duality has endured and serves as a primary factor in spatial conflicts. In districts such as Lagelu and Akinyele, family-owned lands frequently undergo multiple resales by various claimants, leading to overlapping titles, forced evictions, and, in certain instances, physical violence (Olajide et al., 2021).

Territorial disputes within the state can be categorised into three main types: intra-family conflicts regarding inheritance and ownership, inter-community boundary disputes, and clashes between residents and government concerning resettlement and compensation. Intra-family disputes are common in the older sections of Ibadan and Oyo towns, characterised by a lack of formal land documentation and reliance on orally transmitted traditional claims. Inter-community conflicts frequently emerge from unclear or obsolete administrative boundaries, as demonstrated by on-going disputes along the borders of Lagelu and Egbeda LGAs. Conflicts between residents and state actors have increasingly emerged in recent urban renewal programs, where infrastructure initiatives like road expansion or housing schemes result in forced displacement without sufficient compensation or consultation (Adegun, 2023).

The political-administrative framework of Oyo State consists of 33 Local Government Areas (LGAs) and various traditional domains overseen by Obas (kings) and Baales (chiefs). The LGAs hold statutory responsibilities for local planning and development; however, traditional leaders continue to exert considerable influence over land allocation, particularly in rural and peri-urban areas. The dual authorities frequently function independently, exhibiting minimal coordination and lacking integrated

land registry systems. Thus, conflicts arise not only from physical encroachment but also from failures in systemic governance. Traditional governance structures, notably the role of Mogaji (family heads) and land allocation committees under the Oba's authority continue to exert significant influence on the social legitimacy of land ownership. These structures do not receive formal acknowledgement in state planning policies. The on-going exclusion of traditional actors from formal land management processes perpetuates mistrust. This reinforces informal practices like undocumented land sales, leading to territorial disputes when urban development projects commence (Agunbiade et al., 2021). The geospatial dynamics of territorial conflict in Oyo State are intricately linked to its historical, administrative, and demographic contexts.

3. Methodology

This study employs a methodology grounded on a thematic analysis of a corpus of literature, spatial data, and empirical accounts pertinent to the geospatial territorial contest in Oyo State, Nigeria. This study, not primarily field-based, employs a mixed-methods approach through integrating qualitative and quantitative sources of evidence to develop a contextual, evidence-based analysis. This type of design is most appropriate because the intricate, multi-faceted character of land conflicts can be best comprehended by a synthesis of spatial, social, legal, and institutional viewpoints. The objective is to map conflict patterns as well as analyze drivers that drive these conflicts and the planning tools available for their mitigation. The research uses a variety of data sources. The primary dataset consists of Geographic Information Systems (GIS) data obtained from the Oyo State Geographic Information System (OYOGIS), which includes parcel-level land use types, zoning overlays, and cadastral information. Satellite imagery from Google Earth Pro and Sentinel-2 has been utilized in an effort to map the informal settlements and track land transformation processes over a time frame, specifically between 2015 and 2023. This data enables the visualization and spatial depiction of the abrupt morphological changes in peri-urban regions like Akinyele, Lagelu, and Egbeda, which are predominantly occurring in the absence of the new land governance systems (Fabiyi, 2020; Adegun, 2023).

The review harmonizes land registry data and urban planning data from the Oyo State Ministry of Lands, Housing and Urban Development and spatial datasets. The data comprised reports of land allocation, revocations, compensation notices, and court judgments in land disputes, furnishing key institutional context. Qualitative data were synthesized from interviews in prior field-based studies involving residents, local chiefs, planning officers, and legal professionals. In a study in 2021 on land conflict in peri-urban Ibadan, over 300 households were interviewed to identify tenure insecurity, conflict frequency, and familiarity with zoning rules. Findings showed that 47% of participants had encountered or known individuals affected by land conflict within the last five years, but only 19% possessed legally recognized titles (Olajide et al., 2021). The figures provide evidence of the prevalence of informal land practices and their likelihood of being volatile.

Spatial analysis computer programs were key in the research approach. ArcGIS Pro and QGIS version 3.28 were employed to digitize boundary characteristics and overlapping land use classes and conduct proximity analysis around hotspots of conflict. Hotspots were identified at convergence points of informal development, unzones expansion, and customary statutory land overlap. Thematic mapping facilitated the visualisation of territorial disputes concerning administrative boundaries, settlement expansion, and infrastructural developments. Buffer analyses conducted around major roads, such as the Ibadan-Ife Motorway, indicated that numerous contested parcels are situated within 500 metres of designated urban expansion zones, thereby corroborating the speculative pressure on land adjacent to infrastructure corridors (Grey & Amadasun, 2023).

Descriptive statistics were used to aggregate available datasets, namely identifying the frequency of land conflict by Local Government Area (LGA), the ratio of customary to statutory land tenure claims, and population increase rates where there are conflicts. Inferential statistical techniques were applied to determine correlations between informal settlement presence and territorial conflict likelihood while adjusting for population density and heterogeneity issues in land register data. The experimental testing of methods for spatial autocorrelation was limited by the access to high-resolution, geo-referenced conflict information, and this precluded applying advanced analytics. This critique highlighted ethical concerns in terms of proper data use and proper referencing of sources. Secondary data were all accessed from public materials or peer-reviewed publications duly referenced as per academic standards. Several limitations influenced the methodology; the study is limited by its reliance on secondary data, which may not adequately reflect recent developments or the complexities of community dynamics. Secondly, although satellite imagery serves as an effective instrument for land use analysis, its resolution and temporal frequency may fail to capture micro-level disputes or recent informal constructions. The lack of a unified and publicly accessible geospatial land registry for Oyo State limits the extent of cadastral analysis. The lack of a single household level survey for the aim of this research results in a gap in direct community results. The methodological configuration employed here, although faulty offers a viable ground

for comprehending spatial conflicts within Oyo State. The study provides an in-depth account of how territorial conflicts are comprehended using a combination of various forms of data, including spatial, institutional, and narrative elements. This method demonstrates how GIS and thematic analysis can reveal dynamics in land administration that were initially hidden, thereby increasing the efficacy of spatial planning in conflict mitigation.

4. Findings and Discussion

Geospatial analysis shows a discernible concentration of land conflict in some peri-urban areas of Oyo State, viz. Akinyele, Lagelu, and Egbeda. They are buffer zones between the urbanizing core of Ibadan and the rural hinterland. Conflict intensity scores are on a scale of 1-10 and stand at 8 for Akinyele, 7 for Lagelu, and 6 for Egbeda. These scores reflect varying degrees of land pressure corresponding to pressures of urban growth. Encroachment of land by residential use has been intense in the past 10 years for Akinyele because of its location near the Ibadan-Ilorin motorway and other higher institutions of education, and this has triggered speculative sales of land and urban slum development. Boundary overlap occurs in Akinyele and Lagelu, while conflict mainly occurs in Egbeda due to the conversion of arable land.

Field surveys and institutional accounts indicate that the conflict hotspots tend to be regions with high rates of land use change with inadequate regulatory mechanisms. In these districts, contested land parcels generally lie within 300 to 500 meters of newly developed residential areas or infrastructure corridors, indicating direct spatial influences. The existence of unverified ownership claims and the absence of clearly defined administrative boundaries complicate spatial governance. Between 2018 and 2022, the number of legal disputes relating to competing titles for mixed land use increased by over 25% in Lagelu (Olajide, et al 2021). Community members explain that recurring themes of distrust, marginalization, and bureaucratic system failures characterize the conflict patterns. Rapid changes in land ownership, sometimes without formal notification, have been echoed by several citizens in Akinyele. Some have reported being involved in multi-party disputes, where both customary family heads and state authorities give the same plots of land to various developers. Thematic analysis of secondary interview transcripts indicates that residents interpret such experiences as manifestations of injustice and exclusion. Prohibiting land rights, particularly to those who have prior informal tenure, lead to community instability and undermine trust in both government and traditional institutions.

A 2021 household survey revealed that 61% of the participants in Egbeda and Akinyele had suffered or knew of someone who had suffered a forced eviction within the past five years (Agunbiade et al., 2021). Most of these conflicts have their roots in institutional weaknesses. Land administration in the state is quite fragmented, with both statutory and customary authorities making their claims on governance. This duality creates enormous tension, as family chiefs informally sell plots of land while government officials, following statutory procedure, grant certificates of occupancy of the same plots to other claimants. The absence of integration between the systems produces administrative opaqueness. Planners must rely on out-dated cadastral maps, and there is no centralized digital interface combining OYOGIS (Oyo State Geographic Information System) with local land transactions or zoning alterations. Consequently, urban development occurs more or less uncontrolled. In areas such as Akinyele and Lagelu, new structures tend to spring up prior to obtaining the requisite planning permissions, prompting state authorities to make belated attempts at controlling or demolishing such buildings, thereby fuelling conflicts.

Urban growth serves as a stimulant for land use conflicts; as of 2023, the population of Oyo State has surpassed 7.8 million urban dwellers at an average growth rate of 4.5% annually (NPC, 2023). The growth in the population has generated a humongous demand for housing land, especially on the peri-urban outskirts of Ibadan. Infrastructural development, including road networks and industrial estates, has pressured agricultural land use, resulting in opposition to resettlement agreements by households and farmers displaced from their lands. In the Egbeda area, several cases of state expropriation of land for government-driven projects have been recorded in judicial circles, particularly where compensatory payments have been delayed or, where made, have been considered inadequate. Land speculation compounds these issues (Fabiyi, 2020).

The role of customary land management traditions is important, particularly in situations where formal planning institutions do not support land. In many communities, traditional authorities such as Obas and Mogajis oversee initial allocations and sales. These actors frequently possess respect and social legitimacy; however, they lack the legal framework necessary to enforce claims when formal state institutions become involved. Conflicts often emerge when state-sanctioned developers intrude upon customary land without involving traditional stakeholders. In Akinyele, the exclusion of bale councils from land acquisition negotiations caused confrontations in 2021, where youth organizations protested against bulldozers utilized in clearing a private estate (Grey & Amadasun, 2023). In contrast, land administration through institutions is inefficient and politically seen as biased. Obtaining a Certificate of Occupancy involves high costs and lengthy lead times, and therefore, most residents shy away from it. Land registries are also

fragmented, which means poor coordination between the Ministry of Lands and local government planning offices. This is a source of double allocations, unequal enforcement of zoning, and bureaucratic clogging that discourages legitimate developers and residents. In Lagelu LGA, a similar case of four various title documents to a parcel of land, all from different offices or traditional families, has been reported (Adegun, 2023).

The intensity of conflict and spatial patterns are positively correlated. Spaces of high informal settlement expansion and low cadastral accuracy have the most frequent and intense disputes. Akinyele possesses the highest conflict intensity rating of 8/10 and the most unregistered residential pattern expansion. Lagelu is closely monitored, with conflicts likely to occur in the mixed-use development spaces lacking proper reclassification predominantly. The intensity of conflict in Egbeda, though lower to a limited extent, points to peri-urban areas of transition where agro-related vulnerabilities are high. Buffer and hotspot analysis, with the help of GIS tools, establish that disputed places are mainly located around infrastructure nodes and, therefore, reinforce the notion that access and speculative value are core in fuelling conflict. These findings are consistent with the literature; in Lagos, the same patterns were also observed, wherein urban growth greatly exceeded regulatory capability and generated widespread land conflict (Oduwaye, 2018). Syagga (2021) linked the themes of spatial injustice and land tenure history with the modern dilemma of policy inconsistency in Nairobi, Kenya. The socio-political history of Nigeria offers an understanding of the problems experienced by Oyo State, which represent a wider story across urban Africa marked by tension between formal urban planning principles and the existence of informal settlements.

Implications for Urban Planning and Policy

The on-going geospatial territorial conflict in Oyo State highlights critical implications for urban planning and policy. The expansion of the state's urban footprint into peri-urban and rural areas presents challenges related to land disputes, contested ownership, boundary overlaps, and unregulated settlements, which jeopardise sustainable urban development. One of the implications is the need for open, enforceable land use zoning regulations. The zoning process in the state of Oyo lacks coherence and is primarily out-dated and, therefore, opens to encroachment and clandestine alteration. In the areas of Akinyele and Lagelu, new residential developments have appeared in zones reserved initially for agriculture or mixed land use without going through the official process of reclassification. The ambiguity in zoning undermines planning authority and exacerbates territorial conflict through competing claims regarding land use legitimacy (Olajide, Agunbiade, & Bishi, 2021). A robust policy framework is necessary to connect urban expansion with tenure regularisation and amount of land in peri-urban regions remains regulated by customary tenure systems, which do not receive formal acknowledgement under statutory law. Instituting these systems of tenure in the current framework can help curtail contentious claims and safeguard vulnerable communities against displacement. In addition, policies should promote affordable and effective means of acquisition of Certificates of Occupancy and official titles, especially for established residents who are holding the land under customary allocation. This action would enhance legal clarity and facilitate access to credit and services associated with land ownership, thereby promoting social equity.

The establishment of conflict-sensitive dispute resolution frameworks integrated into the urban planning process is equally important. Currently, disputes frequently remain unresolved in the courts, with cases extending for years. One viable solution is the establishment of local land mediation committees that unite traditional leaders, planning authorities, and legal practitioners. These entities can resolve conflicts at an initial phase, potentially preventing escalation into violence or protracted legal proceedings. Community-based adjudication systems, when bolstered by formal institutions, have demonstrated success in some areas of East Africa and may serve as a viable model for Oyo State (Rivera-Williams 2025).

This study highlights the fundamental use of Geographic Information Systems (GIS) in monitoring territorial changes. Geographic Information Systems enable the real-time visualization of land use, boundary definition, and territorial changes, and hence, important to improve decision-making in urban planning. Despite the low usage of digital tools such as OYOGIS, they have the potential to integrate parcel-level information, zoning maps, and transaction data into one digital database. Layering spatial data with social indicators, such as conflict intensity or tenure type, enables planners to identify at-risk areas proactively and intervene prior to the escalation of disputes. Additionally, GIS tools facilitate the visualisation of land allocation patterns, enabling stakeholders to identify inconsistencies or illegal allocations at an early stage (Fabiyi, 2020).

The effective functioning of these systems requires good coordination between different sectors. Consultation with stakeholders has to go beyond shallow consultation to create true partnerships with the local players. Involving Obas, Baales, and Mogajis in urban management strengthens government legitimacy and ensures formal policies align with the local conditions. Land agencies should increase transparency and invigorate administrative procedures to eliminate bureaucratic failures that create dual allocations and speculation. Urban planners are essential in addressing these disparities. Town planning committees, ward-

based zoning forums, and digital platforms for citizen reporting of land issues serve as effective mechanisms to enhance trust and governance. Involving residents in zoning decisions, resettlement plans, and land assessments enables urban planners to align development projects with community requirements as well as address the underlying drivers of spatial disparity. The findings from the case of Oyo State indicate that territorial conflict stems from the lack of proper spatial governance coupled with socio-political complexities. Addressing these issues calls for an integrated policy approach to enhance zoning laws, regularize tenure systems, establish local conflict settlement mechanisms, and make use of GIS-based monitoring for anticipation. It also calls for a culture of planning focused on collaboration, transparency, and justice.

5. Conclusion and Further Research

Spatial analysis has proven the existence of a significant relationship between conflict occurrence and areas with poor cadastral recording, overlapping boundaries, and inconsistencies in the zoning policies of a country. The study illustrates that insufficient institutional coordination and the lack of integration of traditional land authorities into formal planning frameworks exacerbate these disputes. This study enhances understanding by demonstrating the application of tools such as GIS and thematic mapping in monitoring territorial pressure points and facilitating proactive urban policy. This analysis enhances the application of spatial conflict theory and land tenure theory within African urban contexts, highlighting the complex and localized characteristics of territorial disputes. The study emphasizes the importance of formalizing tenure systems, zoning controls, and the inclusion of stakeholders in the planning process. Official recognition of customary authorities in the governance institutions and the enhancement of GIS-based spatial monitoring to anticipate and mitigate conflict is necessary. The holistic approach provides a model for addressing similar problems in areas of Nigeria facing rapid urban growth. Future research should focus on comparative geospatial examinations of other South-western Nigerian states, including Ogun, Osun, Ekiti, and Ondo States. The objective would be to establish regional trends and inconsistencies in land governance and conflict dynamics. Future research can also incorporate participatory GIS methods to map local understandings of boundary legitimacy and spatial disparity, thus enhancing both scholarly understanding and planning practice.

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ACADEMIC PAPERS: THEME 3 -
Sustainable, Low-Carbon, Climate-Resilient Infrastructure, Buildings and Housings

Impact of Environmental Stress and Energy use Behaviours on Thermal Conflict in Multi-Tenanted Student Housing in Ghana

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Abstract

Thermal comfort disputes in shared university student housing are a growing concern, as they combine social tensions with environmental challenges. This study aims to assess the drivers and effects of thermal conflicts on energy use. Using Environmental Stress Theory as a framework, the study surveyed 245 undergraduate student housing unit and 723 student participants through structured questionnaires in Upper West Region, Ghana. The study employed binary logistic regression and multiple linear regression to analyse the effects of thermal disputes on energy behaviours. The findings show that for every 1ºC difference in temperature preference between roommates, the likelihood of conflict nearly doubles (93% increase). The odds also rise by 57% with each additional roommate. However, strong communication skills were found to ease tensions, reducing the chances of conflict by 42%. Notably, cultural diversity and mixed-gender accommodations added to the complexity, further increasing the likelihood of disagreements. Thermal conflicts had a measurable impact on energy usage. Each increase in conflict intensity was associated with an additional 0.84 kWh of daily energy consumption, a 1.2ºC deviation from ideal thermostat settings, and 7.5 extra minutes spent adjusting the temperature. This calls for holistic approaches that address both interpersonal dynamics and energy efficiency to improve overall thermal satisfaction

Keywords: Energy use behaviour, environmental stress, thermal conflict, student housing, energy efficiency

1. Introduction

Rapid urbanisation and increase in student enrolment have challenged the quality of indoor environmental conditions in student housing across universities in developing countries. In Ghana, university housing is faced with challenges of inconsistent energy supply, indoor environmental quality, and high occupancy. This makes it difficult to control and maintain comfortable indoor temperatures in many student housings across campuses. Recently, Agorsor et al. (2025) high indoor temperatures (31.7ºC), low air velocity, high relative humidity, and significant impact on thermal stress among students living in university housing in Ghana. Away from that, their study observed that disparities in gender show that thermal comfort in shared dormitories were unevenly experience. This has the potential to create thermal tension among students.

In Africa, these challenges are not peculiar to Ghana, but represent a broader pattern across African universities. This is because indoor environmental quality (IEQ) in student housing continue to be a challenge. For instance, Ndou (2025) reported that indoor environmental quality and socio-environmental factors significantly affects students' comfort, productivity, and well-being in South Africa Universities. Similarly, Oyeyemi et al. (2025) found that an average hostel room temperature in university student housing in Southwestern Nigeria was 32.6ºC which exceeds the internationally recommended benchmark. Asaju et al. (2022) reported thermal comfort, overcrowding, and inadequate ventilation as the most critical determinant on indoor environmental quality that affects student living in polytechnics students housing in Nigeria. These studies show that thermal discomfort in student housing in Africa, particularly West Africa is widespread problem.

In the developed world, studies have discussed how building characteristics and human behaviours interact to influence thermal comfort in shared rooms. According to Deng et al. (2021), in Chinese Universities, floor level and gender significantly influenced cooling demand in dormitories. Psychologically, Rony and Alamgir (2023) established that heat mediates as a behavioural stressor that affect cognitive stress and increasing aggression among students. Despite the advancement in indoor environmental quality, most of these existing studies focus primarily on thermal comfort, student's satisfaction, and energy consumption, with limited focus on thermal tensions that arises in shared student

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housing. This represents both an empirical and a knowledge gap in the literature. Empirically, little evidence exists on the occurrence and drivers of thermal conflict within shared student housing environments, particularly in African universities. From a knowledge perspective, the relationship between thermal conflict and energy-use behaviour remains poorly understood despite its potential implications for student well-being, interpersonal relations, and energy efficiency.

Empirically, studies in Ghana have contributed to indoor environmental quality. For example, Attakora-Amaniampong et al. (2025) demonstrated that student's behavioural pattern, occupancy density, and university policies affects electricity use among student living in university housing in Northern Ghana. Their study did not address the contribution of conflicting thermal preferences among roommates may influence social relations and energy use. Thermal conflict is explained as the disagreements and tensions that arise when students with different thermal preferences share limited environmental controls (Agorsor et al., 2025). Based on this gap, the aim of the study is to assess the impact of thermal conflict on energy use behaviour in shared student housing in Ghana. The objectives include: to assess the drivers of thermal conflicts, examine the predictors of energy consumption, and assess the predictors of thermal setpoint deviations and thermostat adjustment times.

This study is relevant for several reasons. First, understanding the nature of thermal conflict can influence facilities managers decisions on controlling the indoor environmental stressors that affect social relations and student well-being in university housing. Secondly, understanding the thermostat setpoint and thermal setpoint deviations can inform architects design and student housing management strategies that promote equitable thermal conditions and reduce disputes among students. Lastly, based on the challenges of intermittent electricity supply, assessing the social dynamics of thermal control will enable student housing managers to balance students' thermal comfort with sustainable energy use

2. Literature Review

2.1 Determinants and effects of thermal conflict on energy consumption

Studies on thermal conflict in shared living spaces shows that disagreements over temperature are influenced by a complex interaction of individual tolerance, social behaviour, psychological, and environmental conditions.

The first cohort of researchers emphasize the role of physical infrastructure such as floor level, differences in room orientation, and building layout in shapes students energy use. For example, Deng et al. (2021) classified floor level and gender as non-behavioural features that significantly influence cooling demand among students in Chinese dormitories. Also, Wang et al. (2025) established that the discrepancies in room size preferences and spatial conditions in shared university building affect perceived thermal comfort. These studies suggest that physical and spatial characteristics of student housing play an important role in shaping thermal comfort and energy-use patterns. More importantly, they indicate that thermal conflict may emerge when occupants exposed to different thermal conditions are required to share common cooling systems and thermostat controls. Thus, building characteristics not only influence comfort outcomes but may also create conditions that increase the likelihood of interpersonal disagreements regarding thermal regulation.

Other scholars highlighted that thermal tolerance and behavioural responses shapes discomfort and raises tensions in student housing. According to Jian et al. (2022), found thermal tolerance varies based on demographic groups such as age and gender. Their study further found that long occupants tolerate heat before activating air conditioning and adjust to cooling systems. These created tension in shared buildings where thermal control and cooling decisions were collective. Rony and Alamgir (2023) also observed that the high heat exposure increases stress and aggression intensify interpersonal tension among students living in university housing. Conceptually, Budiawan et al. (2024) situated thermal comfort as a "conflict multiplier" that highlights that the little disagreements between roommates may escalate tensions they experience thermal stress. Suleymanov (2024) supports earlier studies and emphasised that the intersection of cultural expectations, social dynamics, and physical challenges influences thermal conflict. While these studies agree that behavioural adaptation and social interactions influence thermal comfort, they differ in their explanations of how thermal stress translates into interpersonal conflict. This suggests that thermal conflict is a multidimensional phenomenon that cannot be explained solely by environmental conditions.

Additionally, other group of studies identified thermostat behaviour as a social determinate of thermal conflict. For instance, Agorsor et al. (2026) assessed thermal inequalities based on gender among student housing in Ghana. Their study found no significant gender differences in thermostat preferences students living in single rooms compared to double occupants. Similarly, Aragon et al. (2022) emphasised that occupants often misunderstand the function of thermostatic radiator valves. This affect temperature adjustments in the rooms. According to their study, many thermostat disputes arose from technological misunderstanding as compared to differences in comfort needs. Malet-Damour et al. (2025) is of the view that personality traits influence thermostat

negotiations and discomfort. However, their study found a hidden dissatisfaction and disputes among shared university dormitories. A significant observation from these studies is the lack of consensus regarding the role of demographic characteristics such as gender in shaping thermal preferences. While some studies report significant gender-related differences in thermal behaviour, others find limited effects. This suggests that contextual factors may moderate these relationships.

The impact of unresolved thermal conflict goes beyond personal relationships to more energy consumption and environmental impact. According to Arowoiya et al. (2024) and Zhuang and Wu (2019) domestic thermal disputes through competing thermostat often lead to inefficient behaviours such excessive energy use. In Li et al. (2022) view, communication techniques and issues of interpersonal traits significantly affect household energy use. Graff and Nock (2026) shared a different view. According to their study, temperatures rise and energy consumption increases when thermostat disagreements remain unresolved.

Studies related to indoor environmental quality highlighted high implications on cooling behaviours when thermal conflicts are unresolved among occupants. Environmental studies further highlight the wider implications of cooling behaviour. For instance, Wei et al. (2024) established that rising air-conditioning use worsens outdoor heat pressure affect indoor comfort. Efforts on resolving thermal comfort have historically focused on energy efficiency Broday et al. (2023) also observe that most thermal comfort studies historically neglect shared spaced and focused on energy efficiency.

3. Research Methodology

3.1 Research Design

This study adopted quantitative research design to assess the determinants and effects of thermal comfort on energy consumption in students housing in Ghana. Purposive sampling was used to select 245 off-campus university student housing in Upper West Region. Purposive sampling was considered appropriate because the study sought to investigate thermal conflict in a setting where thermal stress and shared occupancy conditions are particularly pronounced. The Upper West Region experiences relatively high ambient temperatures compared to many parts of Ghana, making it a suitable context for examining thermal comfort challenges and energy-use behaviours. Similarly, the University of Business and Integrated Development Studies (UBIDS) was selected because of its large concentration of off-campus student housing, diverse accommodation arrangements, and high student occupancy levels, which provide an appropriate environment for studying thermal conflict among roommates. Based on this, 723 out of 912 students participated in the survey. . Data were collected through a structured questionnaire and measured with 5-point-Likert-scale items. The instruments were designed in three parts. First, the study collected demographic profile of respondents. Second, the instruments captured indoor environmental conditions such as room occupancy, energy consumption, and access to cooling systems. Third, includes behavioural responses such as mode of thermostat adjustments, time spent in rooms, nature of conflict, and negotiation strategies. Multiple linear regression was adopted to determine the effects of thermal conflict related factors on energy consumption. Furthermore, binary logistic regression was used to assess the probability of thermal conflict occurrence among students living in shared off-campus student housing. Variables, such as room size, gender composition, access to air conditioning, ventilation access, and thermostat adjustment behaviour, were measured at the shared-room level because they describe conditions experienced collectively by roommates. The analysis therefore used individual student responses while incorporating room-level characteristics relevant to thermal conflic

3.2 Variable Definition and Measurement

The operationalisation of variables was guided by the study objectives and existing literature on thermal comfort, thermal conflict, and energy-use behaviour. Objective One, which seeks to assess the drivers of thermal conflict, informed the selection of variables such as room size, thermal preference gap, communication style, air-conditioning access, gender composition, and time spent in rooms. These variables were incorporated into the binary logistic regression model to predict the likelihood of thermal conflict occurrence.

Objective Two, which examines the predictors of energy consumption, informed the selection of conflict intensity, cooling setpoint, thermal tolerance range, setpoint adjustment frequency, ventilation access, and negotiation skills. These variables were incorporated into the multiple linear regression models to assess their effects on energy consumption, thermostat adjustment behaviour, and setpoint deviations.

In this study, thermal conflict was defined as the primary dependent variable in the logistic regression model. This explains the incidence of disagreements between roommates regarding temperature settings or cooling device usage. These were measured using a binary scale of 1=presence of conflict, and 0=no conflicts (Agorsor et al., 2025). On the other hand, several independent variables were defined. For instance, room size was defined by Wang et al. (2025) as critical determinant of thermal conflict. This was represented as the occupancy density within each student housing and estimated as the number of roommates sharing a room (1-10).

Also, thermal preference gap was measured as the difference between the indoor temperatures reported by roommates and the threshold setpoint recommended by ASHRE. These were measured in degree Celsius as highlighted in Budiawan et al. (2024) and Suleymanov (2024). Temperature set-point were gauged between 20ºC and 27ºC, and 27ºC and above

Additionally, communication index was also used as an independent variable (Li et al., 2022). This explains the quality of interpersonal interaction among roommates on indoor environmental quality decisions. This was measured using a five-item Likert-scale (1=strongly disagree, 5=strongly agree).

Access to air conditioning was defined as the access to and ability of students to control indoor temperature through mechanical cooling (Jian et al., 2022). This was measured using binary outcome such as 1 = Availability of AC, and 0 = no AC.

Gender composition was defined as a dummy factor that distinguishes mixed-gender rooms from single-gender rooms in the off-campus student housing. This was determined based on the gender arrangement within the student housing.

Moreover, time spent in the room was defined as the average number of hours per day students spend inside their rooms (Deng et al., 2021). This helps to determine their level and exposure to indoor thermal conditions

Other variables related to energy use outcomes were measured. For instance, conflict intensity was defined as the severity of disagreements regarding temperature. This was measured with a five-point self-rated scale (1=very low intensity, and 5=very high intensity. The cooling setpoint was measured in degrees Celsius and defined as the average thermostat temperature selected by the students. Also, thermal tolerance range was measured as the difference between the minimum and maximum temperatures that students consider acceptable in their rooms. This includes (16ºC minimum, and 23ºC maximum).

Drivers of energy use were defined as behavioural energy indicators. First, the frequency of thermostat setpoint changes was measured as the average number of setpoint adjustments made per day (1-5, 6-10, and above 10 times) (Aragon et al., 2022). Ventilation access was also defined as the availability of passive ventilation and operable windows in the rooms (Asaju et al., 2022). These were defined as binary outcome (1 = yes, 0 = no). Finally, student negotiation skills were other variables derived from the field. These were expressed as student's ability to manage indoor environmental disagreements (1=very low compromise, and 5=compromise).

On the other hand, the multiple regression was determined using both dependent and independent variables from the literature. In this model, three dependent variables were assessed. These include, energy consumption, setpoint deviations, and thermostat adjustment time. Energy consumption was measured as a dependent variable and defined as daily electricity use in kilowatt-hours (kWh/day). Energy consumption was measured using electricity meter records and monthly electricity consumption data obtained from student housing units. Monthly electricity consumption values were converted into average daily energy consumption (kWh/day) by dividing total monthly electricity use by the number of days in the billing period.

3.3 Model specification

The study adopted two regression models: binary logistic regression and multiple linear regression. Binary logistic regression was used to predict the likelihood of thermal conflict occurrence, while multiple linear regression was used to examine the effects of thermal conflict-related variables on energy consumption, setpoint deviation, and thermostat adjustment time.. The multiple linear regression was defined

$$Y_i = \alpha_0 + \alpha_1(ConflictIntensity) + \alpha_2(CoolingSetpoint) + \alpha_3(ToleranceRange) + \alpha_4(SetpointChangesPerDay) + \alpha_5(TimeInRoom) + \epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq(1)$$

Where Y_i indicates the energy outcomes. These includes energy use, thermostat adjustments and energy use, and represents the dependent variables. On the other hand $\alpha_1(ConflictIntensity)$ represents conflict intensity, $\alpha_2(CoolingSetpoint)$ indicates the cooling setpoint, $\alpha_3(ToleranceRange)$ shows the tolerance level in the room, $\alpha_4(SetpointChangesPerDay)$ represents the cooling setpoint changes per day in a room. $\alpha_5(TimeInRoom)$ represents the time spent in the room by occupants and ϵ as the error term. To determine the probability of thermal of the occurrence of thermal conflicts among students living in off-campus student housing, the logistic regression was defined as:

$$\text{Log}\frac{p_i}{(1-p_i)} = \beta_0 + \beta_1(RoomSize) + \beta_2(PrefTempGap) + \beta_3(CommunicationIndex) + \beta_4(AC) + \beta_5(GenderComp) + \beta_6(TimeInRoom) + \epsilon \ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots\ldots eq(1)$$

Where $logP_i$ represents the level of thermal conflict in student housing. Likewise, $\beta_1(RoomSize)$ *and* $\beta_2(PrefTempGap)$ were defined as room size and temperature preference gaps among roommates. Also, $\beta_3(CommunicationIndex)$ *and* $\beta_4(AC)$ represents

the level of communication and Access to Airconditioning.
$\beta_5(GenderComp)$ *and* $\beta_6(TimeInRoom)$ represents the gender composition of students in the rooms and time spent in rooms.

3.3 Model Diagnosis and Testing

To ensure statistical robustness, STATA was used to conduct serval test. In the logistics regression model, goodness-of-fit and pseudo R^2 statistics was conducted to assess the fit. To avoid multicollinearity among variables, Variance Inflation Factors (VIF) was examined. Further test was conducted for the multiple linear regression. Breusch–Pagan test was conducted to assess homoscedasticity. The Durbin–Watson statistic was assessed to control autocorrelation in residuals. Finally, the Cook's distance and leverage statistics were assessed to ensure that model estimates are reliable.

4. Findings

Table 1 presents the predictors of thermal conform among off-campus student housing in Ghana. The analysis showed that student housing room size was positive and associated with thermal conflict (β=0.45, (Exp(β))=1.57). This implies that each additional roommate increases the odds of thermal conflict occurrence by approximately 57% (OR = 1.57), suggesting that higher occupancy density significantly increases the likelihood of disagreements regarding thermal conditions. This finding suggests that increasing occupancy density not only intensifies competition for thermal control but also increases the diversity of thermal preferences within a shared room. As the number of roommates increases, achieving consensus regarding cooling preferences becomes more difficult. This increases the likelihood of thermal disagreements. This supports the proposition of Environmental Stress Theory that overcrowded environments amplify interpersonal stress and conflict

Furthermore, the study observed that a larger thermal preference gap was significant and likely to increase thermal conflict (β = 0.67, (Exp(β)) = 1.96). The results further indicate that a one-degree increase in thermal preference differences between roommates increases the odds of thermal conflict by approximately 96% (OR = 1.96). This suggests that mismatched temperature preferences are among the strongest predictors of thermal conflict in shared student housing. The result suggests that thermal conflict is driven less by the physical environment itself and more by differences in how occupants perceive thermal comfort. Even when students occupy the same room, variations in physiological adaptation, previous environmental exposure, and personal comfort expectations may lead to competing demands for thermal control. On the other hand, the communication style used by the students reported negative effect (β= -0.54, ρ = 0.010; OR = 0.58). This finding highlights the importance of social negotiation mechanisms in shared living environments. It suggests that thermal conflict is not solely an environmental problem but also a social process that can be mitigated through effective communication and compromise among roommates. Moreover, Table 1 shows that access to air conditioning had lower thermal conflict values (β = -1.08, ρ= 0.012; OR = 0.34). This finding indicates the mitigating role of indoor environmental quality strategies. The acceptance of mixed-gender in room composition in student housing slightly increased thermal conflict (β = 0.71, ρ = 0.048; OR = 2.03). Likewise, students time spent in the room reported modest effects but significantly positive (β = 0.12, ρ = 0.016; OR = 1.13). This indicates that the longer students stay in rooms leads to disagreement and thermal conflict. Generally, the study can deduce that, social factors such as gender diversity, temperature preference gap, and communication strategies expressively impact thermal conflict, while physical factors such as access to AC and room size were strongest predictors of thermal conflict across off-campus student housing in Ghana.

4.2 Multiple regression

Table 2 presents the multiple regression results of the study. This model assesses the significant effects of thermal conflict on energy consumption among off-

Table 1: Logistic Regression Model Predicting Thermal Conflict Occurrence

Predictor Variable	β	S.E.	Wald χ^2	Odds Ratio (Exp(β))	p-value
Room Size (number of roommates)	0.45	0.19	5.59	1.57	0.018
Thermal Preference Gap (°C)	0.67	0.22	9.28	1.96	0.002
Communication Style Index	-0.54	0.21	6.57	0.58	0.010
AC Access (1 = Yes, 0 = No)	-1.08	0.43	6.28	0.34	0.012
Gender Composition (Mixed = 1)	0.71	0.36	3.91	2.03	0.048
Time Spent in Room (hrs/day)	0.12	0.05	5.76	1.13	0.016

Source: (field data, 2025)

Table 2: Predictors of Daily Energy Consumption (kWh/day)

Predictor	β	Std. Error	Beta	p-value
Conflict Intensity	0.84	0.22	0.42	0.001
Cooling Setpoint (°C)	-0.18	0.07	-0.31	0.011
Tolerance Range (°C)	-0.12	0.06	-0.19	0.048
Setpoint Changes/Day	0.35	0.14	0.27	0.017
Ventilation Access	-0.96	0.29	-0.33	0.002
Negotiation Skill Score	-0.43	0.20	-0.21	0.036

Source: (field data, 2025)

campus student housing in Ghana. Table 2 shows that daily energy consumption and conflict intensity emerged as the strongest positive predictor (β = 0.84, β = 0.42, p = 0.001) of thermal conflict. This result suggest that high levels of thermal conflict are linked to increase in energy use among roommates. This reflects a 0.84kWh unit each increase in energy use when conflict intensity increases.

More so, the tolerance range and cooling setpoint reported negative relationship associations (β = -0.12, β = -0.19, p = 0.048; β = -0.18, β = -0.31, p = 0.011). This implies that wider tolerance ranges and high cooling setpoints minimises energy consumption in off-campus student housing. Conversely, the frequent setpoint changes per day increase energy use (β= 0.35, β = 0.27, p = 0.017). This suggest that the repeated adjustments of cooling setpoints among roommates often raises conflict among them. However, access to ventilation and negotiation skills significantly reduces energy use (β = -0.96, β = -0.33, p = 0.002; β = -0.43, β = -0.21, p = 0.036). This indicates the moderating role of behavioural control in controlling energy consumption and thermal conflicts in students housing in Ghana.

Also, changes in cooling setpoints (setpoint deviation) were positively influenced by conflict intensity (β = 0.41, β = 0.37, p = 0.001). Similar to that, wider tolerance rage and higher cooling setpoints reduce setpoint deviations (β = -0.32, β = -0.29, p = 0.008; β = -0.18, β = -0.22, p = 0.03) (see Table 3). These finding show that roommates who demonstrate more flexible thermal comfort preferences adjust thermostats less frequently.

5. Discussions

The aim of the study was to assess the drivers of thermal conflict and its effects on off-campus student housing energy consumption in Ghana. Using both multiple linear and ordinary logistic regression shows that this study supports and extend the limited discussions of thermal conflict in literature. The study found a positive relationship between room size and thermal conflict. This is in line with (Agorsor et al., 2025; Wang et al., 2025) who reported discomfort and interpersonal tensions among students in dense student housing. While previous studies have identified overcrowding as a contributor to thermal discomfort, the present study extends this discussion by demonstrating that occupancy density influences not only thermal comfort but also interpersonal relationships and energy-use behaviour. This finding suggests that thermal conflict should not be viewed solely as an indoor environmental quality issue but as a socio-environmental phenomenon emerging from the interaction between shared occupancy conditions and competing thermal preferences. Consequently, student housing management strategies that focus exclusively on physical building improvements may fail to address the social dimensions of thermal conflict. Also, the strong impact of thermal preference gaps on thermal conflict supports Suleymanov (2024) and Budiawan et al. (2024) who conceptualised thermal comfort expectations as a "conflict multiplier" in shared living spaces. However, unlike previous studies that largely conceptualise thermal comfort as an individual experience, the findings of this study suggest that differences in thermal preferences become particularly problematic when environmental controls are shared.

Table 3: Predictors of Setpoint Deviation and Thermostat Adjustment Time

Predictor	B	Std. Error	Beta	p-value
Predictors of Setpoint Deviation (°C)				
Conflict Intensity	0.41	0.12	0.37	0.001
Cooling Setpoint	-0.32	0.08	-0.29	0.008
Tolerance Range	-0.18	0.09	-0.22	0.034
2.1.1 Predictors of Thermostat Adjustment Time (minutes/day)				
Conflict Intensity	3.75	1.01	0.40	0.002
Setpoint Changes/Day	2.18	0.88	0.29	0.019
Negotiation Skill	-2.65	0.97	-0.24	0.011

Source: (field data, 2025)

Moreover, conflict intensity increases with thermostat adjustment time and cooling setpoint change (B = 3.75 min/day, β = 0.40, p = 0.002; β = 2.18, β = 0.29, p = 0.019). on the flipside, student's negotiation skills reduce thermostat adjustment time (β = -2.65, β = -0.24, p = 0.011). This indicates that efficient interpersonal management and effective behavioural control can reduce thermostat manipulation and energy consumption in off-campus student housing in Ghana.

This highlights an important distinction between thermal discomfort and thermal conflict. While thermal discomfort can be experienced individually, thermal conflict emerges when individual comfort expectations compete within collective living environments. This distinction contributes to the growing literature on shared thermal environments and student housing management

On the other hand, the negative effects of Access to AC and Communication style significantly support

findings by Rony and Alamgir (2023). More importantly, the findings challenge the dominant assumption that thermal conflict is primarily a technical or environmental problem. The strong influence of communication style and negotiation skills indicates that social interaction processes play a critical role in determining thermal outcomes. This finding reinforces the argument that behavioural interventions may be as important as technological interventions in improving thermal satisfaction among studentsWith respect to energy consumption, conflict intensity was the strongest predictor. This supports Arowoiya et al. (2024) and Graff and Nock (2026) studies who observed that unresolved personal disagreements among students affected thermostat control and higher electricity consumption. The negative relationship between access to ventilation, tolerance range and cooling setpoint, and energy consumption was consistent with studies Wei et al. (2024) and Jian et al. (2022). This confirms that passive cooling strategies and behavioral flexibility among roommates can reduce energy use.

These findings provide empirical support for Environmental Stress Theory. According to the theory, environmental stressors generate psychological and behavioural responses that influence social interactions. In the context of this study, high indoor temperatures, overcrowding, and limited thermal control act as environmental stressors, while thermal conflict represents the social and behavioural response to these conditions. The results therefore demonstrate that thermal conflict is not simply a consequence of temperature differences but a manifestation of environmental stress operating within shared living arrangements.

Similarly, cooling setpoint changes per day reported limited impact on thermal conflict and energy consumption. However, from a predictive standpoint, weak drivers such as gender composition and time spent in the room may slightly affect energy consumption and thermal conflict. Despite that, this effect could be secondary to critical drivers such as conflict intensity. This implies student housing energy interventions targeting access to AC, tolerance range, and negotiation skills are likely to produce high reductions in thermal conflict and energy consumption. Likewise, structural drivers may only partially moderate these impacts.

6. Conclusions

The study examines the drivers and impact of thermal conflict on energy consumption among off-campus student housing in Ghana. Using both multiple and logistics regression models, the study derives both physical and social drivers as critical in influencing thermal conflict and energy consumption in student housing. physically, the study found that thermal preference gaps and room size were the strongest predictors of thermal conflict, while access to AC, negotiation skills, and communication strategies were social determinants. The study concludes that higher occupancy density and the mismatch in temperature preferences significantly increase the likelihood of thermal conflict, whereas student's interpersonal relationship are critical for harmonious shared living in off-campus student housing in Ghana. On the other hand, the intensity of conflict in each student housing served as the strongest determinant of daily energy consumption. Away from that, this intensity had impact on setpoint deviations and thermostat adjustment time across the rooms. On the flipside, access to ventilation and level of tolerance reduce energy consumption levels. Also, time spent in the rooms and gender composition were weak predictors that somewhat influence thermal conflict and energy consumption across the study locations.

These finding have several implications. First, the over reliance on access to air conditioning as thermal control measure is insufficient. Thus, social and behavioural aspects are equivalent factors that need to institutionalised in youth housing such as off-campus student housing. secondly, energy inefficiency is closely connection to social factors. This implies that energy management interventions must be linked to student communication styles, interpersonal, and negotiation skills. Based on this implication, the study recommend that student housing managers must conduct training and develop structured communication approach that can include reporting roommates who do not agree on AC setpoint in rooms. Student housing managers should individualise thermostat access, encourage ventilation, and adjust cooling of student room to a minimum cooling setpoint. With this approach students can combine both natural ventilation with active design approaches to control thermal conflicts. Student housing managers should reduce occupancy density and allow students to make roommate choices. This will improve energy use and thermal conflicts in off-campus student housing in Ghana.

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Research Trends in Digital Infrastructure and Sustainable Construction: A Bibliometric Analysis

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Abstract

This scholarship explored research trends and emerging themes in digital infrastructure and sustainable construction using a bibliometric approach. The study employs a quantitative bibliometric research design, analysing peer-reviewed publications indexed in the Scopus database over a 10-year period from 2015 to 2025. Bibliometric indicators include publication trends, publication sources, keyword co-occurrence, and thematic clusters, mapping out the research output. The search string TITLE-ABS-KEY ("digital infrastructure" OR "smart infrastructure" OR "digital construction" OR "construction digitalisation") AND sustainab*. A total of 716 documents were extracted in CSV file and analysed using VOSviewer software. The study is confined to Scopus-indexed documents and English-language publications. The findings show a consistent increase in research output, with dominant themes centred on intelligent urban systems and smart technologies, digital economy and sustainable development policy and energy systems, investment, and environmental performance. Emerging topics outline the growing relevance of digital twin, smart systems, green economy, internet of things. In conclusion, the findings demonstrate that digital infrastructure is increasingly conceptualised as a systemic enabler of sustainable construction rather than a stand-alone technological intervention, signaling a shift toward integrated, data-driven sustainability transitions in the built environment. The analysis provides important implications for future research by identifying underexplored themes and opportunities for interdisciplinary collaboration. From a practical perspective, the results present valuable insights for policymakers, scholars, and construction professionals seeking to align digital infrastructure investments with sustainability goals. This study mapped the intellectual structure and evolution of digital infrastructure and sustainable construction research, identifying dominant themes, emerging trends, and collaboration networks. It clarifies knowledge gaps, informs interdisciplinary integration, and provides a robust evidence base to guide policy formulation, innovation strategies, and future high-impact scholarly inquiry in sustainable built environments.

Keywords: Built environment; Digital Infrastructure; Research Trends; Smart Infrastructure; Sustainable Construction

1. Introduction

The intersection between digital infrastructure and sustainable construction has attracted growing scholarly attention as governments and industries accelerate digital transformation to meet environmental targets. Recent contributions emphasise how digital infrastructure underpins green development pathways, enhances urban sustainability performance and supports structural upgrading within the digital economy (Liu *et al.,* 2025; Chen *et al.,* 2025). Other studies situate digitalisation within broader sustainability transitions, highlighting its influence on regional coordination, innovation capacity and environmental governance (Chisika & Yeom, 2025; Han *et al.,* 2025). Within construction research specifically, digital infrastructure is increasingly framed as an enabler of smart systems, efficiency optimisation and low-carbon project delivery (He *et al.,* 2025; Zhang *et al.,* 2025). This expanding scholarship signals a decisive shift from viewing digital tools as operational enhancements to recognising digital infrastructure as a structural driver of sustainable construction transformation.

Notwithstanding this momentum, the literature remains conceptually dispersed. A substantial stream of research examines macro-level relationships between digital infrastructure and green development quality (Liu *et al.,* 2025; Zhang & Zhao, 2025), while parallel studies focus on digital governance mechanisms and institutional arrangements for sustainability transitions (Chen *et al.,* 2025; Zhang *et al.,* 2025). In construction-oriented research, emerging work explores smart construction technologies, sustainability-oriented risk governance and collaborative digital ecosystems

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(Dagou *et al.,* 2025; Shirwa *et al.,* 2025). However, these contributions are largely segmented across economic, environmental and engineering domains. There is limited systematic mapping of how intellectual structures, thematic clusters and collaboration patterns collectively shape the research landscape linking digital infrastructure to sustainable construction outcomes.

This bibliometric review addresses that deficiency by synthesising the corpus to identify publication trajectories, influential authors, thematic concentrations and emerging research fronts. Although existing studies provide empirical evidence on digital infrastructure's impact on green growth and sustainability performance (Chen *et al.,* 2025; Chisika & Yeom, 2025), they do not interrogate the knowledge architecture of the field itself. By offering a structured, data-driven analysis of research trends, this study clarifies conceptual linkages and exposes underexplored intersections within the literature. Its originality lies in repositioning digital infrastructure and sustainable construction as an integrated research domain rather than parallel discourses, thereby establishing an evidence-based agenda for future theoretical refinement and empirical investigation grounded strictly in the analysed dataset.

2. Literature Review

In construction, a recent empirical study explores smart construction systems and sustainability-oriented governance mechanisms (He *et al.,* 2025; Dagou *et al.,* 2025; Shirwa *et al.,* 2025). However, while these studies provide robust statistical evidence, they largely examine isolated relationships rather than systematically mapping how knowledge production in this field is structured and evolving.

Literature centres around three dominant themes: (1) digital infrastructure as a driver of green economic transformation, (2) digital governance and institutional capacity for sustainability, and (3) smart construction technologies and project-level optimisation (Chen *et al.,* 2025; Liu *et al.,* 2025; Zhang *et al.,* 2025). Despite this convergence, fragmentation persists across disciplinary boundaries. Studies show macro-level sustainability assessments rarely integrate construction-sector performance indicators (Zhang & Zhao, 2025; Han *et al.,* 2025; Chisika & Yeom, 2025), while construction-focused studies often treat digital infrastructure as a technical enabler without embedding it within broader digital economy frameworks (He *et al.,* 2025; Dagou *et al.,* 2025; Shirwa *et al.,* 2025).

Research on digital infrastructure and sustainable construction is increasingly interpreted through socio-technical systems (STS) theory and innovation systems perspectives, which together provide a robust lens for understanding technological transitions in the built environment. STS theory conceptualises infrastructure development as the outcome of dynamic interactions between technological artefacts, institutional arrangements, and social actors (Han *et al.,* 2025). Within the construction domain, this implies that digital tools such as BIM, IoT, and blockchain do not operate in isolation but are embedded within organisational routines, regulatory frameworks, and stakeholder relationships. Consequently, sustainability outcomes depend not only on technological efficiency but also on alignment with social practices, governance mechanisms, and industry norms.

In the context of digital infrastructure, these perspectives underscore how collaboration among firms, governments, and research institutions drives sustainable innovation. They also stress the importance of policy incentives, capacity building, and ecosystem maturity in enabling the transition towards low-carbon and resource-efficient construction practices.

Despite their relevance, existing bibliometric studies often privilege descriptive mapping over theoretical integration. As a result, the co-evolutionary dynamics between digitalisation and sustainability transitions remain under-theorized. Positioning STS and innovation systems at the outset addresses this limitation by framing research trends as part of a broader systemic transformation rather than isolated technological advancements.

Again, literature confirms the positive sustainability implications of digital infrastructure but lacks integrative mapping and cross-cluster synthesis. By combining bibliometric analysis with socio-technical theoretical framing, this study fills the identified gap and advances a coherent understanding of research trajectories, intellectual structures and future directions within digital infrastructure and sustainable construction.

Addressing these gaps, this study is guided by two objectives:

1.To map intellectual structure and thematic evolution of research on digital infrastructure and sustainability.

2.To identify collaboration networks, influential contributors and emerging research fronts shaping the domain.

2.1. Theoretical Framework

Literature implicitly aligns with socio-technical systems theory and innovation systems perspectives, which conceptualise digital infrastructure as an enabling backbone for coordinated sustainability transitions (Chen *et al.,* 2025; Han *et al.,* 2025; Zhang *et al.,* 2025). These perspectives are suitable because they integrate technological capability, institutional arrangements and performance outcomes within a systemic framework. Complementing this, green

development and digital economy theories provide explanatory grounding for the productivity and spillover effects identified empirically (Liu *et al.,* 2025; Zhang & Zhao, 2025; Chisika & Yeom, 2025). Nevertheless, these frameworks have not been synthesised through a bibliometric lens to reveal structural connections within the knowledge base.

3. Research Methodology

A post-positivist bibliometric approach is therefore suitable for this review, as it explores the systematic mapping of publication patterns, co-authorship networks and thematic clusters using objective and quantitative bibliographic data (Han *et al.,* 2025; Zhang *et al.,* 2025; Dagou *et al.,* 2025). This paradigm supports evidence-based synthesis while acknowledging structural complexity in knowledge production. The study focuses on publication trends from 2015 to 2025. A total of 2142 documents were obtained at the initial search from the Scopus library having used the search string TITLE-ABS-KEY ("digital infrastructure" OR "smart infrastructure" OR "digital construction" OR "construction digitalisation") AND sustainab*. The choice of the Scopus database is influenced by a wide coverage of disciplines that are relevant to construction management and technology, and provides easy access to bibliographic data used by bibliometric software (Ghani et al., 2022). The documents were filtered based on engineering and environmental science subject areas, articles and conference papers, journals and conference proceedings, publications at final stage and English language written documents. 716 documents were finally exported in CSV file for analysis on VOSviewer software.

4. Findings and Discussion

4.1. Publication per year

Out of the total 716 documents that were analysed, 527 were journal articles while 189 were conference proceedings. Figure 1 illustrates a progressive upward trajectory in annual publications on digital infrastructure and sustainable construction between 2015 and 2025. Publication output shows three phases: emergence (2015–2018), consolidation (2019–2021), and rapid expansion (2022–2025). Early growth was modest, rising from 1 to 10 publications. Between 2019 and 2021, output accelerated despite a slight decline in 2021. This temporary decline may be attributed to delays in the publication cycle rather than reduced scholarly interest. From 2022 onward, publications increased sharply from 39 to 360 by 2025, indicating exponential growth. This surge reflects intensified scholarly attention to digital infrastructure as a driver of green productivity, governance reform and sustainable construction transformation (Chen et al., 2025; Liu *et al.,* 2025; Zhang *et al.,* 2025). Recent empirical and governance-focused studies further explain this acceleration (Han *et al.,* 2025; Zhang & Zhao, 2025; He *et al.,* 2025).

4.2. Publication per Country

The bibliometric distribution highlights a clear geographical concentration of research in digital infrastructure and sustainable construction (Table 1 in Appendix 1, and Figure 2). China leads publication output (236 documents, 2601 citations), reflecting its

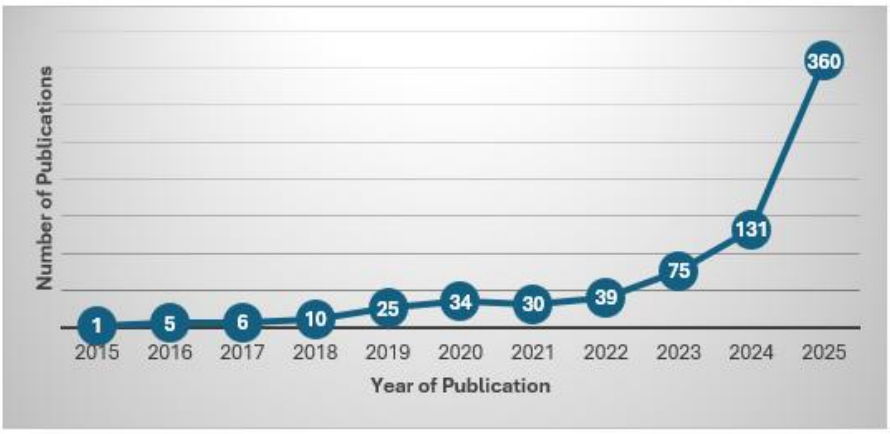

Figure 1: Publication per year

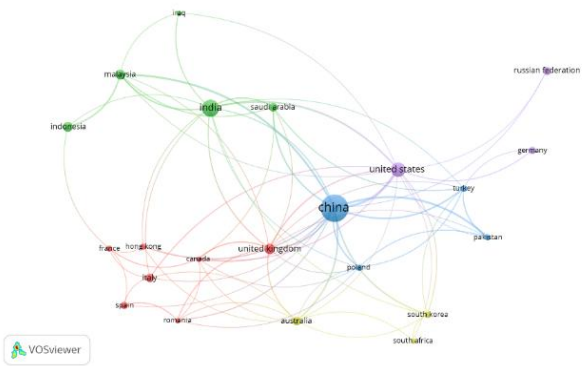

Figure 2: Network visualization for publication per country

large-scale investment in smart cities, digital construction technologies, and green infrastructure transitions. India (93 documents, 751 citations) shows accelerating scholarly engagement aligned with rapid urbanisation and digital transformation. The United States (64 documents, 1543 citations) maintains a strong influence through advanced research ecosystems and sustainability-driven innovation. The United States remains structurally significant due to its strong institutional ecosystem, R&D investment, and high-value output European nations contribute steady, policy-driven study, while emerging economies demonstrate growing but comparatively limited output. Emerging economies like Saudi Arabia, Russia, Turkey, Poland, Pakistan, South Africa, Canada, and Iraq record comparatively lower totals. This pattern is consistent with global disparities in innovation systems, institutional capacity, and research funding (World Bank, 2023; UNESCO, 2021).

4.3. Analysis of Documents per source

Table 2 in Appendix 1 presents leading publication sources in digital infrastructure and sustainable construction, measured by document count and total citations. The criteria for document selection are minimum of 5 documents in a source and minimum of 5 citations in a source. Of the 234 sources 21 meet the thresholds. Sustainability dominates with (130 documents, 918 citations). This indicates it functions as a high-volume outlet with high acceptability. However, its citation per paper impact (=7 citations per article) suggests moderate average influence relative to more specialised journals. Journal of Cleaner Production (13 documents, 651 citations) and Journal of Environmental Management (20 documents, 296 citations) show strong citation performance despite lower output. Notably, Journal of Cleaner Production averages approximately 50 citations per article, indicating high scholarly impact in sustainability research. Similarly, Sustainable Cities and Society (10 documents, 201 citations), Applied Energy (6 documents, 147 citations), and IEEE Access (6 documents, 139 citations) demonstrate strong citation efficiency, suggesting that research published in these outlets is more frequently referenced and potentially more theoretically or methodologically rigorous. Sources such as IOP Conference Series: Earth and Environmental Science (18 documents, 128 citations) and E3S Web of Conferences (16 documents, 55 citations) show moderate publication volume but lower citation density. This pattern aligns with the typical bibliometric profile of conference proceedings, which prioritise rapid dissemination over long-term citation impact. Resources Policy, Energy, Smart Cities, and Business Strategy and the Environment reflect the interdisciplinary spread of the field, integrating environmental policy, energy systems, digital technologies, and sustainability governance.

4.4. Co-authorship Analysis of Country

At least 5 documents and 3 citations of a country. Figures 3 and 4 show a globally interconnected

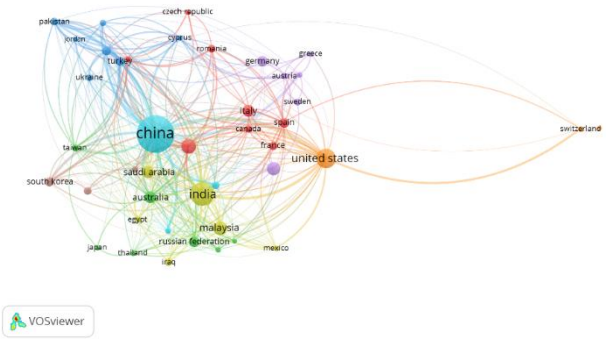

Figure 3: Network visualization of Co-authorship Analysis of Country

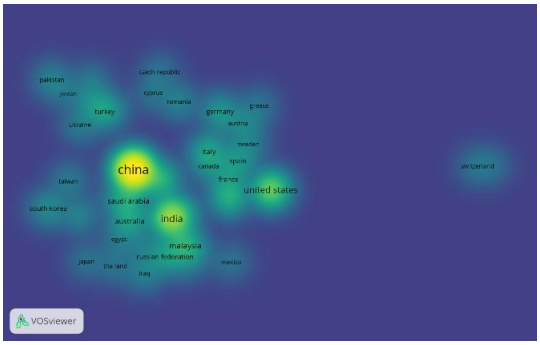

Figure 4: Network visualization Density of Co-authorship Analysis of Country

research network dominated by China, India, and the United States. China forms the largest and most collaborative node, linking extensively with Asian and European countries. India is closely connected to China and other Asian partners, reflecting strong regional integration. The United States also serves as a major hub, though with more selective ties concentrated in Western Europe and Switzerland. Asian and European countries form dense internal clusters, indicating cohesive regional research communities. Switzerland appears peripheral but maintains strong bilateral links, reflecting specialised, high-impact collaboration rather than broad multilateral engagement.

4.5. Cluster Analysis

The VOSviewer co-occurrence map in figure 5 reveals three major thematic clusters structuring the knowledge base on digital infrastructure and sustainable construction**.** Node size reflects keyword frequency, while link density indicates conceptual coupling.

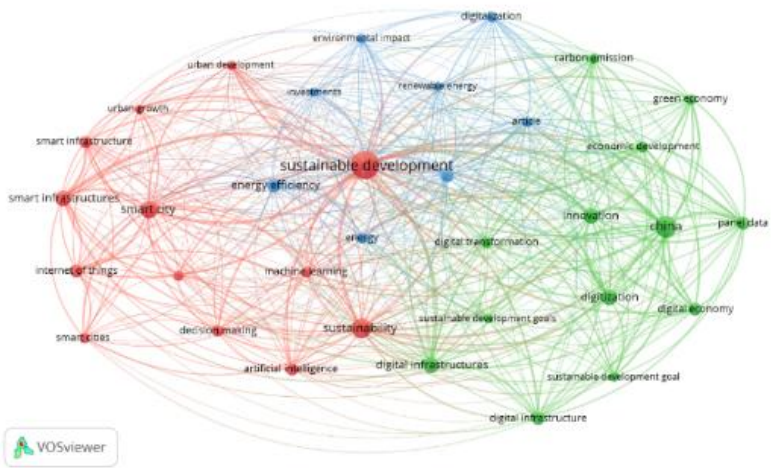

Figure 5: Network visualisation of keywords

Cluster 1: Smart Technologies and Intelligent Urban Systems

This cluster is anchored by smart city, smart infrastructure, artificial intelligence, machine learning, internet of thing, decision making, and urban development. The dense interlinkages suggest a techno-centric research stream focused on how digital technologies optimise infrastructure systems. The prominence of AI and IoT indicates emphasis on data-driven decision-support, predictive maintenance, and cyber-physical systems integration in construction and urban infrastructure (Bibri & Krogstie, 2017; Lee *et al.,* 2015). The strong association between smart cities and sustainability reflects the argument that digital infrastructure enhances resource efficiency, resilience, and lifecycle performance (Caragliu *et al.,* 2015). Within sustainable construction, this cluster aligns with BIM-enabled digital twins, intelligent transport systems, and sensor-based infrastructure monitoring, which reduce operational inefficiencies and environmental burdens (Zhang *et al.,* 2022). The linkage with urban growth highlights digital infrastructure as a response to rapid urbanisation pressure.

Cluster 2: Digital Economy and Sustainable Development Policy

This cluster includes digital economy, digital infrastructure, digital transformation, green economy, carbon emission, economic development, innovation, panel data, and China. Network density indicates macroeconomic econometric research orientation. The coupling of digitalisation and carbon emission suggests empirical investigations into whether digital infrastructure reduces environmental externalities. Studies show that digital economy development can improve energy efficiency and reduce carbon intensity through innovation spillovers and structural transformation (Zhang *et al.,* 2022; Truong, 2022). The presence of panel data reflects quantitative modelling approaches widely used in sustainability digitalisation nexus research (Li & Wang, 2022). The prominence of China indicates geographical concentration in empirical studies, given China's large-scale digital infrastructure expansion and carbon neutrality agenda (Yang *et al.,* 2024). In sustainable construction, this cluster situates digital infrastructure within broader economic restructuring toward green growth and Sustainable Development Goals (SDGs)

Cluster 3: Energy Systems Investment and Environmental Performance

This cluster centres on energy, renewable energy, energy efficiency, environmental impact, infrastructure, investments, and digitalization. It represents the energy–environment performance

dimension of sustainable construction. The close linkage between renewable energy and digitalisation reflects research on smart grids, distributed energy systems, and digital energy management platforms (Lund *et al.,* 2017). Digital infrastructure enables real-time energy optimisation, supporting decarbonised construction and infrastructure systems (IEA, 2017). The presence of investments indicates increasing attention to green finance mechanisms that support digital-enabled sustainable infrastructure (Taghizadeh-Hesary & Yoshino, 2019). This aligns lifecycle sustainability assessment approaches that integrate environmental performance with capital allocation decisions.

5. Conclusion and Further Research

The findings show a strong upward trend in publications since 2022, indicating rapid growth and consolidation of the field. Journal articles dominate, reflecting increased scholarly maturity. China leads in output and citations, followed by India and the United States, with co-authorship networks confirming their central role despite regional clustering. A dual publication system is evident: high-volume journals support dissemination, while specialised outlets achieve greater citation impact. Thematic analysis identifies three core clusters such as smart urban technologies, digital economy and policy, and energy and environmental performance with "sustainable development" as the integrative. However, from a socio-technical systems perspective, these themes reveal weak alignment between technology and social contexts. Innovation systems analysis further exposes uneven knowledge distribution and limited collaboration. Finally, the study highlights a critical gap: the lack of integrated, system-level frameworks linking digitalization with sustainability transitions.

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Appendix 1

Table 1: Publication per Country

Country	Document	Citation	Total Link Strength
China	236	2601	67
India	93	751	25
United States	64	1543	35
United Kingdom	35	770	22
Malaysia	33	249	21
Indonesia	31	116	6
Italy	25	424	7
Australia	23	388	15
Saudi Arabia	23	168	13
Russia	20	283	2
Germany	18	168	3
Spain	17	253	5
Turkey	15	63	16
Poland	14	101	13
South Korea	14	90	10
France	13	74	6
Pakistan	11	271	15
Hong Kong	11	251	7
Romania	10	141	9

Country	Document	Citation	Total Link Strength
South Africa	10	87	3
Canada	10	62	12
Iraq	10	53	4

Table 2: Documents per source

Source	Document	Citation	Impact Factor
Sustainability (Switzerland)	130	918	3.3
Journal of Environmental Management	20	296	8.4
IOP Conference Series: Earth and Environmental Science	18	128	0.402
e3s web of conferences	16	55	0.205
Journal of Cleaner Production	13	651	10
Frontiers in Environmental Science	12	30	3.7
Sustainable Cities and Society	10	201	12
Resources Policy	9	185	-
Energies	9	75	3.2
Land	8	82	3.9
Applied Sciences (Switzerland)	8	40	2.64
Frontiers in Sustainable Food Systems	8	38	3.1
Proceedings of spie - the international society for optical engineering	8	10	-
Applied Energy	6	147	11.446
IEEE Access	6	139	3.6
IOP Conference Series: Materials Science and Engineering	7	90	0.5
Systems	7	34	3.1
Energy	6	96	9.4
Smart Cities	5	167	5.5
Business Strategy and the Environment	5	69	13.3
Journal of Environmental Protection and Ecology	5	5	-

ASSESSING THE IMPLEMENTATION OF ESG FACTORS BY NAMIBIAN CONTRACTORS

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Abstract

This paper aims to assess the extent to which Environmental, Social, and Governance (ESG) factors are implemented by registered construction contractors in Namibia. It evaluates the practical translation of ESG principles from policy and regulatory expectations into operational practices within the construction sector, highlighting implementation gaps and areas of inconsistency across environmental, social, and governance dimensions. A quantitative research approach was adopted under a positivist philosophy. Data were collected through a structured online questionnaire distributed to contractors registered with the Construction Industries Federation of Namibia (CIF). Systematic sampling was used to gather data. The assessment of ESG implementation was conducted using descriptive statistics, including mean scores and standard deviations, supported by Chi-square tests and Cramer's V to examine variations in implementation levels across contractors. The findings reveal that ESG implementation among Namibian contractors is generally moderate but uneven across all three dimensions. Environmental practices such as recycling and waste management show relatively higher and more consistent implementation, while technology-intensive practices, including renewable energy use and land disturbance minimisation, remain limited. Social ESG practices are primarily concentrated on regulated areas such as wages and occupational health and safety, although significant variability exists in enforcement and practical application. Governance implementation exhibits the greatest disparity, with formal governance policies moderately adopted, but critical mechanisms such as risk management, transparent ESG reporting, and leadership diversity remaining weak and fragmented. Overall, ESG implementation is largely reactive and compliance-driven rather than strategically embedded. The findings are limited to registered construction contractors operating within Namibia and cannot be generalised to informal contractors or other national contexts with differing regulatory and institutional environments. The study's quantitative focus restricts deeper exploration of the underlying causes of ESG implementation gaps. The results provide empirical evidence of ESG implementation gaps that can inform policymakers, regulators, and industry bodies in strengthening ESG enforcement, developing sector specific guidelines, and supporting capacity building initiatives. The findings also have regulatory relevance by informing mandatory ESG reporting requirements and the incorporation of ESG performance criteria into public procurement policies. Contractors may use the findings to benchmark their ESG implementation maturity and identify priority areas for improvement. The study's most important consequence is that it rec ognises the necessity of shifting Namibia's construction sector from a mostly compliance-driven strategy to the strategic integration of ESG principles, hence promoting more resilient and sustainable company procedures.This study contributes original, context-specific insights into the actual implementation of ESG practices by contractors in a developing construction market. By moving beyond perceived importance to empirical assessment of implementation, the research advances understanding of ESG operationalisation in Namibia and supports the development of more effective, integrated, and sustainable construction practices.

Keywords: Contractors, Construction Industry, ESG Factors, ESG Implementation, Namibia

1 Introduction

Contractors' implementation of Environmental, Social, and Governance (ESG) factors illustrates how sustainability principles are translated into real-world construction operations (Sosu et al., 2026). Although ESG has gained increasing prominence in corporate reporting and policy frameworks, its implementation within contracting organisations remains inconsistent and context-dependent (Prakash, 2020; Shaikh, 2021). Contractors play a crucial role in achieving sustainable construction outcomes because their activities directly influence labour conditions, environmental performance, and governance practices throughout project execution (YII, 2025). Environmental and social aspects of ESG implementation include resource efficiency, waste management, pollution control, occupational health and safety, and community engagement (Bamgbade et al., 2016; Xie et al., 2017). Governance implementation, in turn, requires the establishment of internal control systems, ethical standards, risk management procedures, and regulatory compliance mechanisms (Prakash, 2020).

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Despite the availability of such measures, previous studies indicate that ESG adoption by contractors is often viewed as a compliance requirement rather than an integrated strategic framework embedded in organisational decision-making processes (Dufvelin, 2018). Empirical evidence further suggests that contractors, particularly in developing countries, encounter several barriers to consistent and comprehensive ESG implementation, including limited technical capacity, financial constraints, inadequate regulatory enforcement, and insufficient ESG awareness (Shilongo, 2023). Although Namibia has made progress in sustainability alignment and ESG reporting at national and corporate levels, gaps remain in the structured implementation of ESG practices within the construction sector (Namibian Stock Exchange, 2022; Shilongo, 2023). Consequently, there is limited empirical evidence regarding the extent to which Namibian contractors have translated ESG principles into operational practices.

This study therefore aims to assess the implementation of ESG factors by registered construction contractors in Namibia and to test the hypothesis that Namibian contractors implement ESG factors to an insignificant degree, not exceeding minimum expectations. By addressing this objective, the study contributes to the sustainable construction discourse by providing empirical evidence on the extent of ESG implementation in a developing country context. The findings are expected to provide practical guidance to contractors, policymakers, and industry stakeholders operating within Namibia's evolving legislative and business environment. The remainder of the paper reviews the relevant literature, describes the research methodology, presents and discusses the findings, and concludes with recommendations.

2. Literature Review

The following section examines existing literature and scholarly perspectives on the implementation of Environmental, Social, and Governance (ESG) factors by contractors within the construction industry.

2.1 Implementation of ESG factors by contractors

The incorporation of sustainability into construction procedures is regarded in contractors' recognition of Environmental, Social, and Governance (ESG) principles. ESG is frequently pushed through corporate reporting and policy, but its actual implementation differs depending on the circumstances (Shaikh, 2021). A comprehensive strategy that incorporates environmental, social, and governance factors into planning, execution, and decision-making is necessary for successful implementation (Dufvelin, 2018; Prakash, 2020). Business ability, market incentives, regulatory enforcement, and project-specific restrictions all affect how much ESG operationalisation is carried out, particularly in developing nations.

2.2.1 Environmental Implementation by Contractors

According to Bamgbade et al. (2016), considering many environmental impacts occur during construction rather than during design, environmental ESG implementation by contractors focuses on lowering the ecological impact of building through resource efficiency, pollution control, and sustainable site management. Bamgbade, Kamaruddeen, and Nawi (2016), together with Mensah, Nani and Ayarkwa (2022), observed that energy-efficient equipment, renewable energy, eco-friendly materials, waste minimization, and recycling are common practices, but adoption is frequently project-specific rather than firm-wide, especially in developing countries with inadequate infrastructure. Particularly in areas with limited water supplies, new techniques including rainwater collection, water-efficient machinery, and controlled curing are being developed. However, according to Shaikh (2021), budgetary constraints, a lack of technical expertise, and inadequate incentives hinder execution. This concurs with the findings of Dufvelin (2018) and the more recent study by Björk, Filander and Mattsson (2024), which indicate that ESG initiatives are frequently client-driven and reactive rather than proactive or adaptable.

2.2.2 Social Implementation by Contractors

According to Xie et al. (2017) and Shaikh (2021), despite the substantial social risks associated with the labor-intensive construction sector, contractors' social ESG initiatives concentrate on labor practices, occupational health and safety (OHS), community participation, and human capital development. Hasan et al. (2018) observed that health and safety is the most researched aspect, with initiatives such as safety inductions, toolbox talks, PPE provision, and regulatory compliance lowering accidents. However, Shilongo (2023) noted that effectiveness is frequently limited by enforcement gaps and financial constraints, particularly in developing nations. Beukert and Sigurdsson (2022), together with Saiful Azlin Puteh Salin et al. (2023), argued that although community participation is occasionally viewed as a secondary issue, activities such as monitoring project impacts and encouraging local employment improve project legitimacy and reduce resistance. Beyond OHS, social ESG implementation also entails diversity, inclusivity, and cultural respect; however, according to Shilongo (2023), this area remains understudied and poorly evaluated in developing countries, a finding that concurs with Xie et al. (2017) and suggests the necessity for context-specific study on contractor practices.

2.2.3 Governance Implementation by Contractors

According to Prakash (2020), governance ESG implementation lays the groundwork for successful environmental and social practices by encouraging accountability, transparency, moral behavior, and regulatory compliance. Alreshidi, Mourshed, and Rezgui (2017) highlighted that internal standards, risk management, audits, and distinct organisational responsibilities are important tools that enable responsible decision-making and assist in avoiding wrongdoing. However, Dufvelin (2018) and Yap et al. (2024) observed that although legal and regulatory compliance is crucial, governance is frequently restricted to procedural observance rather than strategic sustainability, especially in developing nations with insufficient enforcement and disjointed frameworks. Furthermore, Shilongo (2023), Prakash (2020), and Arsecularatne and Sandanayake (2021) advocated for transparency, disclosure, inclusive leadership, and board diversity to increase stakeholder trust and ethical oversight; however, they noted that reporting is frequently selective and leadership structures continue to be largely homogeneous, limiting transformative impact.

2.2.4 Integration of ESG Implementation by Contractors

Contractors must use coordinated tactics, such as establishing quantifiable goals, incorporating ESG into project management, and regularly assessing performance, in order to effectively integrate ESG (Prakash, 2020). Key facilitators of integrated ESG implementation include cooperation throughout the construction value chain, training, capacity building, and the use of digital technology and green tools (Shilongo, 2023; Dufvelin, 2018). Many contractors find it difficult to match ESG with commercial and short-term project goals, despite the fact that integration may improve competitiveness, risk management, and long-term value (Kim & Chang, 2022). Overall, there are still large gaps between ESG goals and practice, particularly in emerging economies, underscoring the necessity of empirical study tailored to particular contexts (Shilongo, 2023). Although previous studies have explored ESG implementation in the construction industry, much of the literature focuses on developed economies or on the importance of ESG rather than actual implementation. Empirical evidence on how contractors operationalise ESG in developing countries, particularly Namibia, remains limited. As a result, there is insufficient understanding of the extent to which Namibian contractors translate ESG principles into practice across environmental, social, and governance dimensions. This study addresses this gap by assessing ESG implementation among registered construction contractors in Namibia.

3. Research Methodology

This study employed a post-positivist paradigm, which is suitable for perception-based research that acknowledges reality as likely and impacted by a variety of circumstances (Saunders et al., 2016). In line with Prakash (2020), a quantitative mono-method was used, gathering data using a survey questionnaire. To guarantee validity and reliability, participants were chosen using systematic selection from the 184 construction enterprises that were registered with CIF. A minimum of 92 replies, or 50% of the population, were targeted (Leedy & Ormrod, 2016; Thomas, 2023). Until the sample threshold was reached, every second contractor on an ordered list was chosen. Three sets of closed-ended questions made up the QuestionPro-created online survey. The primary goals were assessed using a 5-point Likert scale that ranged from "Never" (1) to "Always" (5), modified from Bhandari & Nikolopoulou (2023), while the first part collected demographic and organisational data (Bhandari, 2023). Mean score, standard deviation, and chi-squared tests were used in the data analysis. Standard deviation was used to evaluate variability, ranking variables with smaller deviation higher when means were similar (Trafimow, Wang & Wang, 2018; Beukert & Sigurdsson, 2022). Mean scores were interpreted on a scale from low (1.00–2.00) to high (4.01–5.00) (Hassan et al., 2018). Relationships between categorical variables were assessed using chi-squared tests, and significance was established at $p < 0.05$ (Camilli, 2018; Turney, 2023). With widely recognized thresholds of negligible (0–0.10), weak (0.10–0.30), moderate (0.30–0.50), and strong (>0.50), Cramer's V was used to measure the strength of association between nominal variables, ranging from 0 (no association) to 1 (strong association) (Cramér, 1946; Cohen, 2013; Field, 2018; Rea & Parker, 2014). Since it measures the strength of correlations rather than causality, Cramer's V is non-directional and enhances chi-squared findings.

4 Findings and Discussion

4.1 Response rate and Profile of respondents

95 participants responded to the survey, yielding sufficient data to evaluate profiles in sustainable construction (Table 1 in Appendix 1). With minor contributions from other sectors, the majority of respondents were experts in Project Management (15.79%), Architecture and Real Estate (14.74% each), Quantity Surveying (13.68%), and Civil Engineering (11.58%). This illustrates a multidisciplinary view of sustainable practices and ESG. With bachelor's (25.26%), master's (22.11%), or honors (21.05%) degrees, the majority of participants were well qualified; 8.42% had doctorates, and lesser percentages possessed diplomas, certificates, or postgraduate diplomas. Experience levels were varied, with the largest group having 6–10 years (27.37%), followed by 0–5 years (24.21%) and over 20 years (21.05%),

showing representation across career stages. Nearly half (49.47%) worked on medium-scale projects, with others involved in small-scale (31.58%) and large-scale (18.95%) developments. Respondents were also distributed across company grades, led by Grade 3 (26.32%) and Grade 1 (23.16%) firms, indicating insights from organisations of varying capacities.

4.2 Implementation of ESG factors by Namibian contractors

While governance practices range from medium-high to medium-low levels, environmental and social ESG practices among Namibian contractors lie within the medium-high level of implementation (Mean = 3.01–4.00), according to the study of mean scores and standard deviations in Tables 2 in Appendix 1. Every aspect considered; this points to a moderate degree of ESG adoption in all three dimensions. However, significant variation in reported practices is indicated by standard deviations more than 1.0 for every item (Moore, McCabe & Craig, 2017).

In Table 3 below, chi-square and Cramer's V analysis revealed particular ESG practices with statistically significant variation among contractors ($p < 0.05$). In terms of the environment, adoption of low-VOC paints ($\chi^2 = 9.474$, $p = 0.050$, $V = 0.158$), recycling and reuse ($\chi^2 = 10.000$, $p = 0.040$, $V = 0.162$), and energy-efficient technologies ($\chi^2 = 14.105$, $p = 0.007$, $V = 0.193$). While wages, training, diversity, and community involvement did not exhibit any significant variation, the enforcement of health and safety regulations and the provision of safe working environments were significant ($\chi^2 = 17.579$, $p = 0.001$, $V = 0.215$). Clear policies ($\chi^2 = 21.368$, $p < 0.001$, $V = 0.237$), ethical accountability ($\chi^2 = 13.158$, $p = 0.011$, $V = 0.186$), fair procurement ($\chi^2 = 14.421$, $p = 0.006$, $V = 0.195$), and ESG reporting ($\chi^2 = 13.474$, $p = 0.009$, $V = 0.188$) showed non-significant differences in governance maturity.

The majority of procedures fell between the medium-high range (M = 3.01–4.00), according to the environmental ESG results, which show moderate but inconsistent adoption across contractors. In line with Bamgbade et al. (2016) and Mensah et al. (2022), who relate adoption to capital and technical capacity, energy-efficient technologies shown considerable variation ($\chi^2 = 14.105$, $p = 0.007$; $V = 0.193$), indicating unequal adoption. Recycling and reuse had the greatest mean (M = 3.40, SD = 1.29), followed by low-VOC paints (M = 3.20, SD = 1.28) and waste tracking (M = 3.27, SD = 1.43). However, VOC paints also had substantial variation ($\chi^2 = 9.474$, $p = 0.050$; $V = 0.158$), indicating uneven application. Mensah et al.'s (2022) conclusion that high-investment environmental policies are less systematically anchored is supported by the non-significant results and larger dispersion of renewable energy consumption and land disturbance minimization (both M = 3.00). Health and safety measures were the most distinctive, while social ESG practices also showed medium-high implementation levels. Variations in compliance capability were highlighted by the statistical significance of the provision of safe working environments and the enforcement of health and safety rules ($\chi^2 = 17.579$, $p = 0.001$; $V = 0.215$). While PPE provision (M = 3.32, SD = 1.54) and training (M = 3.31, SD = 1.26) showed considerable attention with some inconsistency, fair and competitive pay recorded the highest mean (M = 3.58, SD = 1.29), confirming Shaikh (2021) and Xie et al. (2017). The lower rankings for safe working environments (M = 3.06, SD = 1.51) and community participation (M = 3.06) are consistent with Beukert and Sigurdsson's (2022) argument that social efforts that go beyond legal requirements are given less importance. The largest discrepancy was seen in governance implementation, which suggests unequal institutional development. Clear governance policies had the highest mean (M = 3.43, SD = 1.36) and the greatest variation ($\chi^2 = 21.368$, $p < 0.001$; $V = 0.237$). Additionally, ethical accountability was significant (χ^2

Table 3: Chi-Square and Cramer's V Results for implementation of ESG practices

Question	χ^2 Value	p-value	Cramer's V	Effect Size Interpretation	Significance
Environmental practices					
Employing energy-efficient technologies	14.105	0.007	0.193	Moderate association	Significant
Implementing recycling and reuse strategies	10.000	0.040	0.162	Moderate association	Significant
Use of low-volatile organic compound (VOC) paints	9.474	0.050	0.158	Moderate association	Significant
Social practices					
Health & safety enforcement	17.579	0.001	0.215	Moderate association	Significant
Safe working environment	17.579	0.001	0.215	Moderate association	Significant
Governance practices					
Clear governance policies					
Ethical accountability	13.158	0.011	0.186	Moderate association	Significant
Fair procurement practices	14.421	0.006	0.195	Moderate association	Significant
Transparency and ESG reporting	13.474	0.009	0.188	Moderate association	Significant

= 13.158, p = 0.011; V = 0.186; M = 3.39, SD = 1.86), confirming Prakash's (2020) assertion that leadership commitment is necessary for enforcement. According to Shilongo (2023), internal audits showed moderate adoption (M = 3.37, SD = 1.33), but transparent ESG reporting, leadership diversity, and risk management scored below 3.00, with risk management scoring the lowest (M = 2.91), and 18 out of 27 ESG factors did not reach statistical significance overall.Thus, the hypothesis that "Namibian contractors implement ESG factors to an insignificant degree, not exceeding minimum expectations" is validated. ESG practices are still scarce and not yet strategically integrated throughout the industry, as seen by the preponderance of non-significant Chi-square results and uneven, compliance-driven implementation concentrated in regulated areas like health and safety and fundamental governance regulations.

5 Conclusion and Further Research

The purpose of this study was to examine the extent to which Environmental, Social, and Governance (ESG) factors are implemented by Namibian contractors and to test the hypothesis that ESG implementation falls short of minimal criteria. The study evaluated the degree and consistency of ESG adoption across organisations using a quantitative survey methodology supported by mean score analysis, Chi-square, and Cramer's V tests. The results show that all three aspects have moderate but unequal implementation. While technology-intensive efforts exhibited poorer and uneven uptake, environmental practices were stronger in well-known operational areas like recycling and waste management. Health and safety received the most emphasis in social practices, which were mostly compliance-driven, whereas more general worker development and community involvement were less regularly integrated. The most significant distinction was found in governance, where formal policies were more prevalent than sophisticated processes like structured risk management and transparent ESG reporting, suggesting reactive rather than deliberate integration. When taken as a whole, the findings confirm the hypothesis and show that the sector's use of ESG is still unequal and restricted. Contractors, lawmakers, regulators, and industry organisations looking to improve compliance frameworks, strengthen ESG capacity, and encourage more organised integration of sustainable practices in construction may find these findings very pertinent. Building on these findings, future studies should improve and evaluate ESG measuring methods unique to the construction sector, especially in developing nations. Longitudinal and mixed-methods research would monitor ESG progress over time and offer a greater understanding of organisational behaviour. Additional investigation into the financial and operational implications of ESG adoption could strengthen the business case for integration, while stakeholder-focused research would offer a broader evaluation of ESG performance and accountability.

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Appendix 1

Table 1: General profile of the respondents

Respondents' Particular	Frequency	Percentage (%)
Field of Qualification		
Construction Management	10	10.53
Quantity Surveying	13	13.68
Civil Engineering	11	11.58
Environmental Management	8	8.42
Sustainable Development	9	9.47
Project Management	15	15.79
Real Estate and Property Development	14	14.74
Architecture	14	14.74
Other (Please specify): Urban planning	1	1.05
TOTAL	**95**	**100**
Respondents' Particular	**Frequency**	**Percentage (%)**
Highest education level		
Certificate	5	5.26
Diploma	13	13.68
Post Graduate Diploma	4	4.21
Bachelors	24	25.26
Honors	20	21.05
Masters	21	22.11
Doctorate	8	8.42
TOTAL	**95**	**100**
Years of experience in the construction industry		
0 – 5	23	24.21
6 – 10	26	27.37
11 – 15	18	18.95
16 – 20	8	8.42
Above 20	20	21.05
TOTAL	**95**	**100**
Type of projects involved in		
Small-scale residential and commercial projects	30	31.58
Medium-scale public and private infrastructure projects	47	49.47
Large-scale and complex infrastructure projects	18	18.95
TOTAL	**95**	**100**
Company's grade classification		
Grade 1 (Highest)	22	23.16
Grade 2	18	18.95
Grade 3	25	26.32
Grade 4	20	21.05
Grade 5 (Lowest)	10	10.53
TOTAL	**95**	**100**

Table 2: Mean Score & Standard Deviation for implementation of ESG practices

Descriptive Statistics			
	Mean Score	**Standard Deviation**	**Rank**
Environmental Implementations			
Implements recycling and reuse strategies to minimise construction waste	3.4000	1.29154	1
Actively track and monitor our waste management efforts to ensure compliance with environmental standards	3.2737	1.42502	2
Use of low-volatile organic compound (VOC) paints in our projects	3.2000	1.28494	3
Incorporate renewable energy sources (e.g., solar, wind) to power construction sites	3.1684	1.41160	4
Employing energy-efficient technologies	3.1368	1.25994	5
Have waste segregation systems in place to facilitate proper disposal and recycling	3.1263	1.37022	6
Water conservation technologies, such as rainwater harvesting systems	3.1158	1.44298	7
Use water-saving devices to reduce water consumption	3.0316	1.37958	8
Employing renewable energy sources to power building sites	3.0000	1.34481	9
Ensures that construction activities are planned efficiently to minimise land disturbances	3.0000	1.44399	10
Social Implementations			
Ensures that employees receive fair and competitive wages	3.5789	1.29302	1
Employees are provided with personal protective equipment (PPE)	3.3158	1.53860	2
Invests in employee training and development programs	3.3053	1.26385	3
Actively monitors and reports occupational hazards and incidents	3.2947	1.42077	4
Enforces strict health and safety regulations to protect workers	3.1474	1.40643	5
Promote diversity and inclusivity within our workforce	3.0947	1.32948	6
Engages with local communities to address their concerns regarding our projects	3.0632	1.25317	7
Provide a safe and healthy working environment for all employees	3.0632	1.51454	8
Ensures that employees receive fair and competitive wages	3.5789	1.29302	1
Employees are provided with personal protective equipment (PPE)	3.3158	1.53860	2
Governance Implementations			
Have clear governance policies and procedures to prevent misconduct and theft	3.4255	1.36381	1
Employees and management are held accountable for ethical business practices	3.3895	1.85825	2
Internal audits are conducted regularly to ensure compliance with governance policies	3.3684	1.32931	3
Competitive bidding and fair procurement practices are followed in all transactions	3.2526	1.33662	4
Ethical business practices are encouraged and reinforced through employee training	3.1684	1.43403	5
Promotes diversity in leadership and decision-making roles. Board includes members with diverse expertise and experiences	2.9579	1.37544	6
Provide transparent and timely reports on ESG activities to stakeholders	2.9579	1.39845	7
Provide transparent and timely reports on ESG activities to stakeholders	2.9579	1.47976	8
Risk management strategies are in place to identify and mitigate governance risks	2.9053	1.48806	9

Artificial Photosynthesis for Net-Zero Energy Integration in Commercial Buildings: A Systematic Literature Review

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Abstract

The transition toward net-zero energy commercial buildings has intensified interest in emerging sustainable technologies capable of enabling low-carbon and self-sustaining energy systems. Among these, artificial photosynthesis has gained growing attention due to its potential to convert solar energy into storable chemical fuels and integrate with building energy systems. This study presents a systematic literature review of research published between 2016 and 2026, examining the role of artificial photosynthesis in net-zero energy integration for commercial buildings. Guided by the PRISMA framework, a structured search was conducted across Scopus AI, ScienceDirect, Google Scholar, and Springer, resulting in the selection of 37 peer-reviewed journal articles for in-depth synthesis. The review analyses technological configurations, energy conversion pathways, system integration strategies and sustainability implications. Findings indicate that while artificial photosynthesis remains at an early developmental stage for building scale applications, it demonstrates strong potential when combined with photovoltaics, hydrogen systems and smart energy management. However, challenges related to efficiency, scalability, cost and policy support persist. The study contributes a consolidated knowledge base and identifies a future research agenda to inform technological development, policy formulation and net-zero energy strategies in commercial building contexts.

Keywords: Artificial photosynthesis, Commercial buildings, Net-zero energy buildings, Sustainable energy technologies, Systematic literature review.

1. Introduction

The transition toward net-zero energy buildings (NZEBs) has intensified in response to global decarbonisation commitments and the growing need to reduce operational and embodied carbon within the built environment (Hamzah & Go, 2023; Horzela-Miś et al., 2025). NZEBs are broadly defined as highly energy-efficient structures that generate as much energy on-site as they consume over an annual cycle, typically through the integration of renewable energy technologies (IEA, 2022; Marszal et al., 2011). The built environment sector accounts for approximately 37% of global energy-related carbon dioxide emissions, with commercial buildings representing a disproportionately large share due to their scale, operational intensity and continuous occupancy demands (IEA, 2022). Achieving net-zero performance in commercial buildings therefore requires not only passive design strategies, but also the deployment of advanced on-site energy generation and storage technologies capable of meeting residual energy needs across variable seasonal and diurnal conditions (Lv et al., 2025; Muthukumaran et al., 2024). While photovoltaic (PV) systems remain the dominant on-site renewable energy solution, their dependence on intermittent solar availability highlights the need for complementary energy storage pathways (Song et al., 2019; Abbas et al., 2020).

Artificial photosynthesis (AP) is a bio-inspired process that replicates the mechanisms of natural photosynthesis to convert solar energy, water and carbon dioxide into hydrogen or other chemical fuels (Wang & Pornrungroj, 2025; Mohlaba et al., 2023). Unlike photovoltaic systems, which generate electricity instantaneously from solar irradiance, AP enables direct solar-to-fuel conversion, producing a storable chemical energy carrier capable of addressing the long-duration storage limitations that constrain current PV-dominant renewable energy strategies (Zou et al., 2025; Ganesh, 2023). Recent advances in photocatalytic materials and photoelectrochemical (PEC) systems have improved laboratory-scale performance, prompting growing interest in AP as part of integrated renewable-hydrogen energy systems (Wang & Pornrungroj, 2025; Li et al., 2021).

Despite increasing research activity, AP literature remains concentrated within materials science and electrochemical engineering, with limited consideration of commercial building applications (Ganesh, 2023; Wenten et al., 2024). Issues such as building integration, lifecycle costs, procurement, safety and regulatory requirements remain

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underexplored (Pillai et al., 2022; Lucchi et al., 2025). This study therefore examines how AP is positioned within net-zero energy research and identifies the technological, economic and implementation barriers affecting its future integration into commercial buildings through a systematic review of 37 peer-reviewed studies published between 2016 and 2026 (Abbas et al., 2020; Sonyy et al., 2026).

2. Research Methodology

2.1. Literature Search Strategy

This study employed a systematic literature review (SLR) approach to synthesise research on artificial photosynthesis for net-zero commercial building integration. Given the early developmental stage of AP technologies and the absence of operational building-scale applications, an SLR was selected as the most appropriate methodological approach, enabling rigorous synthesis of fragmented knowledge across disciplines, including materials science, energy engineering and built environment research, without requiring primary empirical data that does not yet exist at building scale (Nena et al., 2022; Moher et al., 2014). Therefore, a systematic phase-based search was conducted in four selected bibliographic databases (Scopus, Springer, ScienceDirect and Google Scholar) from 2016 to 2026. The search strategy was performed using Boolean operators (Nena et al., 2022) and the following terms were used as search strings: "Artificial photosynthesis" AND "built environment", "Artificial photosynthesis" AND "net zero", "Sustainable energy materials" AND "commercial buildings", "Electrochemical energy systems" AND "construction", "Building-integrated energy systems" AND "carbon reduction".

2.2. Study Selection Process

Following initial database searches, titles and abstracts were screened to remove irrelevant publications, with remaining studies assessed through full-text screening, resulting in a final dataset of 37 studies. The process was documented using a PRISMA flow diagram (Figure 1) to ensure transparency (Moher et al., 2014).

2.3. Data Extraction and Quality Assessment

2.3.1. Data Extraction

Data extracted from each study included publication year, geographical origin, methodological approach, technological focus and key findings. The data were analysed using descriptive statistics and thematic synthesis to identify recurring patterns relating to technology development, system integration, economic feasibility and implementation challenges.

3. Findings and Discussion

3.1. Findings

3.1.1. Temporal Distribution Overview

Publication frequency between 2016 and 2026 demonstrates a consistent upward trend, with significant growth after 2020 reflecting expanding global interest in hydrogen-based renewable systems

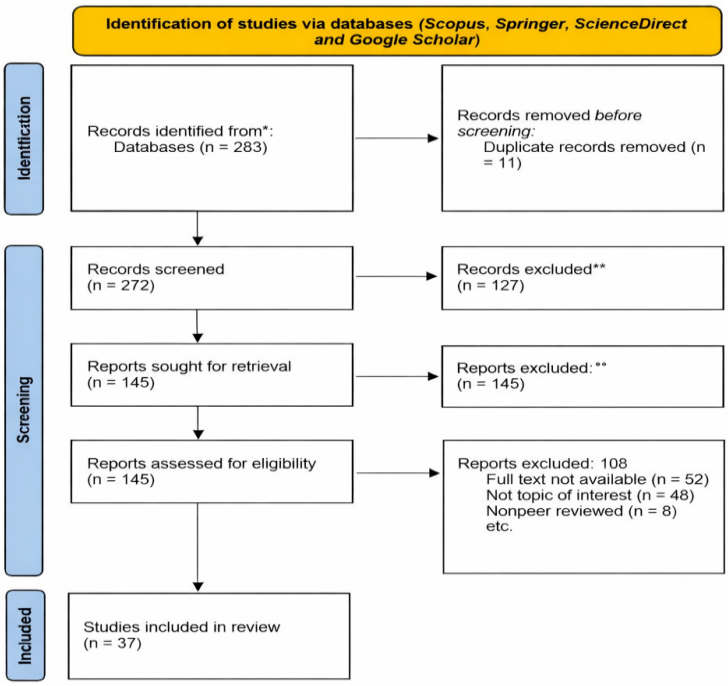

Figure 1: PRISMA Flow Diagram

and solar fuel technologies, peaking between 2022 and 2026 (Figure 2).

3.1.2. Geographical Distribution of Reviewed Studies

China accounts for the highest share of publications (23 studies), followed by India (6), South Africa and Switzerland (3 each), with smaller contributions from several European and Asian countries, concentrated in regions with active hydrogen economy development and strong materials science research infrastructure (Figure 3).

3.1.3. Descriptive Characteristics of Reviewed Studies

The reviewed studies were classified according to study type and technological focus to identify dominant research methodologies and technological orientations, as presented in Table 1 in Appendix 1.

3.2. Discussion

This discussion interprets the findings in relation to the two guiding research questions: (RQ1) how is artificial photosynthesis currently positioned within net-zero energy research for commercial buildings, and (RQ2) what technological, economic and implementation gaps currently limit its uptake in commercial building contexts. The discussion proceeds through a thematic synthesis of the literature, followed by direct responses to RQ1 and RQ2, with practical implications for built environment practice highlighted throughout.

3.2.1. Thematic Synthesis of Reviewed Literature

The thematic synthesis of the reviewed literature identified four dominant research themes within the field of renewable energy integration for net-zero commercial buildings, as shown in Table 2 in Appendix 1. The reviewed studies demonstrate a progression from fundamental technology development toward integrated energy system management and environmental evaluation. While a substantial proportion of the literature remains focused on laboratory-scale technological innovations, an increasing number of studies are exploring system-level optimisation, sustainability assessment and the integration of renewable technologies within built environment applications, signalling that AP is transitioning from a purely scientific research domain toward one with emerging relevance for building energy system design and procurement.

3.2.2. RQ1: Positioning of AP within Net-Zero Energy Systems

The reviewed literature indicates that AP is increasingly positioned within broader net-zero and renewable energy system research rather than being treated solely as an isolated chemical process. Research is primarily focused on solar-to-fuel conversion technologies, particularly photoelectrochemical systems and catalyst development aimed at converting solar energy into hydrogen or other chemical fuels

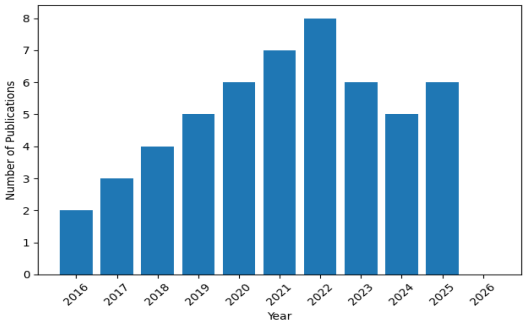

Figure 2: Publications per Year between 2016-2026

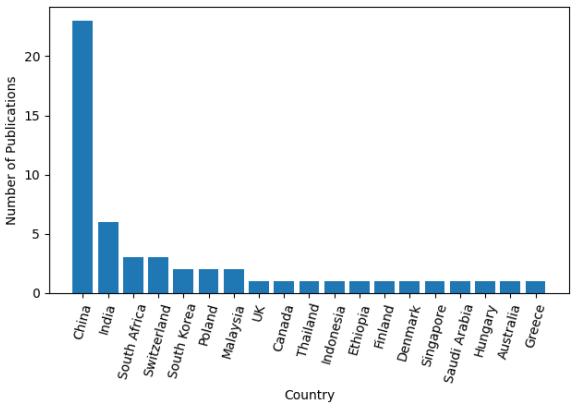

Figure 3: Publications per Country (2016-2026)

(Kuittinen et al., 2021; Temiz & Dincer, 2023; Wenten et al., 2024). These studies primarily originate from materials science and electrochemical engineering disciplines and concentrate on improving catalytic activity, conversion efficiency and long-term stability of artificial photosynthesis systems. Within the broader net-zero energy discourse, hydrogen produced through solar-driven processes is increasingly conceptualised as a long-duration energy storage solution capable of addressing renewable energy intermittency (Song et al., 2019; Li et al., 2021; Zhang et al., 2026). As a result, AP is progressively framed as part of an integrated renewable-hydrogen energy ecosystem that can complement PV electricity generation and energy storage within future building-scale energy systems (Wei & An, 2024; Liu et al., 2025; Hua et al., 2025). In response to RQ1, AP is best understood not as a replacement for PV but as a complementary long-duration storage pathway within integrated net-zero building energy systems, with practical implications for how energy system briefs are drafted, how multi-technology procurement packages are structured, and how lifecycle cost assessments are framed when both electricity generation and chemical fuel storage are involved.

3.2.3. RQ2: Limitations and Gaps in Commercial Building Integration of Artificial Photosynthesis

Despite promising developments, AP integration within commercial buildings remains constrained by technological immaturity, economic uncertainty and institutional barriers (Mohlaba et al., 2023; Wenten et al., 2024; Jachimowski et al., 2025). Key challenges include catalyst degradation, low conversion efficiencies, limited building-scale performance data, uncertain lifecycle costs and hydrogen infrastructure requirements (Kuittinen et al., 2021; Wang et al., 2024; Horzela-Miś et al., 2025). From an economic perspective, several studies identify uncertainties regarding capital costs, hydrogen production economics and the infrastructure requirements associated with hydrogen storage and distribution at the building scale (Song et al., 2019; Li et al., 2021; Wang et al., 2026; Zhang et al., 2026). From a quantity surveying standpoint, the absence of building-scale techno-economic data presents a significant constraint: without reliable cost benchmarks, lifecycle cost modelling and investment appraisal for AP integration cannot be undertaken with confidence. Implementation barriers are further compounded by safety considerations relating to on-site hydrogen storage, regulatory constraints and the lack of large-scale demonstration projects integrating hydrogen-based energy systems within commercial buildings (Ganesh, 2023; Wei & An, 2024; Zou et al., 2025). In summary, RQ2 is answered by the convergent evidence that technological immaturity, economic uncertainty and institutional unpreparedness collectively constrain the near-term integration of AP in commercial buildings, requiring interdisciplinary collaboration across materials science, building engineering, quantity surveying and regulatory policy, as well as further research on techno-economic feasibility, system integration strategies and pilot-scale demonstrations within the built environment (Hua et al., 2025; Liu et al., 2025; Li et al., 2026).

4. Conclusion and Further Research

This review synthesised 37 studies examining the role of artificial photosynthesis in net-zero commercial building research. The findings indicate that AP is increasingly viewed as a complementary technology within renewable-hydrogen energy ecosystems rather than as a replacement for photovoltaic systems. Its principal contribution lies in its potential to support long-duration energy storage through solar-to-hydrogen conversion.

However, AP remains at an early stage of technological maturity. Key barriers include catalyst durability, conversion efficiency limitations, uncertain economic viability, hydrogen infrastructure requirements and underdeveloped regulatory frameworks. The literature also reveals a shortage of building-scale studies, demonstration projects and lifecycle cost assessments relevant to commercial building implementation.

Future research should prioritise pilot-scale demonstrations, techno-economic modelling, lifecycle cost benchmarking and regulatory development for hydrogen-integrated buildings. Greater engagement from construction business and project management researchers will be essential to ensure that emerging AP technologies can be effectively translated into practical built-environment applications.

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Appendix 1

Table 1: Descriptive Characteristics of Studies Included in the Systematic Review

Dimension: *Category*	**Description of Evidence in Reviewed Studies**	**Sources (citations)**
Study Type:		
Experimental	Laboratory experiments investigate the performance of photocatalytic materials, photoelectrodes and reactor designs used in AP.	Jachimowski et al., 2025; Horzela-Miś et al., 2025; Muthukumaran et al., 2024; Abbas et al., 2020; Zhou & Zhou, 2023; Li et al., 2021; Hua et al., 2025; Temiz & Dincer, 2023; Lv et al., 2025; Song et al., 2019; Zhang et al., 2024; Mohlaba et al., 2023; Zhai et al., 2025; Qiu et al., 2025;
Modelling	Computational prediction of energy conversion and system performance	Liu et al., 2025; Ganesh, 2023; Wenten et al., 2024; Zhao et al., 2025
Simulation	Numerical simulations analyse AP system behaviour, solar utilisation efficiency and integration with renewable energy systems.	Wang et al., 2025; Wenten et al., 2024; Rehman et al., 2021; Gebreabe et al., 2025; Wang et al., 2026; Dong et al, 2025; Wei & An, 2024; Zou et al., 2025
Techno-economic analysis	Evaluation of cost, scalability and lifecycle performance	Raman et al., 2024; Kuittinen et al., 2021; Zhang et al., 2026; Wang et al., 2024; Alharasees et al.; 2024
Review	Review studies synthesise existing research to identify technological advances, limitations, and future research directions in artificial photosynthesis.	Ulhøi, 2021; Hamzah & Go, 2023; Sonyy et al., 2026; Lu et al., 2025
Technology Focus:		
Photocatalytic systems	Photocatalytic systems use semiconductor catalysts to enable solar-driven water splitting or CO2 reduction, focusing on efficiency and material stability.	Jachimowski et al., 2025; Horzela-Miś et al., 2025; Muthukumaran et al., 2024; Abbas et al., 2020; Zhou & Zhou, 2023; Li et al., 2021; Hua et al., 2025; Temiz & Dincer, 2023; Lv et al., 2025; Mohlaba et al., 2023; Zhai et al., 2025
Photoelectrochemical (PEC) cells	Photoelectrochemical cells integrate light absorption and electrochemical reactions to improve solar energy conversion efficiency and durability.	Song et al., 2019; Zhang et al., 2024; Liu et al., 2025; Wang & Pornrungroj, 2025; Ganesh, 2023; Arora et al., 2024; Wenten et al., 2024;
Hydrogen production	Many studies focus on solar-driven water splitting to produce hydrogen as a clean and sustainable energy carrier.	Wang & Pornrungroj, 2025; Ganesh, 2023; Arora et al., 2024; Zhao et al., 2025; Wei & An, 2024; Zou et al, 2025
Hybrid PV-artificial photosynthesis systems	Hybrid systems combine photovoltaic technology with catalytic processes to enhance energy conversion efficiency and operational control.	Wang et al., 2025; Wenten et al., 2024; Rehman et al., 2021; Dong et al., 2025; Wei & An, 2024; Hur et al., 2023; Lu et al., 2025; Li et al., 2026

Table 2: Thematic Classification Matrix

Theme	**Description of Theme**	**Key Findings from Reviewed Studies**	**Sources**
Artificial Photosynthesis and Solar-to-Fuel Technologies	Studies focusing on the development of AP systems and photoelectrochemical processes for solar driven fuel production	Research focuses on catalyst development, conversion efficiency and scalability; most studies remain laboratory based.	Muthukumaran et al., 2024; Zhou & Zhou, 2023; Li et al., 2021; Hua et al., 2025; Temiz & Dincer, 2023; Lv et al., 2025; Song et al., 2019; Zhang et al., 2024; Mohlaba et al., 2023; Wang et al., 2025
Hydrogen Production and Energy Storage Systems	Research examining hydrogen generation, storage, and utilisation as part of renewable energy systems.	Hydrogen is viewed as a promising long-duration storage solution, although cost and infrastructure challenges remain.	Li et al., 2021; Lv et al., 2025; Zhang et al., 2024; Liu et al., 2025; Wang & Pornrungroj, 2025; Ganesh, 2023; Arora et al., 2024; Mohlaba et al., 2023; Wang et al., 2025
Photovoltaic and Hybrid Solar Energy Systems	Studies investigating photovoltaic (PV), photovoltaic-thermal (PVT), and hybrid solar technologies for renewable electricity generation and building integration.	PV technologies remain more mature and possess established building-integration pathways.	Jachimowski et al., 2025; Horzela-Miś et al., 2025; Abbas et al., 2020; Wenten et al., 2024; Rehman et al., 2021; Gebreabe et al., 2025; Dong et al., 2025; Zhai et al., 2025; Zhao et al., 2025; Raman et al., 2024; Kuittinen et al., 2021
Energy Optimisation, Smart Systems, and Sustainability Assessment	Studies addressing digital energy management, optimisation techniques, and sustainability evaluation of renewable energy systems.	Machine learning, optimisation and lifecycle assessment are increasingly used to improve renewable energy performance.	Jachimowski et al., 2025; Abbas et al., 2020; Ganesh, 2023; Ulhøi, 2021; Zhang et al., 2026; Qiu et al., 2025; Wei & An, 2024; Wang et al., 2024; Hamzah & Go, 2023; Zou et al., 2025; Alharasees et al., 2024; Sonyy et al., 2026; Hur et al., 2023; Lu et al., 2025; Li et al., 2026

A socio-ecological transition framework for regenerative facilities management: thinking beyond operational efficiency

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Abstract

Traditional facilities management (FM) is attributed by regime-bound performance metrics such as asset optimisation, service reliability, maintenance management and cost control etc. This yardstick tends to constrain the capacity to address complex socio-ecological challenges such as resource depletion, climate vulnerability, and other key sustainability indicators. This study drives the concept of repositioning FM from the perspective of operational efficiency to regenerative practice through the lens of sustainability transition theory, using the Multi-Level Perspective (MLP). A qualitative, theory building approach is deployed for the study. This is achieved through the critical synthesis of interdisciplinary literature with informed insights for the development of a socio-ecological transition framework for regenerative facilities management. The study reveals that traditional facilities management limits sustainability outcomes because it focuses too much on efficiency. A socio-ecological transition framework, based on the Multi-Level Perspective, allows for a shift toward regenerative practices by combining changes in institutions, innovation, and the ability to adjust. This approach improves resilience, ecosystem restoration, and long-term value in the built environment. The developed framework articulates pathways for reconfiguring traditional FM systems and scaling regenerative functions across institutional, organisational and technological dimensions. Furthermore, there is the proposition of FM deliverables beyond conventional efficiency metrics through the infusion of regenerative parameters such as adaptive capacity and ecosystem restoration.

Keywords: Facilities Management, Operational Efficiency, Socio-Ecological Transition, Sustainability.

1. Introduction

Facilities management (FM) has historically been placed in a managerial premise that prioritises outcomes such as reliability and efficiency. This concept portrays the wider transformation of the discipline as a support function within organisational set up, where performance is usually assessed based on quantifiable outputs such maintenance efficiency, energy savings, lifecycle cost optimisation, effective space management, and efficient workforce management etc. (Atkins & Brooks, 2021; Ikuabe *et al*., 2023; Nielsen et al., 2016). While these metrics presents a formidable base for driving operational performance, they remain inadequate in addressing the systemic nature of contemporary environmental challenges. According to the United Nations Environment Programme (2022), the built environment is a major culprit in environmental degradation and carbon emission, thereby positioning facilities as critical nodes within the broader framework of socio-ecological systems. The emphasis of operational efficiency from facilities management obscures underlining structural problems affiliated with unsustainable practices of production and consumption. Amini-Philips *et al*., (2020) noted that attaining efficiency is important, yet it often produces incremental instead of transformative change and may inadvertently strengthen existing stance of resource-intensive development. This fundamental limitation gives the need for a shift geared towards a comprehensive approach that engages with regenerative capacity of ecological systems and resilience of social infrastructures. This study extends the theoretical discourse that facilities management must transition from a performance paradigm centred on optimisation toward one that actively contributes to socio-ecological regeneration. In conceptualising the transition, the study is underpinned using the Multi-Level Perspective, a sustainability transition theory, which outlays a framework for understanding how entrenched systems can evolve through interactions between innovation, institutional structures, and external pressures (Geels, 2011). Consequently, the study develops a socio-ecological transition framework that transposes FM as a key driver in achieving regenerative outcomes in the built environment.

2. Theoretical Foundation: Sustainability Transitions and the Multi-Level Perspective

Sustainability transitions theory has become a key approach for examining how large socio-technical

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systems change. A key part of this concept is the Multi-Level Perspective, which views transitions as dynamic processes shaped by interactions across various levels (Geels, 2011). These include the socio-technical regime, which represents the main set of practices, rules, and technologies; niche innovations, which act as incubators for alternative solutions; and the broader landscape, which covers larger forces like climate change, economic shifts, and cultural changes (Markard & Truffer, 2008). In facilities management, the regime consists of established norms and practices that direct the operation and maintenance of built assets. This includes standard procedures and performance measures that focus on efficiency and cost-effectiveness. Such regimes tend to be stable and dependent on existing paths, which can limit the adoption of more transformative sustainability approaches (Karanasios, 2026).

Conversely, specialised innovations offer a space for testing alternative practices. In facilities management, these might involve initiatives that incorporate circular economy principles or nature-based solutions aimed at improving environmental performance. Although these innovations usually operate on the peripheries, they can gain momentum under the right conditions and help change the regime. The environmental conditions brings in external pressures that can alter existing systems and lead to transformation. Issues such as climate change and new regulations regarding sustainability are particularly important. Moreover, stricter environmental rules and heightened awareness of ecological risks are pushing organizations to rethink conventional facilities management practices (Bröchner, 2019). Using the Multi-Level Perspective in facilities management highlights the need for coordinated action across these various levels. Moving towards regenerative practices needs not just technological innovation, but also institutional change and alignment with wider societal goals. This underscores the importance of taking a systems-oriented approach that acknowledges the connections between different parts of the built environment.

3. Limitations of Conventional Facilities Management Paradigms

Conventional facilities management mainly focuses on operational efficiency, while emphasizing on cost reduction and improving service delivery (Ikuabe *et al*., 2025). While this approach has provided clear benefits, it faces growing criticism for being too narrow and not capable of tackling complex sustainability challenges (Støre-Valen & Buser, 2019). Prioritizing efficiency can lead to short-term gains at the expense of long-term resilience, limiting the potential for real change. Nielsen et al., (2016) stated that a central limitation of this model is its reliance on metrics that overlook the wider impacts of facilities on social and ecological systems. For example, while better energy efficiency might cut operational costs, it may not consider the lifecycle impacts of materials or the indirect effects of increased consumption (Islam *et al*., 2021). This highlights a bigger issue in sustainability discussions, where efficiency is often mistaken for effectiveness, leading to a misalignment between performance metrics and environmental outcomes.

The organizational structure of facilities management reinforces some of the highlighted problems. Weerasinghe and Sandanayake (2017) stated that facilities management functions are often isolated in organizations, which limits chances for collaboration across different fields and integrated decision-making. This separation makes it harder to deal with interconnected challenges like climate adaptation and resource scarcity. Additionally, many facilities management contracts, especially in outsourced models, can create misaligned incentives that favour cost-cutting over sustainability goals (Zesach, 2025). Also, time considerations are also crucial in shaping facilities management practices. The focus on immediate results often discourages investments in long-term resilience and regenerative capacity. This is particularly concerning in the context of climate change, where effects build up over time and require proactive measures. As a result, traditional facilities management approaches tend to be reactive, addressing symptoms instead of the root causes.

4. Conceptualising Regenerative Facilities Management

Regenerative facilities management offers a new way of thinking about how buildings operate in harmony with natural and social systems. Adewale *et al*., (2026) noted that this approach draws on ideas from regenerative development and ecological design. The concept focuses on creating positive effects instead of just reducing harm (Camrass, 2022). It pushes the boundaries of traditional facilities management by seeing buildings as active players in ecological and social processes. Also, regenerative facilities management involves changing both practices and viewpoints. It requires viewing facilities as parts of living systems where human actions and ecological processes influence each other (Pavez *et al*., 2024). This view promotes using nature-based solutions, like green infrastructure and water-sensitive design, in facility operations. Also, the concept strives to not only improve environmental performance but also support wider ecosystem services, such as promoting biodiversity and regulating the climate (Kasina *et al*., 2025). Another key part of regenerative facilities management is adopting circular economy principles. According to Onyia *et al*., (2025), this means rethinking how resources flow within buildings to reduce waste and increase the reuse and regeneration of materials. These methods challenge the linear consumption models found in traditional practices and encourage

more sustainable resource use (Geissdoerfer *et al*., 2017). Redefining performance metrics to reflect regenerative outcomes is equally important. Traditional indicators, like cost efficiency and service reliability, are joined by measures of ecological health, social value, and adaptive capacity. This calls for new evaluation frameworks that capture the diverse impacts of facilities management activities. Regenerative facilities management also requires a change in organizational culture and governance. It needs a move towards more collaborative and participatory methods, where stakeholders play a role in creating solutions (Kasina *et al*., 2025). This aligns with broader trends in sustainability governance, which highlight the importance of inclusivity and shared responsibility.

4.1. A Socio-Ecological Transition Framework for Regenerative FM

The proposed socio-ecological transition framework builds on the Multi-Level Perspective to offer a clear way to shift from conventional to regenerative FM. It views this transition as a process of reconfiguring systems that includes changes in institutional arrangements, organizational practices, and technological systems. As shown in Figure 1, at the institutional level, the framework highlights the need for policies and regulations that support regenerative practices. This includes creating standards and guidelines that focus on long-term sustainability rather than short-term efficiency. Policy tools like incentives, subsidies, and performance-based regulations can play a vital role in making this transition happen. At the organizational level, the framework stresses the importance of including regenerative principles in strategic decision-making. This means aligning organizational goals with sustainability aims and making these priorities part of daily operations. Building capacity and sharing knowledge are crucial for helping organizations gain the skills needed for regenerative FM. Technological innovation is another key factor in this transition. Digital tools like building information modelling and Internet of Things technologies can improve the monitoring and management of facilities, providing useful data for decision-making. However, the success of these technologies relies on their integration within a broader socio-ecological framework that focuses on regenerative outcomes. The framework also acknowledges how external factors can influence the transition. Landscape pressures such as climate change, economic shifts, and societal expectations create both challenges and opportunities for FM. By addressing these pressures, organizations can establish themselves as leaders in sustainability and resilience.

4.2. Implications for Policy and Practice

The move toward regenerative facilities management requires a significant change in both policy and practice. It calls for an intersection between regulations and decision-making processes. At the policy level, there is a need to shift from a focus on compliance to one that supports flexibility and performance. Traditional regulations in the built environment often focus on basic requirements for energy use and environmental rules. While these are important, they are not enough to drive regenerative practices. Policymakers should create regulations that encourage positive environmental outcomes and long-term resilience. Facilities should be assessed not just on how they reduce negative impacts but also on their ability to create ecological and social benefits. Furthermore, financial tools like tax breaks and subsidies can further

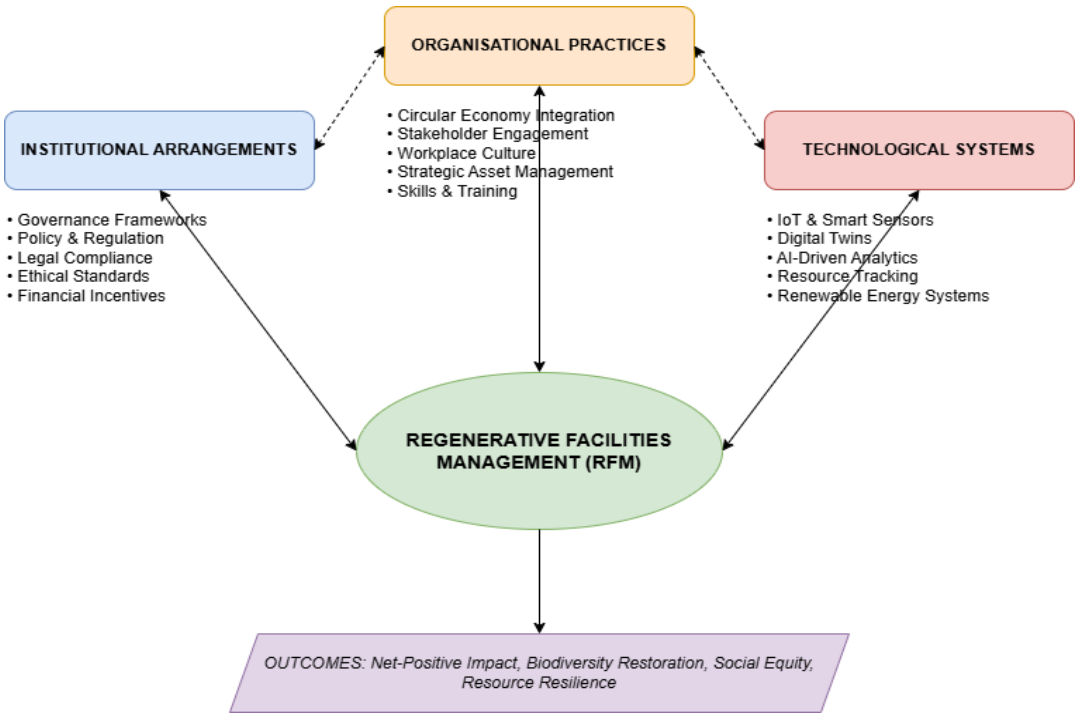

Figure 1: A Socio-Ecological Transition Framework for Regenerative FM

support the adoption of regenerative practices by lowering the perceived financial risks of long-term investments. These policy tools are especially important in developing countries, where funding limitations can hinder the use of innovative sustainable practices. Moreover, leadership from the public sector is essential, given its position as a major client and property owner in the built environment. Governments can use public procurement as a way to promote regenerative facilities management by adding sustainability criteria to bidding processes and service agreements. This involves including requirements for regenerative performance metrics and life-cycle impact evaluations in contracts. By doing this, public institutions can drive market changes and create a demand for regenerative solutions for facilities management.

From a governance perspective, this transition requires a more cooperative institutional drive. The complexity of social and environmental issues demands coordination across several policy areas, such as urban planning, environmental management, infrastructure, and economic policy. Fragmented governance systems often weaken sustainability efforts. Therefore, a more holistic approach is needed, one that supports collaboration across sectors and aligns goals at various decision-making levels. For professionals, this shift has major implications. Regenerative facilities management requires a change in job roles and strategies within organizations. Facilities managers need to go beyond their traditional tasks and engage more deeply with sustainability goals. This means employing systems thinking skills, which outlines the relationships between facility operations and ecological systems. This perspective allows for better decision-making that considers long-term effects and emerging risks. Moreover, integrating regenerative principles into an organization's strategy also means changing how to manage performance. Traditional metrics that focus on cost and reliability need to be supplemented with measures that assess ecological recovery and climate resilience. This calls for new evaluation frameworks and data systems that can handle complex, often unpredictable outcomes. Digital tools like building information modeling and advanced analytics can aid this transition by offering immediate insights into facility performance, but their use must have a clear goal of promoting regeneration to avoid reinforcing a narrow focus on efficiency.

5. Conclusion

This study has advanced the discourse on facilities management by critically interrogating the limitations of an efficiency-driven paradigm and proposing a transition toward a regenerative, socio-ecological model. By placing facilities management within the framework of sustainability transitions and using the Multi-Level Perspective, the study shows that real change in the built environment needs systemic change instead of incremental optimisation. The current facilities management system, which emphasizes operational performance, is increasingly becoming outdated with urgency of today's environmental and social challenges. The socio-ecological transition framework developed in the study offers a way to rethink facilities management practices at institutional, organizational, and technological levels. It underscores the need to connect specialised innovations with broader pressures to enable system change. This framework positions regenerative facilities management not as an optional concept but as a necessary evolution of the discipline in response to global sustainability needs. A key contribution of this study is its rethinking of performance in facilities management. By going beyond traditional efficiency measures, the research highlights the importance of assessing facilities based on their ability to produce positive ecological and social outcomes. This change in how performance is viewed carries significant implications. It challenges long-held beliefs about value creation and calls for new measures and governance methods. The study also emphasizes the need for integrating different fields to tackle complex socio-ecological issues. Facilities management inherently connects with various areas, including engineering, environmental science, economics, and social policy. A regenerative approach requires blending these viewpoints to enable more comprehensive and flexible responses to new risks and opportunities. This interdisciplinary focus is especially important in the face of climate change, where the effects are diverse and interconnected.

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Construction and Demolition Concrete Waste Management in Gauteng: Challenges and Strategic Interventions for Circular Construction.

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Abstract

This paper investigates the challenges of construction and demolition (C&D) concrete management in Gauteng Province, South Africa, and proposes strategic interventions aligned with circular economy principles. A qualitative-dominant mixed-methods design was adopted, comprising semi-structured interviews and open-ended questionnaires with nine construction professionals (contractors, site managers, waste handlers) who have practised for a minimum of five years across multiple sites in Gauteng (Benoni, Springs, Roodepoort, Germiston, Parktown Roseband and Johannesburg). Data were analysed using thematic analysis following Braun & Clarke's six-phase framework. Construction-phase waste is driven by over-ordering, miscalculations, and a "build-first, manage-later" culture. Demolition-phase waste is exacerbated by lack of pre-demolition audits, inadequate site security, and failure to separate rebar from concrete. Common barriers across both phases include misconceptions that recycled concrete is weak or short-lived, high transport costs, absence of nearby recycling facilities, low Building Information Modelling (BIM) awareness, and inconsistent enforcement of the National Environmental Management: Waste Act (large projects monitored, small projects ignored). The modest sample (n=9) and geographic focus limit generalisability; quantitative waste audits are needed. Integrated strategies include mandatory pre-demolition audits, landfill taxes, decentralised recycling infrastructure, SME-friendly BIM training, and municipal provision of waste storage containers. This study provides the first empirical application of the COM-B behavioural framework to C&D concrete waste in an African urban context, distinguishing construction-phase from demolition-phase barriers.

Keywords: Circular economy, concrete waste management, construction and demolition waste, South Africa, sustainable construction

1. Introduction

The construction industry is a major contributor to environmental degradation through extensive resource consumption, waste generation, and high energy use (European Commission, 2023; UNEP, 2026). Globally, the sector accounts for over 30% of natural resource extraction, 25% of solid waste, and 40% of greenhouse gas emissions (European Commission, 2023), while also contributing nearly 50% of global material extraction, 37% of global emissions, and 28% of global energy consumption (UNEP, 2026). Gauteng Province, South Africa's economic hub with over 16 million residents (Cowling, 2024), exemplifies this challenge. Rapid urbanisation drives numerous construction and demolition (C&D) activities, generating substantial concrete waste from over-ordered ready-mix and washout on construction sites, to reinforced concrete slabs and columns from demolition sites (Alazaiza *et al.*, 2024; Simon, Beushausen and Alexander, 2025).

Concrete is one of the most dominant waste streams in South Africa's construction sector. Phuluphedziso (2022) found that concrete and brick account for a significant proportion of waste on Gauteng construction sites. Nationally, Berge and Von Blottnitz (2022) estimate that C&D waste will increase significantly, with concrete representing the largest fraction. Most of this waste is landfilled, contributing to pollution, landfill overflow, and resource depletion. Poor planning, over-ordering, weak supervision, and inadequate site management exacerbate the problem. The absence of pre-demolition planning further compounds demolition-phase waste (Fitchett and Rambuwani, 2022).

The environmental impacts of poor C&D waste management are extensive. Estokova, Fabianova and Ondova (2022) note that the construction sector substantially contributes to greenhouse gas emissions through inefficient material use. Unmanaged concrete waste also generates dust pollution, poor air quality, and unsafe conditions for surrounding communities (de Jager and Kubanza, 2025). Economically, waste increases project costs through unnecessary procurement, transport, and disposal. Circular economy principles offer a critical pathway to improve sustainability (Velenturf and Purnell, 2021). Despite growing international attention, adoption of sustainable C&D concrete waste management in South Africa

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remains limited due to technological, behavioural, infrastructural, and regulatory barriers (Ishola and Gumbo, 2026; Aseni et al., 2025). The problem is that concrete waste is increasingly generated on C&D sites in Gauteng due to poor handling, inadequate supervision, poor planning, and lack of pre-demolition waste recovery strategies, contributing to environmental degradation and health risks (Fitchett & Rambuwani, 2022).

This research investigates the root causes of concrete waste in Gauteng's C&D sectors and proposes practical strategies to reduce waste and promote sustainability. The objectives are: (1) identify primary causes of concrete waste generation; (2) examine environmental and operational impacts; (3) assess current management practices; (4) evaluate strategy effectiveness; (5) identify barriers; (6) assess stakeholder awareness; and (7) recommend context-specific strategies. The hypothesis is that ineffective planning, poor supervision, low awareness, and recycling barriers are key contributors, and that targeted strategies can significantly reduce waste. This paper reports on a qualitative-dominant mixed-methods study using semi-structured questionnaires and thematic analysis. Limitations include a small sample (n=9), limited time and geographic focus on Gauteng. The originality lies in the first empirical application of the COM-B behavioural framework to C&D concrete waste in a South African urban context. The findings benefit policymakers, contractors, and industry bodies.

2. Literature Review

2.1. Defining Construction and Demolition Concrete Waste

C&D waste is the stream arising from construction, renovation, and demolition activities (Alazaiza et al., 2024). Concrete waste has two distinct types. Construction-phase waste includes over-ordered ready-mix, washout, and off-cuts, typically fresh and uncontaminated. Demolition-phase waste includes reinforced concrete from foundations, columns, and slabs, heterogeneous, often contaminated with steel, brick, soil, and hazardous materials, requiring mechanical processing (Alazaiza et al., 2024). This distinction matters because policies and technologies effective for fresh construction waste may be unsuitable for demolition waste. This paper addresses both categories, recognising that their causes differ but management solutions overlap under circular economy principles (Simon et al., 2025; Velenturf & Purnell, 2021).

2.2. Construction-Phase Concrete Waste: Causes and Patterns

Construction-phase concrete waste arises from operational inefficiencies on active building sites, including new builds and renovations. Unlike demolition waste generated from teardowns, construction-phase waste stems from over-ordering, poor inventory management, inaccurate quantity forecasting, and inadequate supervision (Phuluphedziso, 2022). Fitchett and Rambuwani (2022) describe a "build-first, manage-later" culture where waste management is an afterthought, leading to over-pouring, material damage, and excessive off-cuts.

De Villiers et al. (2024) note that South Africa generates an estimated 12.2–24.3 million tonnes of C&D waste annually, while the national demand for aggregate and supplementary cementitious materials is 77.9 million tonnes, a significant gap that underscores the potential for recycling. Simon et al. (2025) observe that the traditional linear approach using virgin materials prolongs environmental challenges, contributing to increased energy usage and CO_2 emissions.

2.3. Demolition Practices and Concrete Waste Generation

Demolition activities present unique challenges distinct from construction-phase waste. Key demolition-specific issues include lack of pre-demolition audits, systematic surveys to identify reusable and recyclable materials, mandatory in several European countries and Cape Town, but not in Gauteng (Fitchett & Rambuwani, 2022). Without audits, valuable concrete is contaminated during uncontrolled demolition. Inadequate site security allows unauthorised access and illegal dumping, increasing contamination. Failure to separate rebar from reinforced concrete requires mechanical processing that many small contractors lack, sending mixed waste to landfill (Alazaiza et al., 2024). Contamination with hazardous materials (asbestos, lead paint) must be removed before recycling, and decontamination costs discourage recycling (Amadi & Mahachi, 2025). These demolition-specific barriers are largely absent from general C&D literature focused on construction-phase waste.

2.4. Construction Culture and Behavioural Barriers

A critical driver of concrete waste is the prevailing cultural approach. Fitchett and Rambuwani (2022) describe a "build-first, manage-later" mentality where timelines and cost pressures override sustainability, treating waste as unavoidable. The same applies to demolition: "demolish-first, manage-later" means no planning for material recovery. Ngcobo et al. (2024) confirm that ineffective project management is a critical challenge.

Phuluphedziso (2022) notes that many teams lack formal waste management training and effective communication, leading to over-pouring and miscommunication. Aseni et al. (2025) identify entrenched resistance to change, limited awareness, and fragmented industry practices as significant

behavioural barriers to circular economy adoption. Marsh et al. (2021) apply the COM-B model (Capability, Opportunity, Motivation) and Theoretical Domains Framework, finding that many professionals lack capability (skills and knowledge), opportunity (resources and time), and motivation (incentives and cultural support) to implement waste-reducing strategies.

2.5. Technological and Policy Interventions

Building Information Modelling (BIM) can reduce waste by improving design coordination, quantity estimation, and real-time decision-making, reducing over-ordering (Liphadzi et al., 2022). For demolition, BIM can model existing buildings to plan selective demolition sequences and estimate recoverable volumes. However, BIM adoption in South Africa remains uneven, particularly among SMEs, due to cost, skills shortages, and lack of awareness. Constraints to clients' acceptance of recycled materials (2024) identifies lack of recycling facilities, resistance to change, absence of appropriate technology, limited availability of materials, and lack of proper standards as key barriers.

Recycling concrete waste is another area of interest. Dun et al. (2021) found waste concrete powder performs comparably to traditional grouts. Simon et al. (2025) note that while successful international practices exist, South Africa's recycling rate needs improvement. De Villiers et al. (2024) quantify that the annual demand for aggregate and supplementary cementitious materials (77.9 Mt) far exceeds available CDW (12.2–24.3 Mt).

At the policy level, the National Environmental Management: Waste Act (NEMWA) No. 59 of 2008 mandates waste reduction, but compliance is inconsistent (Nzima & Koranteng, 2022). Municipal enforcement is weak (Berge & Von Blottnitz, 2022), and unlike Europe, South Africa lacks landfill taxes or recycling subsidies (Hasselsteen et al., 2026). Hasselsteen et al. (2026) compare the UK's landfill taxation and Extended Producer Responsibility (EPR) with the UAE's innovation-led approach, offering transferable lessons.

International best practices, such as the EU's Waste Framework Directive and Japan's pre-demolition audit requirements, offer transferable lessons, including enforceable recovery targets and economic incentives. Amadi and Mahachi (2025) confirm that landfill taxes, penalties for illegal dumping, and taxes on virgin material use are among the most effective policy interventions.

3. Research Methodology

This study adopted an interpretivist research philosophy, recognising that waste management practices are shaped by social, cultural, and organisational contexts. Interpretivism focuses on practical, real-world problem-solving (Merli et al., 2020). A qualitative-dominant mixed-methods design was employed, combining semi-structured interviews and open-ended questionnaires to enable in-depth understanding of behavioural, operational, and institutional factors. An exploratory design captured rich stakeholder insights. The target population comprised construction professionals in Gauteng's demolition and construction sectors, including contractors, site managers, supervisors, and site-based workers. A purposive sampling strategy selected participants with direct concrete waste management experience. Selection criteria were: (a) minimum five years' continuous experience in the South African construction industry; (b) direct involvement in demolition, waste handling, site supervision, or construction management; and (c) operation across multiple Gauteng sites (Benoni, Springs, Roodepoort, Germiston, Johannesburg). Purposive sampling was appropriate because the research problem requires in-depth, context-specific insights from information-rich cases, with the five-year threshold ensuring sufficient practical exposure.

Data were collected over three weeks through telephonic and in-person engagements. The semi-structured questionnaire covered causes of concrete waste, material handling, recycling awareness, technological adoption (BIM), policy compliance, leadership, and education. A purely quantitative approach would fail to capture contextual details such as why contractors hold misconceptions or how the "build-first" culture operates. The qualitative-dominant design allows open-ended responses that capture nuance and unexpected themes, while the sample of nine respondents provides sufficient breadth to identify recurring patterns. Data were analysed using thematic analysis following Braun and Clarke's (2006) six-phase framework: familiarisation, initial coding, theme generation, theme review, theme definition, and write-up. Two researchers independently coded 20% of the data, achieving 87% inter-coder agreement. The questionnaire was pilot-tested with two professionals to ensure clarity and relevance. Ethical compliance followed University of the Witwatersrand guidelines: informed consent, anonymisation, and secure data storage. Clearance certificate protocol number CEM: EC/08/25/FG3/2427203/, Status: Approved, minimum risk.

4. Findings and Discussion

4.1. Findings

The questionnaire responses from nine construction professionals across Benoni, Springs, Roodepoort, Germiston, Parktown, Rosebank and Johannesburg revealed seven dominant themes. Table 1 summarizes

Table 1: Themes, sub-themes, representative quotes, and frequency (n=9)

Theme	Sub-themes	Example quote	Frequency
1. Poor planning and demolition protocols	Over-ordering, miscalculations; lack of pre-demolition audits; inadequate site security; no waste recovery plan	"Miscalculations by foremen ordering more concrete, suppliers supply in bulk." (Respondent 5, online)	7/9
2. "Build-first, manage-later" culture	Waste obstructs workspace; cleanup neglected due to fatigue or lack of resources; cost and schedule prioritised	"It creates piles of waste on sites which later are not effectively managed." (Germiston respondent)	8/9
3. Misconceptions about recycled concrete	Perceived as weak, low grade, short lifespan, contaminated, unsuitable for structural use	"Recycled concrete is perceived as being weaker than traditional concrete… full of contaminants." (Respondent 2, online)	8/9
4. Recycling infrastructure barriers	No nearby facilities; high transport costs; lack of municipal support; no storage containers for small projects	"Facilities are not enough close by for the majority of communities." (Benoni respondent)	9/9
5. Low technological adoption (BIM)	Unfamiliarity with BIM; lack of knowledge, skills, training; some recognise potential for accurate quantity estimation	"BIM is not known, people don't use it, they don't know it." (Roodepoort respondent)	9/9
6. Inconsistent policy enforcement	National Waste Act applies to large projects but ignored for small works; many professionals unaware of the Act	"For bigger projects it is effective, but for smaller projects people don't even know about it." (Germiston respondent)	8/9
7. Leadership and education gaps	Leadership influences behaviour, but few have received formal training or stakeholder collaboration	"No educational programs have been introduced to me." (8/9 responded "No")	8/9

the themes, sub-themes, representative quotes, and frequency of mention.

Poor planning was the most frequently cited cause. One participant noted, "Miscalculations by foremen ordering more concrete, suppliers supply in bulk" (Respondent 5). Another cited "non-compliance from unregistered construction companies dumping waste at convenient locations" (Respondent 1). The Benoni respondent added, "Not having proper equipment to store the material, disposing at convenient areas around them." Eight respondents described the "build-first, manage-later" culture. The Germiston company stated, "It creates piles of waste on sites which later are not effectively managed." A Roodepoort participant added, "It creates extra work and people will be tired to clean after." Eight respondents reported misconceptions that recycled concrete is weak or short-lived. Respondent 2 said, "Recycled concrete is perceived as weaker than traditional concrete… full of contaminants." All nine identified infrastructure deficits as a major barrier, with the Benoni respondent noting, "Facilities are not enough close by for the majority of communities." All nine were unfamiliar with BIM; the Roodepoort participant stated, "BIM is not known, people don't use it, they don't know it." Eight observed inconsistent policy enforcement, noting the Waste Act is effective for bigger projects but ignored for smaller ones. Eight of nine said leadership influences sustainable behaviour, but eight also reported no educational programs or stakeholder collaborations had been introduced.

4.2. Discussion

Applying the COM-B model (Marsh, Brent & De Kock, 2021) reveals systemic deficits. Capability deficits include lack of BIM knowledge, recycling methods, and misconceptions about recycled concrete quality. Opportunity deficits include absence of nearby recycling facilities (all nine respondents), high transport costs, lack of municipal storage containers, and weak policy enforcement that allows smaller projects to operate with impunity. Motivation deficits include the "build-first" culture (eight respondents), prioritisation of speed and cost over sustainability, absence of financial penalties for landfilling, and lack of economic incentives. These categories reinforce each other: low capability reduces motivation, while limited opportunity makes sustainable practices impractical even when capability exists.

The findings align with Phuluphedziso (2022) and Fitchett and Rambuwani (2022) on poor planning and construction culture. However, this study extends prior work by providing demolition-specific insights (lack of

pre-demolition audits, rebar separation, contamination) largely absent from general C&D literature. Infrastructure barriers confirm Berge and Von Blottnitz (2022), and the BIM awareness gap aligns with Liphadzi, Musonda and Onososen (2022). The two-tier enforcement reality documented here provides empirical evidence for what previous literature had only suggested.

This study makes three contributions. First, it is the first empirical application of the COM-B model to C&D concrete waste in an African urban context. Second, it explicitly distinguishes construction-phase from demolition-phase waste, revealing barriers unique to demolition. Third, it documents two-tier policy enforcement empirically. Based on these findings, the following recommendations are offered: mandatory pre-demolition waste audits for all demolition permits (Gauteng municipalities); introduction of a landfill tax with recycling rebate (National Treasury/DEFF); investment in decentralised recycling infrastructure such as mobile crushing units (municipalities/private sector); mandatory CPD training on C&D waste management (industry bodies); expansion of university curricula to include circular economy and design for deconstruction; municipal provision of waste storage containers for small contractors; and strengthening policy enforcement across all project scales through random inspections and integration with permitting systems (Figure 1).

5. Conclusion and Further Research

This research concludes that ineffective C&D concrete waste management in Gauteng arises This research concludes that ineffective C&D concrete waste management in Gauteng arises primarily from a reactive construction culture, insufficient planning, limited technical and regulatory capacity, and persistent misconceptions about recycled materials. Using the COM-B framework, the study demonstrates

Figure 1: Conceptual Framework: Com-B Model for C&D Concrete Waste (adapted from Marsh, Brent & De Kock, 2021)

that sustainable waste management requires simultaneous improvements in capability (training, awareness, skills), opportunity (infrastructure, enforcement, incentives), and motivation (leadership, culture, economic drivers). While the National Environmental Management: Waste Act provides a strong legislative framework, its enforcement remains inconsistent – largely benefiting large contractors while neglecting smaller and informal projects. However, findings indicate a clear willingness among professionals to adopt improved practices, provided they receive institutional support through education, financial incentives, infrastructure development, and stronger leadership engagement. A holistic, collaborative approach integrating behavioural change, regulatory reform, technological innovation, and multi-stakeholder participation is essential to align South Africa's construction sector with circular economy principles and the Sustainable Development Goals.

Further research should include: (1) quantitative waste audits to measure demolition waste volumes, disposal costs, and recycling rates; (2) cost-benefit analyses of recycling versus landfilling in Gauteng; (3) longitudinal studies assessing the long-term impact of policy interventions and training programmes; (4) investigation of the informal sector's role in C&D waste recovery; (5) pilot studies of digital waste tracking platforms; and (6) comparative studies across South African provinces to identify region-specific barriers and best practices.

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A Predictive Model for Estimating the Service Life of Floor Finishes in Public Office Buildings in Nairobi: Implications for Maintenance Practice and Policy

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Abstract

Service life prediction, a key component of lifecycle-based asset management, remains underdeveloped and underutilized in Kenya's public building sector. The absence of empirical prediction tools has contributed to reactive maintenance leading to inefficient use of resources in public office buildings. The main aim of the study was to develop a predictive model for estimating the service life of floor finishes in public office buildings in Nairobi. The study examined the common types of floor finishes and their service lives, determining the factors influencing service life and examining relevant regulatory frameworks using a mixed-methods approach. Quantitative data was collected from 42 government-owned office buildings through a questionnaire to facility managers as well as observations on the floor conditions. Qualitative insights were obtained from officials at the State Department for Public Works, Kenya Bureau of Standards (KEBS), and the Kenya Association of Manufacturers (KAM). Multiple regression analysis was used to examine the influence of nine determinants on observed service life.The regression model was statistically significant ($F(9,32)=2.313$, $p=0.039$) and explained 39.4% of the variance in service life ($R^2=0.394$). Management practices ($\beta=-0.580$, $p=0.005$), design deficiency ($\beta=0.447$, $p=0.021$), accidents/force majeure ($\beta=0.356$, $p=0.041$), and poor workmanship ($\beta=0.383$, $p=0.043$) were statistically significant predictors. Management-related factors had the strongest influence, highlighting the role of institutional culture in material performance .The study recommended stronger implementation of the existing maintenance policies while standardizing maintenance practices across all public office buildings. The proposed model provides a practical decision-support tool for lifecycle-based procurement and predictive maintenance scheduling for efficient use of public resources.

Keywords: Floor Finishes, Lifecycle Costing, Maintenance Planning, Predictive Modelling, Public Buildings

1. Introduction

Public buildings, according to (Christiaens, 2022) are assets created to disperse government services, making it important to minimize maintenance costs to ensure efficient use of public resources. Despite this, their long-term performance in many developing countries is compromised by inadequate maintenance, poor materials selection, and the absence of evidence-based planning tools(Zeni & Kikwasi, 2023). Floors, one of the most heavily used elements in building interiors, are particularly vulnerable to deterioration due to continuous foot traffic, furniture movement, and environmental exposure.

International standards such as ISO 15686 provide structured approaches for service life planning. Despite this, applying them in Kenya has been limited due to differences in climatic conditions, procurement practices, and installation quality(Ferreira et al., 2021). Current policy instruments in Kenya including the National Building Code (2024) and Sessional Paper No. 2 of 2015, recognize the need for structured maintenance but lack practical tools for predicting service life or guiding material selection based on empirical performance. In the absence of the empirical models, maintenance managers lack the capacity to forecast replacement cycles, prioritize resource allocation, or justify budgets using objective indicators (Plebankiewicz & Gracki, 2024). This gap results in haphazard maintenance, premature material replacement and inefficient utilization of resources. Existing literature on service life prediction predominantly focuses on building envelopes and structural systems, with limited empirical modelling of interior finishes and especially floor finishes. In addition, most models put emphasis on physical deterioration without taking into consideration the influence of managerial and institutional culture on the service life of finishes.

In response to the identified gaps in service life prediction and maintenance planning for floor finishes in Kenyan public buildings, this study was undertaken to support more evidence-based decision-making in the management of public assets. Through integration of service life prediction with lifecycle costing principles, the study seeks to contribute to more efficient use of public funds, improved building performance, and safer indoor environments for users.The study findings contribute to existing knowledge by bridging the gap between service life planning, maintenance

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management, and lifecycle costing in the context of developing countries. This study is expected to be beneficial to facility and maintenance practitioners, built environment professionals and policy makers by providing practical tools that can aid life-cycle based procurement decisions and maintenance planning.

2. Literature Review

2.1. Performance Requirements for Floor Finishes Relating to Service Life

The service life performance of floor finishes can be defined as the time during which a floor finish fulfills it's intended functional, aesthetic and safety requirements without the need for a major repair or replacement (Silva, et al., 2022) . Floor finishes play an important role in enhancing the comfort of users, the protection of the substrates of and enhancing the overall building functionality.The performance of floor finishes is influence by several factors including characteristics of materials, quality of installation, maintenance practices and usage patterns as discussed in the subsequent paragraphs. For this study, the service life performance of floor finishes was the dependent variable while the factors influencing service life performance including design quality, quality of workmanship, maintenance practices, management practices and accidental factors were the independent variables.

According to (Harris and Fitzgerald, 2017) the selection of floor finishes is primarily driven by durability, safety, resistance to wear, and ease of maintenance. However, for finishes to achieve their intended design life, they must be applied to sound, dry substrates. Poor installation or moisture control drastically shortens their longevity (Folorunso, 2021). Environmental factors including high humidity , temperature changes and use of harsh chemicals have also been shown to reduce the service life performance of floor finishes (Folorunso, 2021). Similarly, the intensity of usage is also another factor that heavily affects the performance of floor finishes. Heavy foot traffic, rolling chairs, carts and equipment all abrade the surface. High-traffic areas such as lobbies and corridors see constant abrasion impacting the performance (Dixit et al., 2019). Heavily used spaces are also more prone to accumulated dirt, sand, and grit which cause abrasion and accelerate wear and tear , shortening the service life.

In addition to physical factors, management and maintenance decisions also play a role in service life performance. Management decisions influence maintenance practices, repair routines and lifecycle planning all which can extend or minimize the service life (West et al., 2024). Therefore, the service life performance of floor finishes should be viewed as a function of technical design quality, workmanship, usage conditions, environmental exposure, and institutional management practices.

2.2. The case for Service Life Prediction and the Degradation Theory

Service life prediction is dependent on a systematic approach for estimating the period within which building materials and components can satisfactorily meet their performance requirements. De Brito and Silva, (2020) assert that service life prediction is generally addressed by the determination of mechanical and chemical loads (such as in laboratory tests in-service) where the building materials are most likely to be subjected; features of the materials and components; computerized knowledge of the materials and their components; articulating performance requirements and criteria for evaluating the materials' performance; and figuring out the mechanism of degradation of the materials and systems. Such predictive approaches support proactive maintenance planning and informed decision-making regarding repair and replacement interventions.

The degradation theory provides the foundation for this study, positing that material deterioration is driven by the interaction between an object's internal energy and its external environment(Varlamov et al., 2018). In the case of floor finishes, factors such as moisture exposure, temperature fluctuations, mechanical abrasion, and use of harsh chemical contribute to the deterioration process and ultimately affect service life performance. While critics such as (Lacasse et al., 2020) argue that degradation models can be overly theoretical, empirical evidence by (Shao et al., 2013 ; Varlamov et al., 2018) shows that targeted maintenance can substantially mitigate these effects and extend service life. This theory provides a framework for examining how design quality, workmanship, environmental conditions, usage intensity, and institutional management practices influence the service life performance of floor finishes. It further supports the argument that effective maintenance and management interventions can modify deterioration rates and improve long-term performance.

3. Research Methodology

The study used a mixed methods approach that combined quantitative performance data with qualitative insights from facility managers and maintenance personnel. This approach allowed for an in-depth analysis of statistical evidence with institutional factors that influence service life. The study covered public office buildings in Nairobi City County. Census sampling was preferred in this study since due to the relatively small overall number of buildings made it feasible to conduct a full census. A preliminary audit identified 77 government-owned buildings with the final sample size reducing to 49

buildings after excluding demolished structures, small buildings (with a plinth area of less than 4000 sq. ft.), and inaccessible sites. Data was received from 42 buildings, indicating an 86% response rate, using structured questionnaires, observation checklists and key informant interviews with representatives from The State Department for Public Works, The Kenya Bureau of Standards(KEBS) and the Kenya Association of Manufacturers(KAM). The variables captured reflected the conceptual framework of service life performance, including Design deficiency, Quality of workmanship, Type and Frequency of maintenance, Management Practices, Accidental/force majeure impacts and the Observed service life in years. The qualitative component was primarily used to support the interpretation and validation of quantitative findings. The detailed interview and observation results are not presented separately in this paper but are reflected in the discussion of the quantitative findings.

For data analysis, descriptive and inferential statistics including frequencies , correlation analysis , ANOVA and Multiple Regression Analysis were used to quantify the influence of these independent variables on the observed service life of floor finishes. Multiple Regression Analysis was selected as the primary technique because it allowed for the simultaneous examination of multiple factors. It also offered a practical, interpretable tool for asset managers, while alternative probabilistic models were deemed unsuitable due to local data constraints.

4. Findings and Discussion

4.1. Model Summary

The model summary was used to assess the overall fit of the regression model and to evaluate how well the set of nine predictors namely; normal wear and tear, vandalism, design deficiency, negligence/misuse, accidents/force majeure, infestations, management issues, poor workmanship, and client preference, which collectively explains variations in the service life of floor finishes (SLFF). This analysis provided key indicators of the strength of the relationship between the predictors and the dependent variable, as well as the proportion of variance in SLFF accounted for by the model (Table 1).

The regression model produced an R value of 0.628, indicating a moderate relationship between the combined predictors and the service life of floor finishes (SLFF). The coefficient of determination (R^2 = 0.394) revealed that approximately 39.4% of the variance in SLFF was accounted for by the nine independent variables included in the model.

Although the level of explanatory power indicated that additional unobserved factors may influence service life outcomes, it is consistent with studies examining institutional and behavioural determinants of building performance. The adjusted R^2 value of 0.224 accounted for the number of predictors. The statistically significant F-change (p = 0.039) confirmed that the model contributed meaningfully to explaining variation in SLFF. These results justified further examination of the individual regression coefficients (Table 2) to

Table 1: Model Summary for Regression Predicting Service Life of Floor Finishes (SLFF)

Model	R	R Square	Adjusted R Square	Std. Error of the Estimate	Change Statistics				
					R Square Change	F Change	df1	df2	Sig. F Change
1	.628[a]	.394	.224	.136	.394	2.313	9	32	.039
a. Predictors: (Constant), Normal wear and tear, Vandalism, Design deficiency, Negligence/misuse, Accidents/force majeure, Infestations, Management issues, Poor workmanship, Client preference									

Source: (Field study ,2025)

Table 2: Regression Co-efficients

Model		Unstandardized Coefficients		Standardized Coefficients	t	Sig.	Correlations		
		B	Std. Error	Beta			Zero-order	Partial	Part
1	(Constant)	-.161	.068		-2.354	.025			
	Normal wear and tear	.127	.065	.356	1.947	.060	.087	.325	.268
	Vandalism	.094	.085	.199	1.101	.279	-.057	.191	.151
	Design deficiency	.195	.080	.447	2.428	.021	.383	.394	.334
	Negligence/misuse	.045	.049	.145	.920	.365	.189	.160	.127
	Accidents/force majeure	.120	.056	.356	2.135	.041	.247	.353	.294
	Infestations	-.009	.107	-.012	-.083	.934	-.035	-.015	-.011
	Management issues	-.237	.079	-.580	-3.014	.005	-.070	-.470	-.415
	Poor workmanship	.118	.056	.383	2.106	.043	.180	.349	.290
	Client preference	-.036	.059	-.115	-.607	.548	.189	-.107	-.084
a. Dependent Variable: Service Life of Floor Finishes (SLFF)									

Source: (Field study, 2025)

identify which predictors have the strongest influence on SLFF.

4.2. Regression Co-efficients

The multiple regression analysis identified four statistically significant predictors of SLFF: management issues (β = -0.580, p = 0.005), design deficiency (β = 0.447, p = 0.021), accidents/force majeure (β = 0.356, p = 0.041), and poor workmanship (β = 0.383, p = 0.043). Management issues had the strongest standardized effect and the only negative coefficient. This indicates that decision making in regards to maintenance planning can contribute to a shorter service life of finishes. This finding thus suggests that institutional practices also have a great influence on service life and durability of materials.

Design deficiency and poor workmanship both had a positive and statistically significant relationship to the service life of floor finishes. This highlights the importance of technical quality both during the design and construction phases. Accidents and force majeure events also had a significant contribution, indicating the important role of risk preparedness and mitigation strategies in extending service life. Statistically non-significant variables included vandalism, infestations, negligence/misuse and client preference. This suggested that their influence may be indirect or context-dependent when controlling for other factors. Thus, the model demonstrated that the deterioration of floor finishes in Nairobi's public buildings is driven more by institutional behavior and management culture than by material properties alone

4.3. Discussion

The regression model established that the selected determinants collectively explained 39.4% of the variation in the service life of floor finishes in public office buildings in Nairobi. This indicated that service life performance is influenced by a combination of technical, operational and institutional factors and not just by material characteristics alone. The finding supports the service life prediction approach advanced by ISO 15686, which recognizes that the performance of building components is influenced by design conditions, workmanship, use conditions, maintenance practices and management decisions.

Management issues had the strongest influence on service life . The negative relationship suggests that ineffective maintenance planning, delayed interventions and weak asset management practices contribute to reduced service life of floor finishes. This finding agrees with Plebankiewicz and Gracki (2024), who emphasized that inadequate maintenance strategies contribute to accelerated deterioration and increased lifecycle costs of buildings. Similarly, Ferreira et al. (2021) found that inappropriate maintenance actions or delayed maintenance interventions increase degradation rates of building components.

Design deficiency was also a significant predictor of service life. This highlights the importance of appropriate design decisions in determining long-term performance of floor finishes. The finding supports Harris and Fitzgerald (2017), who noted that flooring selection should consider durability, anticipated traffic levels, maintenance requirements and lifecycle costs rather than initial cost considerations alone. Similarly, Dixit et al. (2019) established that inappropriate floor finish selection for particular usage conditions contributes to premature failure.

Another significant predictor was poor workmanship. This confirmed the importance of installation quality in achieving the expected performance of floor finishes. The finding is consistent with Folorunso (2021), who demonstrated that poor installation practices reduce the effectiveness and durability of floor finishes. Observation assessments in this study identified workmanship-related defects such as uneven installation, poor finishing details and premature deterioration in some buildings, further supporting the regression results.

Accidents and force majeure factors were also significant predictors. Although these events are not always predictable, their influence indicates the importance of risk preparedness and resilience considerations in maintenance planning. This aligns with the degradation theory perspective, which explains that deterioration occurs through interaction between materials and external stressors (Varlamov et al., 2018). The finding suggests that effective inspection and timely corrective actions following unexpected events can reduce long-term damage and enhance the performance of floor finishes.

5. Conclusion, Recommendation and Further Research

This study revealed that service life prediction for floor finishes can be locally modelled using empirical data on the performance of floor finishes. The study also discovered that organizational practices and managerial decision making play a huge role in the service life performance of floor finishes, alongside technical processes and material properties. The study established that facility managers in public buildings lack structured tools for estimating replacement timelines and rely heavily on experience or reactive decision-making. The model addresses this gap by offering an evidence-based basis for predicting the service life performance of floor finishes .

The findings of this study have several implications for maintenance management, construction practice and policy recommendations. For maintenance

management, the strong influence of management issues indicates the need for a shift from reactive maintenance towards preventive and predictive maintenance approaches. Facility managers can use service life prediction models to prioritize inspections, estimate replacement cycles and allocate resources more effectively. For construction practice, the findings emphasize the need for improved design coordination, material selection and workmanship standards. Public procurement processes should consider lifecycle performance rather than only initial acquisition costs.

At a policy level, the study contributes empirical evidence that can inform the implementation of Kenya's maintenance and building regulatory frameworks. While existing policies recognize the importance of systematic maintenance, they do not provide tools for estimating component service life or prioritizing interventions. The study demonstrates that service life modelling is both feasible and relevant within the Kenyan context. Integrating such models into public asset management systems would enhance planning accuracy, budget predictability, and long-term building performance.

In conclusion, this research has proven that service life prediction is not merely a technical exercise but it is also a policy and management tool. By developing a local service life prediction model, the study reinforces the need for locally sensitive approaches to building maintenance especially in the public sector. The study and the model provides a foundation for future work on predictive maintenance, digital asset management, and lifecycle-informed procurement, that can be extended to other building components and public infrastructure systems.

6. Contribution to knowledge

This study provides empirical evidence on the actual service life performance of floor finishes in public buildings. The study will thus serve as a basis for other researchers seeking to study service life performance of not only floor finishes, but others as well in the Kenyan context. The study also provides valuable information to policy makers and built environment professionals that can support data driven material choice and maintenance planning decision making for a more efficient and sustainable built environment. Future studies can conduct a longitudinal study to observe the service life performance of floor finishes, over time and under controlled monitoring. This study was cross sectional in nature and a longitudinal study would make it possible to study and track service life performance over different lifecycle stages. This would strengthen service life prediction models and better inform decision making.

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Analysing Sustainable Housing Investment in Gauteng, South Africa: A Multidimensional Framework

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Abstract

Gauteng's housing sector is shaped by rapid urbanisation, spatial inequality, affordability constraints, and fragmented governance, all of which constrain efforts to mobilise housing investment in more sustainable and inclusive ways. This study aims to develop a multidimensional framework for analysing sustainable housing investment in Gauteng, South Africa. A qualitative desk-based design was adopted, combining a structured review of academic literature with qualitative content analysis of selected policy and governance documents from Gauteng, São Paulo, and Greater Manchester. The analysis was guided by Institutional Theory, Stakeholder Theory, and the Resource-Based View to examine how governance arrangements, stakeholder coordination, and strategic resource capacities influence housing investment outcomes. The findings indicate that sustainable housing investment in Gauteng is constrained by fragmented institutional mandates, regulatory uncertainty, weak intersectoral coordination, and limited mechanisms for meaningful stakeholder participation. In response, the study proposes a four-dimensional framework comprising institutional, financial, stakeholder, and spatial-equity dimensions. The paper contributes a context-sensitive analytical framework for assessing housing investment conditions and informing policy and planning debates on sustainable urban development in Gauteng.

Keywords: Sustainable housing investment, urban governance, spatial equity, stakeholder participation, qualitative content analysis,

1. Introduction

Since 1994, South Africa's housing and human settlements agenda has sought to expand access to adequate housing, promote spatial transformation, and support more sustainable urban development (Shiba, Walter, et al, 2025). Despite these policy commitments, Gauteng continues to experience persistent housing pressures linked to rapid urbanization, affordability constraints, spatial fragmentation, infrastructure deficits, and uneven coordination across national, provincial, and metropolitan spheres of governance (Turok et al., 2024; Khalil & Rubin, 2020). These challenges complicate efforts to align housing investment with broader goals of inclusion, resilience, and spatial integration.

Although sustainable housing investment is increasingly recognised in urban scholarship and policy discourse, existing studies tend to examine governance, regulation, finance and stakeholder participation in isolation. In the Gauteng, this limit understanding of how these factors interact to shape housing investment decisions and housing delivery outcomes. There is therefore a need for an integrated analytical framework that can explain the institutional, financial, stakeholder, and equity dimensions of sustainable housing investment in this context.

This study aims to develop a multidimensional framework for analysing sustainable housing investment in Gauteng, South Africa. Drawing on comparative insights from Gauteng, São Paulo and Greater Manchester, it addresses three research questions: -

1. What policy, institutional, and regulatory conditions shape sustainable housing investment in Gauteng?
2. How do stakeholder coordination, financial considerations, and risk management mechanisms influence housing investment decisions and delivery outcomes; and
3. What lessons from São Paulo and Greater Manchester can inform a multidimensional framework for Gauteng?

This paper adopts a qualitative desk-based design, combining a structured review of academic literature with qualitative content analysis of selected policy, planning and governance documents. Guided by Institutional Theory, Stakeholder Theory, the Resource-Based View, the analysis proposes a four-dimensional framework comprising institutional, financial, stakeholder, and equity dimensions. The study contributes a context-sensitive analytical framework for research and policy debate on sustainable housing investment in Gauteng

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2. Literature Review and Theoretical Framework

Sustainable housing investment is not only a question of capital allocation or housing output; it is also shaped by institutional, financial, governance, and distributive conditions under which housing is planned and delivered (Brown et al., 2023; Wang et al., 2022; HRSC, 2024). In this paper, sustainable housing investment refers to investment conditions and practices that support financially viable, socially inclusive, spatially integrated, and institutionally durable housing outcomes. This framing is especially relevant in Gauteng, where housing delivery is shaped by rapid urbanisation, socio-spatial inequality, infrastructure pressure, and multi-scalar governance complexity.

Existing literature provides useful insight into factors influencing housing investment, but it remains fragmented. Studies commonly address regulation and policy, housing finance, participatory governance, or social outcomes as separate themes. As a result, limited attention has been paid to how these dimensions interact to shape investment decisions and delivery outcomes in unequal city-regions. To address this gap, the present study reviews the literature through four linked dimensions: Institutional-regulatory conditions, stakeholder governance, financial-resource arrangements, and equity spatial outcomes.

2.1. Institutional and Regulatory Conditions

First, institutional and regulatory environments shape the predictability, coordination, and implementation capacity required for housing investment (Scott, 2023; Mbambo, 2023). Research in South Africa shows that fragmented mandates, uneven state capacity, and weak intergovernmental coordination can delay planning approvals, constrain land release, and undermine alignment between housing, infrastructure, and spatial planning (Banda et al., 2022; Mhlongo et al., 2024; Turok, 2025). In this study, regulatory fragmentation refers to the misalignment or overlap of rules, mandates, and procedures across institutions involved in housing delivery (Cirolia & Berrisford, 2017; Smit, 2021).In city-regions such as Gauteng, these conditions influence not only project viability, but also which forms of development are prioritised and where investment is channelled

2.2. Stakeholder Roles, Governance and Engagement

Second, housing investment is shaped by stakeholder relations, governance processes, and the politics of housing decision-making. Stakeholder participation includes the involvement of state institutions, private developers, financiers, community organisation, and affected residents in decision-making related to housing investment and delivery. While the literature suggests that inclusive governance can improve legitimacy, reduce conflict, and better align projects with local needs, participation is often uneven and constrained by power asymmetries (Arnstein, 1969; Mitlin, 2008). In South Africa, formal consultation may remain procedural rather than substantive, limiting the influence of marginalised groups on investment priorities and project design (Smit, 2021; Rust & Napier, 2023; Modise, 2025). This makes stakeholder configuration a constitutive, rather than secondary dimension of housing investment,

2.3. Financial and Resource Arrangements

Third, financial and resource arrangements determine whether investment can be mobilised, sustained, and directed toward inclusive housing outcomes. These arrangements include public subsidies, grants, guarantees, concessional finance, blended finance, and other risk-sharing mechanisms intended to improve project feasibility (UN-Habitat, 2020; CAHF, 2023; IFC, 2023; Rust, 2023). Although such instruments can attract capital and expand supply, critics caution that finance-led approaches may privilege housing as an asset class over housing as a social good, with possible consequences for affordability and exclusion (Aalbers, 2016; Fields & Uffer, 2016; CAHF, 2023). In Gauteng, this issue is compounded by uneven access to formal finance, infrastructure backlogs, and uncertainty around land and service provision.

Sustainable housing investment, therefore, depends not only on the presence of funding instruments but also on the institutional and governance conditions that make them effective and equitable (Scheba, 2023; Mbatha, 2024).

2.4. Equity, Spatial Outcomes and Multidimensional Integration

Fourth, housing investment must be assessed in terms of its socio-spatial consequences. Equity in this paper refers to the extent to which housing investment supports fairer access to well-located, serviced, and opportunity -linked housing across different social groups. South African scholarship has shown that housing delivery can reproduce peripheralization and spatial inequality where investment is weakly aligned with transport, livelihoods and urban opportunity structures (Todes, 2012; Harrison & Todes, 2024). Similar findings from Latin America show that increased housing output does not necessarily translate into inclusion or resilience if projects reinforce segregation or expose households to new risks (Rolnik, 2019). This suggests that investment should be evaluated not only by delivery volume, but also by where development occurs, who benefits, and how risks and opportunities are distributed

The study's theoretical framing integrates Institutional Theory, Stakeholder Theory, and the Resource-Based View. Institutional Theory explains how rules, norms and governance arrangements shape housing

investment conditions and implementation behaviour (Scott,1995); the Resource-Based View draws attention to the strategic capacities and resource required to mobilise, manage, and sustain housing investment (Barney, 1991) including finance, land, technical capability, and implementation capacity; and Stakeholder Theory highlights how actor interests, power relations, legitimacy and coordination influence decision-making and delivery outcomes (Freeman,1984). Used together, these theories provide an integrated basis for analysing how institutions structure action, how stakeholders negotiate priorities, and how resources are assembled and deployed in practice.

The literature review identifies a clear gap. Although prior studies offer valuable insight into governance, finance, participation, and spatial justice, fewer studies integrate these dimensions into a single analytical framework for sustainable housing investment at the city-region scale. This gap is particularly evident in Gauteng, where multiple governance actors, uneven capacity, affordability pressures, and socio-spatial inequality interact in complex ways. The present study responds by developing a multidimensional framework that treats institutional, financial, stakeholder, and equity dimensions as interdependent rather than separate explanatory factors. Comparative reference to São Paulo and Greater Manchester is used heuristically to illuminate how different city-regional arrangements shape investment conditions and outcomes.

2. Methodology

2.1. Research Design

This study aimed to develop a contextually grounded framework for analysing sustainable housing investment in Gauteng, South Africa. More specifically, it examined how housing investment is governed, financed, and institutionally coordinated and how these dynamics shape progress towards inclusive and sustainable urban development in relation to Sustainable Development Goal (SDG 11). In light of this aim, the study adopted a qualitative, theory-informed design located within an interpretivist paradigm. This approach was appropriate because the study sought to understand how sustainable housing investment is framed, organised, and operationalized across different institutional contexts rather than to test causal relationships quantitatively. The analysis followed an abductive logic, moving iteratively between empirical material and theoretical interpretation. Two interrelated methods were employed. First, a PRISMA-informed structured literature review was conducted to identify and synthesise academic and policy scholarship on sustainable housing investment, governance, housing finance, and stakeholder participation. Second, a qualitative documentary analysis was conducted on selected policy, planning, legislative, and governance documents from Gauteng, São Paulo, and Greater Manchester. These two strands were integrated during analysis to provide both conceptual grounding and comparative empirical insight.

2.2. Literature Review Procedure

The literature review was undertaken to establish the conceptual and empirical basis for the study and to clarify the main dimensions of sustainable housing investment. Searches were conducted in Scopus and Web of Science, with supplementary searches in Google Scholar to identify additional relevant sources. Grey literature was also purposively collected from the websites and repositories of key institutions, including UN-Habitat, the World Bank, the OECD, South African Departments, national and Gauteng provincial government departments, and metropolitan municipalities. The search covered literature published between 2000 and 2024 to capture contemporary debates on sustainable urban development, housing governance, finance, and SDG-related policy. Search terms combined concepts related to sustainable housing, affordable housing, housing investment, housing finance, governance, stakeholder participation and inclusive urban development. Additional searches were conducted using case-specific terms, including Gauteng, São Paulo and Greater Manchester.

Sources were included when they addressed sustainable housing, housing investment, governance, urban policy, or stakeholder participation in a way that contributed conceptually, empirically, or policy-relevantly to the study's aim. Included materials comprised peer-reviewed journal articles, scholarly books or book chapters, official legislation, policy documents, strategic plans, and reputable institutional reports. Sources were excluded if they addressed housing only tangentially; focused narrowly on technical construction issues without relevance to governance or finance, lacked clear authorship or credibility; were duplicates; or did not meaningfully inform the research aim.

Records were screened first by title and abstract then through full-text assessment against the inclusion criteria. To strengthen rigour, the included sources were appraised for clarity of research purpose, methodological transparency, analytical depth, institutional credibility, and relevance to the study. A structured extraction matrix was used to record the author, year, geographical focus, source type, methodology, key concepts, governance arrangements, financing mechanisms, stakeholder roles, sustainability outcomes, and theoretical orientation. The review was the synthesised thematically to identify conceptual convergences, divergences, and gaps relevant to framework development.

2.3. Documentary Analysis and Case Selection

Documentary analysis was used to examine how sustainable housing investment is articulated and governed in formal institutional practice. Gauteng was selected as the primary case because the study aimed to develop a framework applicable to that context. São Paulo and Greater Manchester were selected as comparator cases because they are metropolitan regions characterised by complex housing pressures, multi-level governance arrangements, and policy responses relevant to sustainable housing delivery. The comparison was analytical rather than statistical and was intended to generate transferable insights rather than generalisable findings. Documents were selected purposively based on relevance, authority, and information richness. Included documents were official or institutionally recognised texts directly related to housing, human settlements, spatial planning, infrastructure, finance, or governance in one of the three cases. The document corpus included legislation, policy frameworks, strategic plans, spatial development frameworks, housing strategies, public budget or financing instruments, and public-private partnership regulations.

The documents were analysed using qualitative content analysis. Coding combined deductive and inductive approaches. Deductive codes were derived from the study's conceptual and theoretical framing and included institutional coordination, regulatory instruments, financing mechanisms, stakeholder participation, accountability, implementation capacity, and equity-related outcomes. Inductive coding allowed context-specific themes to emerge from the documents, including intergovernmental fragmentation, land and infrastructure constraints, delivery bottlenecks, and governance innovations. Coded segments were grouped into broader categories and synthesised into cross-cutting themes, which were then compared across the three cases to identify enabling conditions, recurring constraints, and context-specific differences.

3.4. Data Analysis, Rigour, And Limitations

Analysis integrated findings from the literature review and documentary analysis through thematic synthesis. This involved comparing themes across both strands to identify convergence, divergence, and complementarity. Interpretation was informed by Institutional Theory, Stakeholder Theory, and the Resource-Based View. Institutional Theory supported analysis of regulatory and governance arrangements; Stakeholder Theory focused attention on actor roles, interests, and power relations; and the Resource-Based View highlighted the strategic capacities and resources required to mobilise and sustain housing investment. Together, these lenses informed the development of the final multidimensional framework.

Several steps were taken to enhance trustworthiness. Credibility was strengthened through triangulation between literature and documentary evidence. Dependability was supported by explicit search procedures, defined inclusion and exclusion criteria, and a transparent coding process. Confirmability was addressed by grounding interpretations in documented evidence and maintaining alignment between the research aim, analytical categories, and findings. The study has limitations. Because it relies on secondary and documentary sources, it is better suited to analysing formal policy, institutional arrangements, and stated governance priorities than lived experience or implementation practice on the ground. The comparative cases were selected for analytical relevance rather than representativeness, which limits broader generalisation. In addition, documentary analysis cannot fully capture the gap between policy intent and implementation. These limitations are acknowledged, but they do not diminish the study's value as a framework-building exercise grounded in comparative and policy-relevant evidence. The study relied exclusively on publicly available literature and documentary sources and involved no human participants; therefore formal ethical clearance was not required.

3. Findings and Discussion

The literature review and documentary analysis identified four interrelated dimensions shaping sustainable housing investment at the city-region scale: (1) institutional and regulatory conditions; (2) financial and resource configurations; (3) stakeholder and governance arrangements; and (4) equity and outcome dimensions linked to SDG 11. These dimensions recur across Gauteng, São Paulo, and Greater Manchester, although their expression varies by context. Figure 1

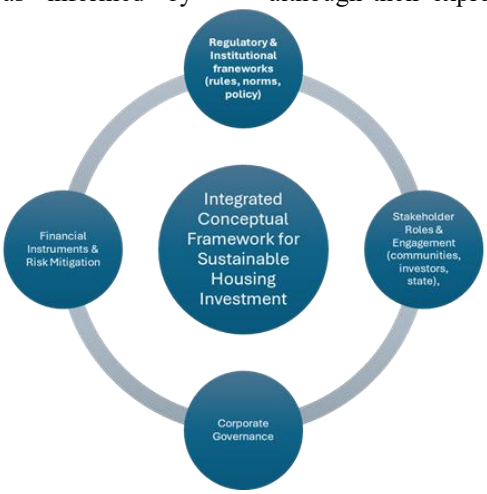

Figure 1: Multidimensional sustainable housing investment framework for Gauteng (Phase 1 synthesis)

synthesises these findings into a multidimensional framework for Gauteng.

First, institutional and regulatory conditions emerged as a foundational determinant of housing investment. Across the literature and policy documents, regulatory clarity, policy coherence, and coordination across levels of government were consistently associated with stronger delivery conditions. Conversely, fragmented mandates, weak alignment between housing, land, and infrastructure planning, and slow approval processes were identified as major constraints. These challenges were especially evident in Gauteng and São Paulo, while Greater Manchester showed relatively stronger city-regional coordination. This finding underscores that investment depends not only on the availability of capital but also on stable and credible institutional arrangements.

Second, financial and resource configurations were shown to extend beyond access to finance alone. Sustainable housing investment depends on the interaction among funding mechanisms, land availability, infrastructure provision, administrative capacity, and risk management. Across all three cases, public subsidies, blended finance, and partnership-based arrangements were used to address affordability and feasibility pressures. However, the analysis indicates that financing instruments are unlikely to produce sustainable outcomes in the absence of supportive institutional and spatial conditions. Investment capacity therefore rests on the combined mobilisation of financial, organisational, and territorial resources.

Third, stakeholder and governance arrangements strongly influenced how housing priorities were defined and implemented. The evidence shows that state actors, private developers, financiers, and communities play unequal roles in shaping delivery processes and outcomes. While collaborative governance and partnership models are widely promoted, their effectiveness depends on accountability, transparency, and meaningful participation. In Gauteng and São Paulo, fragmented governance and uneven power relations often constrain inclusive decision-making, whereas Greater Manchester demonstrates more institutionalised coordination, albeit with continuing tensions between growth and inclusion. Governance quality is therefore central to how risks, responsibilities, and benefits are distributed.

Fourth, equity and outcome dimensions were critical to assessing whether housing investment contributes to sustainable urban development. The review and documentary analysis suggest that housing investment should be evaluated not only in terms of delivery volume or financial viability, but also in terms of affordability, spatial inclusion, access to services and opportunities, and broader resilience outcomes. This is particularly important in Gauteng, where spatial inequality continues to shape housing delivery patterns. Similar tensions are evident in São Paulo, while Greater Manchester shows that stronger governance does not automatically resolve affordability pressures. Sustainable housing investment must therefore be assessed through socio-spatial and distributional lenses aligned with SDG 11.

The cross-case comparison highlights both convergence and divergence. All three city-regions face the challenge of balancing affordability, investment mobilisation, and spatial justice. However, the cases differ in the degree of institutional coordination and policy stability available to support these goals. Greater Manchester benefits from relatively clearer strategic coordination, while Gauteng and São Paulo face deeper fragmentation and land-use tensions. These differences suggest that the framework should be used as a context-sensitive analytical tool rather than as a template for direct policy transfer. Overall, the findings show that sustainable housing investment in Gauteng cannot be reduced to a question of finance. Rather, it is shaped by the interaction of institutional coherence, resource capacity, governance arrangements, and equity outcomes. The study, therefore, reframes de-risking as a multidimensional process involving not only financial instruments but also regulatory predictability, implementation capacity, and participatory governance.

4. Conclusion

This study examined how sustainable housing investment may be conceptualised in Gauteng in relation to affordability, spatial integration, and sustainable urban development. Drawing on a PRISMA-informed structured literature review and comparative documentary analysis of Gauteng, São Paulo, and Greater Manchester, it developed a multidimensional framework for analysing the conditions that shape housing investment and delivery. The study finds that sustainable housing investment is not solely a financial matter. It depends on the interaction of institutional and regulatory coherence, financial and resource capacity, stakeholder and governance arrangements, and equity-oriented development outcomes. On this basis, the article argues that de-risking should be understood as a systemic governance challenge rather than a narrowly financial one.

The main contribution of the study is the development of a four-dimensional framework for analysing sustainable housing investment in Gauteng. Although exploratory, the framework offers a structured basis for understanding how institutional, financial, governance, and socio-spatial factors interact in shaping housing delivery. It also provides a foundation for future

empirical research on housing governance and investment in Gauteng and comparable city-regions. The study is limited by its reliance on secondary and documentary sources and does not directly capture implementation practices or stakeholder perspectives. Future research should therefore test and refine the framework through primary empirical investigation involving public-sector actors, private developers, financiers, and communities engaged in housing delivery.

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Exploring the disasters that occur in informal settlements: A case study on the lived experiences of the residents

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Abstract

The study explores the nature and impact of disasters occurring in informal settlements, focusing on the lived experience of residents.
Purpose: This study explores how environmental, social, and infrastructural vulnerabilities shape disaster occurrence and responses in informal settlements, addressing the limited understanding of residents' lived experiences of disaster risks.
Design: A qualitative case study approach was adopted, using in-depth semi-structured interviews with 20 purposively selected participants. Data were collected in line with ethical protocols, including informed consent, and analysed using thematic analysis to identify patterns of vulnerability and coping strategies. Data collection continued until saturation was achieved.
Findings: Residents experience recurring hazards such as flooding, fires, and disease outbreaks, intensified by inadequate housing, poor service delivery, and weak institutional support. Despite these conditions, strong community-based coping mechanisms and informal support networks enhance local resilience. The findings provide context-specific insights consistent with existing literature on disaster vulnerability and resilience in informal settlements.
Research Limitations and Implications: The study focuses on a single informal settlement, limiting generalisability; however, the findings offer transferable insights for similar contexts. The study contributes to understanding the interplay between vulnerability and resilience in disaster-prone informal settlements.
Practical Implications: The study highlights the need for targeted disaster risk reduction strategies, including improved drainage systems, housing upgrades, and enhanced service delivery. Effective implementation requires collaboration among local government, NGOs, and community leaders, with interventions structured across short- and long-term planning horizons

Keywords: Disaster risk reduction; Informal settlements; Lived experiences; Vulnerability; Resilience; South Africa

1. Introduction

Rapid urbanisation continues to increase pressure on housing systems in cities worldwide. The United Nations projects that the global urban population will reach 68% by 2050 (United Nations, Department of Economic and Social Affairs, 2018). This growth has intensified demand for affordable housing, particularly in developing countries (Wanjiru & Pahari, 2024). However, formal housing delivery often fails to meet this demand, resulting in the expansion of informal settlements in many urban areas (Marutlulle, 2021).

Informal settlements refer to residential areas that develop outside formal planning regulations and legal land tenure systems (Geyer Jr, 2023). These settlements are typically characterised by inadequate infrastructure, limited access to basic services, and insecure housing structures (Chumo, et al., 2023). Such conditions increase residents' exposure to environmental hazards and heighten social vulnerability (Palacios, et al., 2022). In this study, "disasters" are defined as both environmental hazards (such as flooding and fires) and the socio-economic and infrastructural conditions that intensify their impacts on vulnerable communities.

Environmental conditions within informal settlements further elevate disaster risk. Many settlements are located on marginal land such as riverbanks, wetlands, steep slopes, or near waste disposal sites (Oktarini, et al., 2023). These locations expose residents to hazards including flooding, landslides, fires, and pollution-related events (Tavares, et al., 2024). Housing structures, often built from materials such as timber, plastic sheeting, and corrugated metal, are highly susceptible to fire and structural failure ((Quiroz, et al., 2021); (Dutta, et al., 2024)). In addition, limited road access and high population density restrict emergency response during disasters (Abudu, et al., 2025), further increasing risk and prolonging recovery.

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Drawing from established disaster perspectives, ranging from Acts of Nature to socially constructed risks (Lindell , et al., 2006); this study conceptualises disasters as the outcome of interconnected environmental, social, and economic factors that shape vulnerability in informal settlements.

Disasters affect multiple dimensions of life in informal settlements. They damage housing, disrupt livelihoods, and destroy essential household assets ((Comerio, 2023); (Kim, et al., 2025)). Health risks increase due to overcrowding, poor sanitation, and exposure to contaminated water (Walika, et al., 2023), while residents often experience psychological stress and uncertainty (Hambrecht, et al., 2022). Despite these impacts, existing research tends to focus on economic loss and physical infrastructure damage, with limited attention given to residents' lived experiences and how these intersect with broader structural conditions.

This study addresses this gap by exploring how disasters are experienced in everyday life within an informal settlement context, with attention to the interaction between environmental hazards and social vulnerability. It is guided by the following research questions: (1) How do residents in informal settlements experience disasters in their daily lives? (2) What environmental, social, and infrastructural factors shape their vulnerability to disasters? (3) What coping strategies do residents employ before, during, and after disaster events? A qualitative case study approach was adopted, using semi-structured interviews with twenty participants, and thematic analysis to identify recurring patterns of vulnerability and coping.

2. Literature Review

2.1. Demystifying Disasters in Urban Contexts

Disasters have increasingly been understood as products of social organisation rather than inevitable consequences of natural hazards. Earlier theoretical discourses framed floods, storms, or fires as external shocks detached from human systems (Chmutina, et al., 2019). Contemporary urban and disaster scholarship, however, conceptualises disasters as processes embedded within patterns of inequality, governance arrangements, and development trajectories (Oliver-Smith, 2022). From this perspective, hazards only become disasters when they intersect with vulnerable populations and fragile urban systems. This shift is critical for understanding disaster risk in informal settlements, where exposure is shaped by structural and spatial inequalities rather than by hazards alone. Cities, particularly in low- and middle-income countries, illustrate this process, as rapid urbanisation often occurs alongside inadequate housing provision, weak infrastructure, and limited planning control (Gunaratna & Wimalaratana, 2025). Disasters thus reveal how urban environments are produced and for whom they function. This perspective is particularly relevant to informal settlements, where structural inequalities directly shape exposure, sensitivity, and recovery. This conceptual shift moves analysis away from the hazard itself towards the conditions that shape exposure, sensitivity, and recovery, laying the foundation for understanding disasters as socially constructed and unevenly experienced phenomena.

This framing is evident in urban contexts across Asia, Africa, and Latin America, where disaster impacts are closely linked to informal urban development. In Bangladesh and India, informal settlements located along riverbanks and floodplains experience recurrent flooding, disrupting livelihoods and household stability (Islam, et al., 2024). In Kenya and Nigeria, cities such as Nairobi and Lagos report frequent fire outbreaks associated with dense housing and unsafe energy practices (UN-Habitat, 2020). These urban experiences demonstrate that disaster impacts are patterned along socio-economic and spatial lines rather than randomly distributed. These patterns reinforce the argument that disaster risk is socially produced and closely tied to how cities are planned and governed. In each case, disasters expose the underlying conditions of exclusion and infrastructural neglect that shape everyday urban life. Rather than exceptional moments of crisis, disasters emerge as recurring manifestations of how cities manage land, housing, and services.

In South Africa, similar structural dynamics are evident. National disaster profiles identify flooding and shack fires as dominant urban risks, particularly in informal settlements (National Disaster Management Centre, 2021). Provinces such as KwaZulu-Natal and Gauteng experience repeated flood events affecting vulnerable communities (Department of Water and Sanitation, 2022). Within the City of Tshwane, recurring shack fires are linked to overcrowding, informal electricity connections, and limited emergency access (City of Tshwane, 2020). These repeated events illustrate that disasters are not isolated incidents but part of everyday urban vulnerability. This highlights the importance of examining disasters within their local context, particularly in cities such as Tshwane where informal settlements are highly exposed to recurring risks. Demystifying disasters in this context requires recognising them as outcomes of historical spatial inequality, uneven service delivery, and constrained municipal capacity, rather than as unpredictable natural occurrences.

2.2. Conceptualisation of Informal Settlements

Informal settlements are increasingly understood as outcomes of urban governance processes rather than anomalies existing outside the formal city. Contemporary theory conceptualises informality as a structural condition shaped by state regulation, market dynamics, and selective enforcement (Park, et al., 2025). Informality thus emerges from the interaction between formal systems and populations excluded from

affordable housing and secure tenure. This perspective is important for disaster studies, as it positions informal settlements not merely as vulnerable spaces but as products of systemic exclusion that influence disaster risk exposure. Informal settlements therefore exist in relation to, rather than in opposition to, the formal city (Changsoo, 2023).

This understanding is evident across diverse urban contexts. In Brazil, favelas in Rio de Janeiro and São Paulo have evolved into long-established communities, often located near economic centres yet excluded from full infrastructure integration (Fix & Arantes, 2022). In India, informal settlements in cities such as Delhi and Mumbai accommodate large segments of the urban workforce, despite persistent tenure insecurity and service deficits (Sociology Institute, 2025). In Accra, Ghana, and Addis Ababa, Ethiopia, informal settlements have expanded rapidly due to rural-urban migration and constrained formal housing supply (International Organization for Migration, 2015); (Shafi & Negussie, 2022)). Across these cities, informal settlements are characterised by high residential density, incremental housing construction, and uneven access to services such as water, sanitation, and electricity (Abagissa, 2019). Global estimates suggest that more than one billion people reside in informal settlements worldwide, with the majority living in Africa and Asia (United Nations, 2022). These conditions are directly linked to increased disaster vulnerability, particularly in relation to flooding, fires, and health risks. These patterns underscore that informal settlements are not transitional anomalies, but durable and integral components of contemporary urbanisation.

In South Africa, the conceptualisation of informal settlements is inseparable from the country's history of racialised spatial planning and enduring socio-economic inequality. Apartheid-era land and housing policies systematically excluded the majority of the population from well-located urban land, producing fragmented cities that persist in the democratic era (COGTA, 2016). Informal settlements in metropolitan areas such as Johannesburg, Tshwane, and eThekwini are shaped by this legacy, alongside slow housing delivery and rapid urban growth. National policy frameworks recognise informal settlements as areas characterised by insecure tenure, inadequate infrastructure, and limited access to basic services (Department of Human Settlements, 2025). Statistics South Africa reports that approximately 12–13 per cent of households live in informal dwellings, with higher concentrations in Gauteng Province (Stats SA, 2023). Within the City of Tshwane, informal settlements range from long-established communities with partial service access to newer settlements lacking basic infrastructure (Chaane, 2025). This context is important for understanding how historical inequality continues to shape present-day disaster risk in informal settlements.

2.3. The Nexus Between Disasters and Informal Settlements

The relationship between disasters and informal settlements is best understood through the ways urban space is produced and governed, rather than through the characteristics of hazards alone (Del Pinto, et al., 2024). Informal settlements emerge where formal planning systems fail to provide accessible land, affordable housing, and basic services, resulting in the concentration of vulnerable populations in environmentally precarious locations (UN-Habitat, 2018). Disaster risk is therefore embedded in everyday urban conditions such as overcrowding, informal construction, and infrastructure deficits. This suggests that disasters do not create vulnerability but rather expose and intensify pre-existing conditions. When hazards occur, they expose these accumulated vulnerabilities rather than introducing new ones. Informal settlements thus function as critical sites where socio-economic marginalisation, spatial exclusion, and environmental exposure converge. Disasters in these spaces are not episodic interruptions, but predictable outcomes of urban development pathways that privilege some populations while rendering others disproportionately at risk (Agbo, 2026).

This pattern is evident across diverse urban contexts beyond a single region. In Brazil, informal settlements such as favelas in Rio de Janeiro and São Paulo experience frequent landslides and flooding linked to hillside occupation and inadequate drainage infrastructure (Verniz, 2020). In Peru, informal neighbourhoods in Lima located on arid slopes face recurring flood damage during El Niño events, exacerbated by poor stormwater management (Jarman, 2020). In Southeast Asia, informal settlements in Jakarta, Indonesia, are routinely affected by flooding due to land subsidence, river encroachment, and limited access to protective infrastructure (Meshkani, 2024). In Southern Europe, informal Roma settlements in parts of Romania and Italy have been disproportionately affected by floods and fires, reflecting social exclusion rather than environmental exposure alone (Alexandrescu, et al., 2024). These varied cases demonstrate that the disaster–informality nexus is a global urban phenomenon, shaped by how cities manage land, infrastructure, and inequality rather than by geography or climate alone.

In South Africa, similar dynamics are evident, though shaped by the country's unique spatial history. National disaster reports consistently identify informal settlements as areas of heightened vulnerability to flooding and shack fires (NDMC, 2024). In Gauteng Province, rapid urban growth and land scarcity have resulted in informal settlements occupying low-lying or poorly serviced land, increasing exposure to seasonal flooding and fire outbreaks (Nhamo, et al., 2021). Within the City of Tshwane, informal settlements

experience recurrent shack fires and flood incidents associated with inadequate infrastructure (Mogotsi, 2024). These repeated events disrupt livelihoods, damage dwellings, and strain household coping capacities. Over time, disasters become normalised within these communities, reinforcing cycles of vulnerability and recovery. This underscores the need to examine disaster risk as a continuous condition rather than as isolated incidents.

2.4. Community Lived Experiences of Disasters in Informal Settlements

Approaching disasters through lived experiences highlights how risk and recovery are encountered in everyday life (Ramalho, 2020). In informal settlements, repeated exposure creates conditions where disasters become normalised, shaping behaviour and coping strategies (Ncube, et al., 2023). This perspective is critical because it shifts analysis from institutional responses to resident experiences, providing deeper insight into vulnerability and resilience. Experiences of fear, uncertainty, and resilience are inseparable from struggles over housing, livelihoods, and access to services. Lived experiences therefore reveal dimensions of disaster impact that extend beyond physical damage, including psychological stress, social disruption, and prolonged insecurity (WHO, 2025). By centring everyday experiences, disasters are understood as social processes that unfold over time, shaping how residents navigate informality and vulnerability within urban environments.

Accounts from informal settlements in Latin America, Asia, and Southern Africa illustrate how disasters are lived as cumulative and repetitive phenomena. In Medellín, Colombia, residents describe landslides as recurring threats that shape everyday decision-making (Smith, et al., 2020). In Port-au-Prince, Haiti, repeated disasters have led to strong community-based coping strategies (Rivera, 2024). In Jakarta, Indonesia, seasonal flooding disrupts livelihoods and health (Meshkani, 2024). In Cape Town, South Africa, residents affected by shack fires report prolonged recovery and overcrowding (Pienaar, 2021). These studies highlight that disasters are experienced through cycles of loss, adaptation, and incomplete recovery. Social networks and community knowledge play a critical role in navigating these conditions.

In Gauteng Province, lived experiences reflect similar patterns of repetition and normalised risk. Residents report recurring fires and floods, resulting in loss, displacement, and prolonged recovery ((Mogotsi, 2024); (Zhou, et al., 2022)). Recovery is largely self-managed, relying on community support and incremental rebuilding. However, there remains limited research that directly captures how these lived experiences shape coping strategies and perceptions of risk at the local level.

3. Methodology

A qualitative single case study design was applied to examine disaster experiences in one informal settlement called “Marry Me”, located in the City of Tshwane, South Africa. The approach focused on perceptions, meanings, and coping strategies rather than statistical measures. Limiting the scope to one settlement allowed detailed analysis of environmental, infrastructural, and institutional vulnerabilities shaping disaster patterns and responses.

3.1. Study Area

The Marry Me informal settlement faced poor infrastructure, overcrowding, and repeated hazards including floods, fires, and disease outbreaks. Its history of disasters and visible vulnerabilities made it suitable for in-depth study.

3.2. Sampling Strategy and Participants

Purposive sampling was used to identify participants with direct experience of disasters. The target population comprised community members and representatives aged 18 years and above, with a minimum of five years’ residence and direct experience of disaster events within the settlement. A total of 20 participants were recruited, including 18 community members, 1 community representative, and 1 ward councillor**,** ensuring diversity in age, gender, and length of residence. Data collection continued until saturation was reached, with no new themes emerging after the twentieth interview.

3.3. Data Collection

Semi-structured interviews were conducted with all 20 participants. Themes explored included disaster experiences, perceived causes, coping strategies, and institutional responses**.** Interviews were conducted in Setswana, a language understood and preferred by all participants, and lasted between 20 and 30 minutes. With participants’ consent, 8 interviews were audio-recorded, while the remaining 12 were documented through detailed handwritten notes**.** Interviews were subsequently transcribed and translated into English, with careful attention to preserving the meaning and nuance of participants’ responses.

3.4. Ethics

Ethical clearance was granted by the Tshwane University of Technology Research Ethics Committee. Written informed consent was obtained from all participants. Anonymity and confidentiality were maintained through the use of pseudonyms and removal of identifying information. Participants were informed of their rights, including the right to withdraw at any stage. Interviews were conducted with sensitivity to the potential emotional impact of discussing disaster experiences.

3.5. Data Analysis

Thematic analysis was conducted following (Braun & Clarke, 2006)'s six-step framework. Coding was conducted manually, with thematic codes generated from recurring concepts and significant points raised by participants. The process was iterative, allowing themes to emerge inductively from the data. Credibility of the analysis was enhanced through careful comparison of codes across transcripts and consistent interpretation of themes.

3.6. Trustworthiness

Lincoln and Guba's (1985) criteria were applied to ensure methodological rigour. Credibility was supported through member checking. Transferability was enhanced through rich contextual description. Dependability was ensured through systematic documentation of the research process, and confirmability was maintained through reflexive notes and an audit trail.

3.7. Limitations

The use of a single case study limits generalisability. However, the findings provide analytical insights that are transferable to similar informal settlement contexts.

4. Findings And Discussion

The study generated three major themes: (1) types of disasters experienced, (2) factors contributing to vulnerability, and (3) lived experiences of residents. These themes are discussed in relation to existing literature on disaster vulnerability and resilience in informal settlements.

4.1. Types of Disasters Experienced

Disasters in informal settlements are frequent and varied, reflecting fragile environmental and infrastructural conditions. Participants identified flooding, fires, and health-related risks as the most common hazards.

"Flooding is a major challenge here. The slope of the land is not ideal, and the soil retains a lot of water" (Participant 13).

"*Fires caused by illegal electrical wiring pose a serious hazard, sometimes resulting in children being electrocuted while playing in the streets"* (Participant 1).

"My house faces a large heap of waste where residents dump their rubbish, and no one comes to collect it. Despite how unsanitary it is, children still play there, and as a result, they often catch infections and spread them to others. There are a lot of rats coming from the dumping site, and the smell is also very unpleasant. We have to buy pesticides because the rats are a constant problem, but there is nothing we can do about the bad odour" (Participant 4, 12).

These findings align with existing studies which identify flooding and fires as dominant risks in informal settlements due to poor drainage systems, unsafe energy practices, and inadequate waste management (UN-Habitat, 2020; Tavares et al., 2024). This supports the argument that hazards become disasters when they intersect with vulnerable urban environments shaped by infrastructural deficits (Oliver-Smith, 2022).

4.2. Factors Contributing to Vulnerability

Participants identified environmental, infrastructural, and socio-economic drivers of vulnerability.

"Most of the houses are built from temporary materials like zinc sheets and wood, often without proper foundations. That makes them extremely vulnerable to strong winds, heavy rains, and fires" (Participant 15).

"Because the land slopes downwards, water always runs toward us and gets trapped here with no way out" (Participants 5, 20).

"Unemployment is another big issue which also increases the number of young people on the streets, which sometimes contributes to crime and makes it harder to maintain social order during emergencies" (Participant 15).

"Access for emergency services is limited due to narrow, unplanned routes, making it difficult for ambulances, fire trucks, or police to reach people in urgent situations" (Participants 8, 15)**.**

"Lack for secure land tenure. Without legal land ownership, we are excluded from government assistance or disaster planning efforts" (Participant 16).

"Sanitation facilities are often communal and poorly maintained, with overflowing toilets and uncollected waste posing serious public health risks" (Participant 6).

"Lack of education and access to information is also a challenge. Many residents are not aware of early warning systems or disaster preparedness strategies, so they are caught off guard when emergencies happen. We only hear about warnings after the damage is already done" (Participants 5, 11, 15).

"At the local level, we try to advocate for services and raise awareness, but we are limited by budget constraints and policy limitations. So, while there are efforts being made, I do believe that stronger, more inclusive policies and targeted investments are urgently needed to reduce the community's vulnerability" (Participant 15).

"Some people do not have ID documents, so they cannot apply for aid or assistance from NGOs after disasters" (Participants 10, 11)**.**

These findings confirm existing literature that disaster vulnerability in informal settlements is socially produced and linked to poor housing conditions, insecure tenure, and limited-service provision (UN-Habitat, 2018; Del Pinto et al., 2024). They further support studies highlighting how governance failures and spatial inequality increase exposure to hazards (Agbo, 2026; Nhamo et al., 2021).

Importantly, this study extends current knowledge by emphasising the role of documentation status and institutional exclusion, which limits access to post-disaster aid, an aspect less explored in existing disaster literature.

4.3. Lived Experiences of Residents

Participants described disasters as deeply disruptive to daily life, affecting emotional well-being, livelihoods, and security.

"*With no electricity, I am always anxious that the candles or paraffin stove might cause a fire while I am away"* (Participant 14).

"*It was terrifying. I did not know if my shack would collapse, so I stayed up all night with a candle, watching the roof leak. After the attacks, many people moved out. The ones who stayed feel abandoned and forgotten"* (Participants 2, 18).

"Many live hand-to-mouth, so even a small disruption like flooding or a fire, can push them into crisis" (Participants 9, 12, 15).

"We lost everything: clothes, IDs, my kids' schoolbooks. My kids missed school because their uniforms were soaked and muddy. They were too embarrassed to go" (Participants 13, 17, 20).

"I saw things I wish I had not. Dead bodies in the street, mothers crying. That disaster changed how we see this place forever. The children became very fearful. They do not play outside anymore, and they cry during thunderstorms" (Participants 2, 11, 20).

"I had no way to call for help. My phone got wet in the flood and I could not reach anyone" (Participant 3).

"What truly breaks my heart is how unsafe and insecure our settlement is. The types of crimes that happen here are beyond words. My daughter is now disabled and unable to speak, she was one of the community patrollers who was attacked by thugs" (Participant 7).

"*Rain washes our plants every time with its flooding, such that as residents we can no longer plant vegetables, leaving us with fewer ways to feed their families. As a result, many residents have lost one of the few ways they had to feed their families. Floods often wash through our homes and damaging belongings*" (Participants 18, 19, 14).

These accounts reinforce literature that conceptualises disasters as lived, ongoing processes rather than isolated events, shaping everyday experiences of risk and recovery (Ramalho, 2020; Ncube et al., 2023). They also align with findings that disasters in informal settlements produce long-term psychological, social, and economic impacts (WHO, 2025; Hambrecht et al., 2022).

Furthermore, the findings contribute to this body of work by illustrating how fear, loss of dignity, and disrupted childhood experiences form part of the long-term impacts of disasters, particularly in contexts of repeated exposure.

5. Conclusion And Further Research

The study highlights the recurring nature of disasters in informal settlements and the structural conditions that intensify vulnerability. Flooding, fires, and disease outbreaks emerge as persistent hazards shaped by inadequate infrastructure, overcrowding, and weak institutional support. Residents' lived experiences reveal both the immediate impacts of disasters and the coping strategies developed within constrained environments.

Importantly, the study contributes to knowledge by demonstrating how disaster risk is embedded in everyday socio-economic and spatial conditions, rather than occurring as isolated events. It provides context-specific insight into how vulnerability and resilience interact in informal settlements, particularly within the Tshwane context.

The findings underscore the need for targeted and context-specific disaster risk reduction interventions that address both physical vulnerabilities and social resilience. Practical measures include improving drainage systems to reduce flooding, upgrading housing structures to enhance fire resistance, and strengthening access to basic services such as waste management and sanitation. Effective implementation requires collaboration between local government, non-governmental organisations, and community leadership structures. Interventions should be structured across short-term (emergency response and awareness), medium-term (service delivery improvements), and long-term (infrastructure upgrading and settlement planning) strategies.

The research further demonstrates that disaster vulnerability is shaped by structural inequalities, including insecure land tenure, limited access to services, and governance constraints. Addressing these challenges requires integrated approaches that combine urban planning, infrastructure development, and community-based disaster management.

Further research should expand beyond a single settlement to include comparative studies across multiple urban contexts. Longitudinal research is needed to understand how vulnerabilities and coping strategies evolve over time. Incorporating quantitative data alongside qualitative insights would provide a more comprehensive understanding of risk patterns and resilience mechanisms. Future studies should also examine institutional coordination, particularly the roles of municipal authorities, NGOs, and community organisations in disaster response. Additionally, research focusing on gender, age, and socio-economic differences would provide deeper insight into differentiated disaster experiences and vulnerabilities.

By grounding disaster research in lived experiences and structural realities, future work can inform more inclusive and effective policies aimed at strengthening resilience in informal settlements.

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Understanding Energy Consumption and Management in University Buildings: A Sustainability and Socio-Technical Perspective

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Abstract

The built environment accounts for roughly one-third of global energy use, a pattern that carries far-reaching consequences for the natural world, most notably through its contribution to climate change and the progressive depletion of finite resources. This paper aims to raise awareness and deepen understanding of how energy is consumed and should be managed in university buildings, drawing on two complementary theoretical lenses: sustainability theory and socio-technical theory. Methodologically, the paper is grounded in a conceptual narrative review that prioritises constructing reasoned arguments, synthesising scholarly work, and tracing new conceptual linkages, all aimed at generating theoretical insights rather than reporting primary field data. It is openly acknowledged that the absence of original empirical evidence introduces the possibility of interpretive subjectivity. Arguably, the investigation uncovers seven steps ideal for managing energy consumption in university buildings, which include establishing the theoretical foundation underpinning the concepts, recognising energy management as a socio-technical system, mapping stakeholder interactions and motivations, and diagnosing patterns of energy use and identifying hotspots. Additionally, the steps include integrating behavioural change programmes with technological solutions, institutionalising continuous improvement and learning, and fostering a culture of sustainability. The findings attempt to close the gap between academic theorising and day-to-day institutional practice, offering actionable guidance to researchers, facility managers, and university administrators. It is argued that consistent application of this step holds real potential for achieving sustained improvements in energy performance. Nevertheless, the conceptual insights (seven steps) presented in this paper should be tested empirically; future studies are encouraged to collect primary data on the practical effectiveness of sustainability-oriented and socio-technical approaches in real-world university contexts.

Keywords: Energy consumption, energy efficiency, energy management, facility management, socio-technical theory, sustainability theory.

1 Introduction

Rapid urbanisation and continuously rising living standards around the world have placed an unprecedented burden on building energy systems (Lei Liu *et al.,* 2023). Accurately accounting for this demand is complicated by the multifaceted nature of energy infrastructure and the numerous variables that bear on consumption outcomes (Lei Liu *et al.,* 2023). Among the most telling signs of this complexity is the marked shift observed in how building occupants use energy variations that signal a meaningful transformation in everyday consumption behaviour (Lei Liu *et al.,* 2023). These shifts are not benign; their cumulative effect is environmentally significant. The United Nations Environment Programme (UNEP, 2020) has projected that, despite mounting pressure from climate obligations and resource constraints, global energy consumption will continue to rise, potentially reaching 740 million terajoules by 2040. Against this backdrop, many governments have moved to accelerate low-carbon urban transformation programmes in direct response to urbanisation-driven energy pressures (Zhang, 2023).

The construction and buildings sector is widely regarded as one of the most energy-intensive sector of the global economy, responsible for over 40% of total energy consumption and approximately 35% of worldwide CO^2 emissions (UNEP, 2020). Recognising this, governments and industry bodies in many countries have developed targeted policy instruments and technical frameworks aimed at curbing building energy use. These range from China's Building Energy Conservation and Green Building Development Plan (2021–2025) (Ministry of Housing and Urban-Rural Development, 2022) and its Science and Technology Support to Carbon Peaking Implementation Plan (2022–2030) (National Energy Administration, 2022), to internationally recognised green building rating tools such as BREEAM (United Kingdom), LEED (United States), Green Globes (Canada), NABERS (Australia), SBTool (international), CASBEE (Japan), HQE (France), HK-BEAM (Hong Kong), E-audit (Poland),

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LEnSE (European Union), and Protocollo ITACA (Italy) (Akram *et al.,* 2022). In South Africa, the foundational reference remains the White Paper on Energy Policy (Department of Mineral and Energy, 2005). However, shortcomings in how energy use is assessed within the building sector continue to undermine confidence in the reliability of conservation policies, contributing to resource inefficiency and worsening environmental outcomes (Huo *et al.,* 2018). Robust assessment practices are indispensable for both sound policy formulation and practical energy management (Lei Liu *et al.,* 2023).

2. Literature Review

2.1 Energy consumption in buildings

It is no longer news that global energy consumption has been on the rise, as Lombard, Ortiz, and Pout (2008) and Amasyali and El-Gohary (2018) have noted. This has led to concerns regarding the environmental consequences of energy consumption. The global contribution of buildings to energy consumption, including residential and commercial buildings, has consistently increased, with figures ranging from 20% to 40% in developed countries (Lombard et al., 2008). This is due to the escalating demand for building services and comfort levels, as well as the increase in the amount of time spent indoors. This guarantees that the upward trend in energy demand will persist in the future. The ability to anticipate how buildings will consume energy is of direct practical value, because it allows utility providers, occupants, and facility managers to make better-informed decisions about efficiency improvements, cost control, and resource planning (Okorafor *et al.,* 2019; Anh-Duc *et al.,* 2020). The building sector's position as the single largest contributor to global energy demand and carbon emissions reinforces why a thorough grasp of energy use patterns is foundational to any credible energy and climate policy (Allouhi *et al.,* 2015). This is the reason why it is imperative to comprehend and effectively manage energy consumption at all levels.

2.2 Energy management in university buildings

According to Liu, Cai, and Chen (2026), university buildings are densely populated and have many activities going on. Due to the heterogeneous behaviour of humans, such diversity greatly impacts occupant behaviour and electricity consumption. As key institutions in any nation and significant energy consumers, universities have a critical responsibility to lead efforts in energy efficiency and renewable energy use to reduce their environmental impact (Türle and Celen, 2026). In this context, a study carried out by Türle and Celen (2026) at Gümüşhane University building has identified the sources of greenhouse gas emissions and provides the opportunity to track, measure, and suggest reduction strategies in the years to come. These results suggest that universities need to focus on their energy consumption patterns to reduce their carbon emissions, for example, by placing greater emphasis on renewable energy sources, energy efficiency, and balanced consumption (Guo *et al.,* 2018; Killian and Kozek, 2016; Türle and Celen, 2026). Arguably, there is extant research on energy consumption and management in South African university building.

2.3 Energy Consumption Prediction Patterns

Forecasting building energy use is particularly valuable during the operational and maintenance phases of a building's life cycle, where accurate data can drive meaningful improvements in performance (Anh-Duc *et al.,* 2020). Broadly speaking, two analytical traditions have emerged for this purpose: physics-based simulation and data-driven modelling (Amasyali and El-Gohary, 2018). Physics-based tools including DOE-2 and EnergyPlu work by modelling the thermodynamic properties of building components, HVAC configurations, internal loads, and meteorological conditions in detail (Anh-Duc *et al.,* 2020). Their primary limitation is that they demand substantial, often unavailable input data and are ill-suited for rapid or large-scale analyses, particularly when extending to city or national scale assessments (Amasyali and El-Gohary, 2018; Anh-Duc *et al.,* 2020).

Data-driven approaches offer a contrasting advantage: they derive predictions from historical energy records, and their practical relevance has grown considerably alongside advances in AI and the Internet of Things (Anh-Duc *et al.,* 2020; Lei Liu *et al.,* 2023). Open data availability is central to their effective deployment. Numerous ML-based prediction frameworks have been developed and applied in building energy research, including artificial neural networks (ANNs) (Qiao and Liu, 2020), decision trees (Killian and Kozek, 2016), adaptive neuro-fuzzy inference systems (ANFIS) (Xie *et al.,* 2019), and support vector machines (SVM) (Wu *et al.,* 2007).

Reducing energy consumption through smarter and more efficient use carries a triple dividend: it brings down costs, cuts carbon emissions, and strengthens energy security (McNeil *et al.,* 2019). A quantitative method was also proposed to assess how building greening interventions affect overall energy use, providing a decision-support tool for urban policy implementation (Qiao and Liu, 2020). Yet the complexity of evaluating energy use at urban or national scales largely because of the layered interdependencies within building systems remains a persistent challenge (Huo *et al.,* 2022).

Three broad methodological categories are commonly used to assess building energy consumption: top-down, bottom-up, and hybrid modelling approaches (Lei Liu *et al.,* 2023). Top-down approaches treat an entire building stock as a single unit, estimating consumption

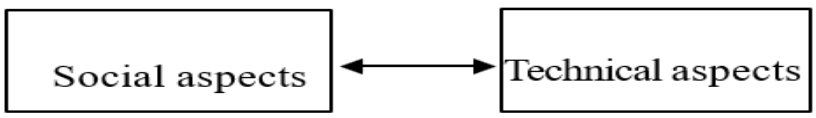
by reference to macroscopic variables such as climate conditions, population density, and the morphology of the urban environment (Huo *et al.,* 2022; Zhang *et al.,* 2021; Zhou *et al.,* 2023). In contrast, bottom-up approaches disaggregate consumption by examining individual building characteristics and aggregating detailed sub-system data (Howard *et al.,* 2012; Huo *et al.,* 2019; Wang *et al.,* 2020). Guo's (2020) EBEC-China model exemplifies this approach, showing that re-estimated national consumption figures derived from bottom-up methods can deviate from top-down estimates by between 10% and 36%.

While both approaches have seen widespread application, each carries inherent weaknesses including ambiguous assessment criteria and opaque internal causal structures (Huo *et al.,* 2022; Guo, 2020). Hybrid models have been proposed as a remedy, drawing variously on behaviour based energy economy frameworks (Rivers and Jaccard, 2005), integrated multi-commodity price formulations (Böhringer and Rutherford, 2006), and combined benchmarking strategies that blend top-down indicators with bottom-up reference values (Hollberg *et al.,* 2019). Though promising, hybrid models have not fully resolved the problem of internal complexity or overcome the constraints of static assessment methodologies (Lei Liu *et al.,* 2023). Ocampo Batlle *et al.* (2020) demonstrated the potential of energy baseline and performance indicator frameworks in an educational building context, finding potential annual savings of up to 9.6%. Building on these observations, the present paper aims to advance a logical, theory-grounded argument that identifies and deepens the understanding of energy consumption and management dynamics in university buildings through a coherent, step-by-step guide.

2.4 Adopted theory of the study

Sustainability theory, as Childers *et al.* (2014) note, resists a single fixed definition but tends to coalesce around human needs, values, and the interests of future generations themes that echo the foundational formulation in the Brundtland Report (1987). At its core, this theory insists on resource efficiency as the mechanism for meeting present demands without foreclosing the options of those who come after. Within universities, sustainability extends beyond straightforward energy conservation; it involves embedding sustainability as a fundamental dimension of organisational culture and institutional operations. The socio-technical theory, on the other hand, brings into focus the interplay between social dynamics and technical systems. Okorafor (2019) has previously drawn attention to the disconnect that often exists between these two dimensions in building retrofit and management efforts a gap that Swan and Brown (2013) characterise as a structural feature of a fundamentally socio-technical problem, one that cannot be resolved by engineering alone but requires coordinated expertise drawn from across industrial, technical, and social domains.

Ma *et al.* (2012) add texture to this view by identifying the range of socio-technical factors at stake: retrofit technologies, occupant behaviour, building-specific parameters, client expectations, and unpredictable environmental influences. Authors such as Natural Resources Canada (2015) have further argued that one of the most persistent barriers to long-term energy management planning is the challenge of accounting for how building occupants behave. Fulford (2011) captured this succinctly, observing that behavioural change while invisible in engineering terms can be decisive in determining whether an energy management initiative succeeds or fails. Karvonen (2013) reinforces the point: achieving meaningful reductions in energy demand depends on integrating changes in how stakeholders understand, perceive, and practise energy use alongside physical and technical interventions. Taken together, these perspectives lead to the conclusion that any effective intervention in university building energy management must be simultaneously grounded in sustainability theory and attuned to socio-technical realities. Despite this, current energy efficiency measures in public buildings have generally failed to give sufficient weight to these dimensions (Okorafor, 2019). Addressing this gap calls for developing a richer understanding of the variables involved in energy efficiency initiatives, the dynamics that govern their interaction, and the relationships between them that either enable or obstruct effective management. The research gap identified in this literature the missing bridge between social and technical dimensions of energy management is illustrated in Figure 1.



(Source: Author, 2026)

Figure 1: The missing link between the social and technical aspects of energy consumption and management

The mechanisms through which sustainability and socio-technical integration produce effective energy management in university buildings remain underspecified in the existing literature. This study positions itself within that gap, seeking to advance understanding of the phenomenon through a socio-technical and sustainability-informed lens and, in

practical terms, to propose a structured, step-by-step guide for achieving optimal energy consumption and management outcomes in university buildings.

3. Research Methodology

This study is anchored in a conceptual narrative literature review methodology informed by sustainability theory and socio-technical theory. Rather than generating new empirical data, the approach is oriented toward constructing rigorous theoretical and logical arguments, consolidating and synthesising existing scholarship. The methodology serves as the scaffolding for the conceptual understanding and findings of the paper.

4. Findings and Discussion

4.1 A Conceptual Guide for Optimal Energy Consumption and Management

The following seven steps are guided around the theoretical foundations outlined above (see section 2.4), with each step grounded in explicit logical reasoning and reviews from scholarly articles.

Step 1: Recognising energy consumption and management through sustainability and socio-technical lenses

Universities like other corporate entities should no longer treat sustainability as an optional or peripheral concern (Lozano *et al.,* 2015). Corporate sustainability, in its contemporary form, involves the deliberate balancing of economic performance, environmental responsibility, and social accountability across both present and future time horizons (Lozano *et al.,* 2015). This means that universities should not base their decisions about energy consumption and management solely on cost considerations. Institutional decision-making must factor in environmental impacts, including CO_2 emissions, resource depletion, and ecosystem effects, from the outset. This orientation aligns with the core logic of sustainability theory, which demands that resource management decisions account for long-term consequences and embed a sense of obligation toward future generations. Energy management, framed this way, becomes an exercise in environmental stewardship as much as an operational or financial concern.

Step 2: Recognise Energy Management as a Socio-Technical System

Energy management is the process of planning, monitoring and controlling the use of energy to ensure it is used efficiently, cost-effectively and sustainably. Energy consumption and management have moved to the centre of organisational life in virtually every sector, and this centrality has grown in direct proportion to the urgency of CO^2 reduction commitments (Christina *et al.,* 2015). Adopting a socio-technical systems lens means recognising that energy performance is not purely a technical outcome; it emerges from the interaction between physical infrastructure and the people who use, govern, and maintain it. This involves understanding the interdependencies between technological systems (tools, equipment, sensors), organisational processes and work patterns, and institutional culture (Christina *et al.,* 2015; Swan and Brown, 2013). In practical terms, a university building should be understood as a living socio-technical system: one in which students, staff, and visitors co-exist with policies, schedules, building management systems, and physical infrastructure all of which influence one another continuously. The interrelationship between user behaviour and technical infrastructure is not incidental but constitutive of energy outcomes (Karvonen, 2013). The key constructs at this level are occupant behaviour, regulatory mechanisms, and technological enablers.

Step 3: Map Stakeholder Interactions and Motivations

Within any university, different constituents such as; students, academic staff, administrative staff, facilities managers, cleaners, maintenance contractors, university leadership and visitors approach energy use with different levels of awareness, different motivations, and different degrees of agency (Li and Zeng, 2024). Managing this diversity requires that institutions move beyond uniform communication strategies and instead develop a clear picture of who the relevant stakeholders are, what drives their behaviour, and how their interests can be aligned with broader energy management objectives. Koshman and Ulyanova (2014) have argued that human beings are not passive elements in an energy management system they are integral participants whose motivations and actions shape system performance. Karvonen (2013) extends this logic by suggesting that meaningful progress in energy management is often achieved not through blanket measures but through facilitated engagement between occupants, housing or facilities providers, and technical professionals engagement that produces solutions sensitive to the particular circumstances of each context. The author of this paper argues that constructing a stakeholder map one that captures each group's incentive structure and identifies potential points of alignment and conflict is a prerequisite for the kind of coordinated governance that sustainable energy management demands. The key constructs here are stakeholder engagement, incentive alignment, and participatory governance. This entails involving all individuals and organizations affected by energy policies and decisions by ensuring that stakeholders share common energy management goals through rewards and policies. This approach enables stakeholders to actively participate in the planning, policy formulation, implementation, and monitoring of energy-related activities.

Step 4: Diagnose Patterns of Energy Use and Identify Hotspots

Identifying energy hotspots in university buildings aims to pinpoint systems or activities exhibiting significant energy usage. This hotspot might be laboratories, libraries, lecture halls, residences, HVAC-intensive buildings and computer labs. The indicators that can be used include kWh/m²/year, peak load, occupancy-adjusted energy use, and equipment-level consumption. Identifying these hotspots is essential for enhancing energy efficiency. Energy-saving behaviour in higher education institutions is crucial not only for immediate financial gains but also for the broader societal goal of achieving a low-carbon transition (Li and Zeng, 2024). Implementing those objectives in institutional practice demands more than aspirational policy; it involves contextual specificity. Li and Zeng (2024) have identified a specific need for customised strategies that might foster genuine energy-conscious habits within university communities. The author asserts that targeted and effective intervention commences with a comprehensive understanding of the specific contexts, timings, and methods of energy use (Pandit et al., 2023). In the absence of diagnostic clarity, interventions may become generic and inadequately aligned with the actual energy consumption patterns of a specific building or campus. Energy audits, sub-metering, and occupancy monitoring are instruments used for this aim, and their results form the foundation for crafting remedies that are specifically tailored rather than indiscriminately adopted from other contexts.

Step 5: Integrate Behavioural Change Programmes with Technological Solutions

Consequently, behavioural change initiatives such as switch-off campaigns, energy dashboards, feedback systems, incentives, training and student-led initiatives can be integrated with technology solutions such as smart meters, occupancy sensors, LED retrofits, building management systems and HVAC optimisation. This step sits at the heart of the socio-technical approach. A notable consensus exists in the literature exemplified by the positions of Natural Resources Canada (2015), Fulford (2011), and Karvonen (2013) that behavioural dimensions are among the most consequential and most frequently underestimated aspects of energy management. The inability to address occupant behaviour consistently is identified as a major structural barrier to the realisation of energy management plans. Fulford (2011) makes the provocative point that behavioural change though it produces no hardware, installs no sensor, and draws no engineering diagram can determine the ultimate success or failure of a management initiative. Natural Resources Canada (2015) goes further, characterising energy management as fundamentally a change management challenge, with technical interventions as necessary but not sufficient conditions for success. Karvonen (2013) captures the integrative logic well: reducing energy demand over time requires changing not only physical systems but also the habits, perceptions, and motivational frameworks of the people who use them. Technological solutions and behavioural programmes should therefore not be designed in parallel silos but as mutually reinforcing components of a single integrated strategy.

Step 6: Institutionalise Continuous Improvement and Learning

Energy management cannot be treated as a problem to be solved once and then set aside. Gallo and Capozzoli (2024) stress that effective energy governance must be dynamic, capable of responding to changing conditions, emerging data, and the evolving nature of institutional needs. This requires universities to embed practices of monitoring, reporting, and evaluation into their management routines, not as an administrative burden but as the engine of an ongoing learning process (Dahiya and Laishram, 2024). Regularly reviewing and acting upon performance data enables institutions to cultivate the adaptive capacity necessary for transforming positive intentions into sustainable energy outcomes. Over time, this process cultivates a community of practice, a social structure built on shared knowledge, collective learning, and the willingness to adjust approaches in response to evidence. The key constructs at this stage are knowledge-sharing mechanisms, adaptive management, and organizational learning. Knowledge-sharing mechanisms, as confirmed by Gluch, Johansson, and Räisänen (2013), enhance energy information dissemination among university building stakeholders through training workshops, awareness campaigns, online platforms, and research collaborations. This approach fosters better energy efficiency and sustainability. Adaptive management, which involves modifying strategies based on monitoring and feedback, allows for adjustments in energy management in response to changing conditions and includes regular energy performance assessments and updates to energy-saving measures (Gluch et al., 2013), whereas organizational learning enhances energy management by using past experiences and data analysis to drive continuous improvement, such as reviewing energy audits and utility consumption data.

Step 7: Foster a Culture of Sustainability

Ultimately, sustained improvement in energy performance depends on more than policies and procedures; it requires that sustainability become a living part of institutional identity (Worts, 2006). Cotton and Winter (2026) argue that embedding sustainability into a university's values and day-to-day operations is the most reliable way to ensure that the commitment endures beyond individual leadership cycles or specific initiatives. The author contends that this cultural embedding can be achieved through a combination of three mutually reinforcing strategies: integrating energy and sustainability themes into the

academic curriculum; demonstrating visible institutional commitment through the decisions and public communications of senior leadership; and cultivating community ownership through student-led projects, green societies, and grassroots campus initiatives. When sustainability becomes genuinely embedded in institutional identity, it shifts from being an external requirement to being an internal norm shaping how people think, communicate, and act in ways that make energy efficiency a shared and self-reinforcing aspiration (Cotton and Winter, 2026; Worts, 2006). The key constructs here are sustainability education, leadership commitment, and community participation. Arguably, sustainability education should be part of the university's energy management that teaches responsible energy use and environmental protection through campaigns, workshops, and inclusion in the curriculum, as Dyer and Dyer (2017) espoused. The aim is to encourage energy-saving habits among students and staff. Furthermore, leadership commitment is critical, as university management should actively champion energy policies, resource allocation, and stakeholder engagement to place sustainability goals at the forefront. Involvement of the community increases the feeling of shared responsibility through activities like sustainability clubs and public consultations, which helps increase awareness and collaboration in energy management efforts (Dyer and Dyer, 2017).

5. Conclusion and Further Research

This paper has been developed using a conceptual narrative review shaped by sustainability theory and socio-technical principles applied to the challenge of understanding and improving energy consumption and management in university buildings. The conceptual contribution takes the form of a seven-step design to guide institutional thinking and practice moving away from fragmented or purely engineering-driven responses toward a holistic, integrated approach that recognizes people, technology, policy, and culture as interdependent dimensions of the energy management challenge. These steps vis-à-vis are a theoretical foundation underpinning the concepts, recognizing energy management as a sociotechnical system, mapping stakeholder interactions and motivations, diagnosing patterns of energy use and identifying hotspots, integrating behavioural change programs with technological solutions, institutionalizing continuous improvement and learning; and fostering a culture of sustainability. The argument advanced here is that this kind of sustainability-oriented and socio-technically informed approach is not merely desirable but necessary for achieving the depth and durability of improvement that universities need. Consistent and purposeful application of the proposed steps has the potential to generate meaningful gains in energy performance. However, the conceptual nature of this study carries inherent limitations such as no primary data, no empirical validation, possible author subjectivity, limited methodological transparency, and limited context-specific evidence. Empirical research is now required to test and refine these propositions in practice, particularly empirical studies using case studies, surveys, energy audits, or intervention-based evaluation.

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Making the case for sustainable buildings: Evidence from the limitations of conventional buildings

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Abstract

Existing buildings face environmental, economic, and health-related challenges due to traditional construction methods, and the slow adoption of sustainable practices. The study investigates the impact this has on operating costs, marketability, indoor environmental quality (IEQ), and interior material durability for buildings in the Nelson Mandela Bay Metropole (NMBM). The quantitative approach entailed administering a Likert-type scale questionnaire among 65 East Cape Master Builders Association (ECMBA) general contractor (GC) members. The 21 surveys returned, resulted in a 32.3% response rate. The findings indicate that existing conventional buildings perform poorly compared to sustainable buildings in terms of operating costs, marketability, IEQ, and interior material durability. High operating costs were primarily attributed to inefficient occupant behaviour, frequent repairs or replacement of building systems, and dependence on grid electricity. The primary factors associated with reduced marketability include lower resale / rental value, outdated design or lack of modern visual appeal, and overall energy efficiency of the building. High internal humidity levels leading to dampness or mould, ventilation rate and air circulation, and inconsistent indoor thermal comfort were factors linked to IEQ and occupants' health in existing conventional buildings. Recommendations include targeted policy intervention, improved regulatory enforcement, and increased industry awareness to accelerate sustainable practices.

Keywords: Conventional buildings, Energy efficiency, Indoor Environmental Quality, Lifecycle performance, Sustainable buildings

1 Introduction

Buildings contribute significantly to global energy consumption and environmental degradation, accounting for approximately 40% of global energy use (Aridi & Yehya, 2022). In developing countries, this impact is intensified by continued reliance on conventional construction practices and slow adoption of sustainable transformation practices. As urbanisation and energy demand rises, existing conventional buildings are increasingly associated with high operating costs, declining market value, deteriorating IEQ, and harmful impacts on occupant health.

The construction industry is recognised as a major contributor to environmental degradation (Olubunmi, Xia & Skitmore, 2016), prompting a growing emphasis on sustainable construction practices (Aigbavboa, Ohiomah & Zwane, 2017). While energy efficient designs and sustainable construction approaches have demonstrated clear economic, environmental, and social benefits (Malik *et al*., 2025), their implementation in developing countries remains slow due to high upfront costs (Du Plessis, 2007; Chipade *et al*., 2025).

The aim of this study is to examine the economic, market, health, and material performance limitations of existing conventional buildings in the NMBM, with the objective of generating evidence-based insights to support the adoption of non-demolition sustainable transformation practices, with a specific focus on factors contributing / influencing operating costs, marketability, IEQ, and interior material durability.

The paper proceeds by discussing the literature reviewed relative to the subject area, then outlines the research method adopted, next is presentation and discussion of the empirical findings, and concludes with the practical and policy-oriented recommendations to advance sustainable transformation of existing conventional buildings in the context of developing countries.

2 Literature Review

2.1. Energy Inefficiency and Escalated Operating Costs in Conventional Buildings

Energy inefficiency is a major limitation of conventional buildings, especially in developing countries experiencing rapid urbanisation (Nkini *et al*., 2023; Zhang *et al*., 2019). Global urbanisation is projected to be 68% by 2050, despite that many buildings continue to rely on outdated systems with minimal integration of energy-efficient technologies (Shuja, Gardezi & Idrees, 2021; Berardi, 2017). A

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study conducted by Nasr *et al.* (2023) and Cheekatamarla *et al.* (2022) revealed that conventional buildings are characterised by inefficient building envelopes, poor thermal performance, inadequate insulation, over-reliance on energy-intensive heating, ventilation and air conditioning (HVAC) systems, and limited integration of renewable energy technologies. For this reason, these buildings consume a lot of energy that translates into escalated operating costs throughout the building life cycle (Islam *et al.*, 2015). Another critical concern is occupant behaviour. Previous studies indicate that inefficient usage patterns can account for substantial energy waste, even in unoccupied buildings (Delzendeh *et al*., 2017). While technologies such as smart HVAC systems and lighting systems can improve efficiency (Chen *et al*., 2021), the gap between predicted and actual energy use in buildings suggests that behavioural factors remain insufficiently addressed.

Alberini (2018) opines that energy inefficiency directly causes an upsurge in utility costs through higher electricity and fuel consumption. Consequently, end-users are supposed to spend more on cooling, lighting, ventilation, and equipment operation to achieve desired comfort levels. In developing countries, the situation is exacerbated by higher electricity tariffs due to energy supply constraints and infrastructure deficits. Hence, inefficient buildings impose significant financial burdens on households and businesses. Consequently, sustainable interventions have demonstrated the potential to significantly reduce energy consumption, with reported savings of up to 40% in some contexts (Berardi, 2017; Nkini *et al*., 2023). However, these findings reflect ideal conditions and do not account for real-world constraints in developing countries.

2.2 Marketability and Building Performance in Evolving Property Markets

Sustainability increasingly influences building valuation and market performance. Sustainably constructed and transformed buildings have been shown to achieve rental premiums and improved asset value over conventional buildings due to enhanced energy efficiency and occupant productivity (Zhang *et al*., 2018). Hossain *et al.* (2023) further state that deficiencies, such as poor building design, inefficient technologies, and inadequate energy management practices associated with conventional buildings, contribute to increased energy consumption and higher operating costs. Consequently, having a negative effect on the marketability of existing conventional buildings

In developed countries, regulatory enforcement and green certification systems further accelerate sustainable transformation adoption (Evans, Roshchanka & Graham, 2017; Darko & Chan, 2018). However, in developing countries, barriers of weak enforcement of regulations, non-existent regulations, high upfront costs, and limited awareness constrain the adoption of sustainable transformation practices (Vine, Williams & Price, 2017; Chan *et al*., 2018)

2.3 Indoor Environmental Quality (IEQ) and Occupant Health

IEQ is a critical component of building performance as occupants spend over 90% of their time indoors (Mirzaei *et al*., 2020). Poor IEQ in conventional buildings has been linked to sick building syndrome (SBS), which negatively affects occupant health and productivity (Valderrama-Ulloa *et al*., 2020; Emetere *et al*., 2024).

Conventional buildings rely on outdated ventilation systems and low-quality materials that contribute to indoor air pollution through volatile organic compounds (VOCs) (Kurmanbekova, Du & Sharples, 2025). Research indicates that transformed buildings can significantly reduce SBS symptoms and enhance occupant well-being (Allen *et al*., 2015). For instance, MacNaughton *et al.* (2017) determined that occupants working in a sustainable building can report up to 30% less SBS symptoms and 46% better sleep quality than those working in a conventional building. However, these findings originate primarily from developed countries, with limited validation in developing contexts.

2.4 Material Durability and Lifecycle Performance

Material durability is a key determinant of lifecycle performance and maintenance costs. Conventional materials commonly used in developing countries are vulnerable to environmental degradation, which is further intensified by climate change (Phillipson, Emmanuel & Baker, 2016; Ferrara, La Noce &Sciuto, 2023).

Emerging research highlights the potential of sustainable materials to improve durability and performance. For instances, recycled concrete aggregates (RCA) and alternative composites have demonstrated enhanced strength and resilience under controlled conditions (Adams *et al*., 2016) However, these findings are largely experimental, with limited large-scale real-world application in developing countries.

3 Research Methodology

This study adopted a positivist research paradigm using a quantitative research approach to generate objective and measurable evidence regarding the performance limitations of existing conventional buildings and the implications of limited adoption of sustainable transformation practices. The quantitative approach was adjudged suitable because it facilitates the collection of numerical data and enables the use of statistical techniques (i.e., descriptive and inferential) to examine and analyse the data as indicated by Almusaed *et al.* (2025).

A cross-sectional survey design was employed, with primary data collected using a structured questionnaire consisting of close-ended questions measured on a five-point Likert scale. The questionnaire items were developed based on variables identified in the literature review, including operating energy drivers, marketability determinants, IEQ indicators, and interior material performance. The questionnaire was distributed electronically to GC's affiliated with the ECMBA who have experience with both conventional and sustainably transformed buildings in the NMBM. Purposive sampling was considered appropriate because it enabled the researchers to target individuals who could provide informed responses in relation to the subject matter, thereby enhancing the relevance and quality of the data collected (Leedy & Ormrod, 2015).

A total of 65 GCs were identified, of which 21 completed the survey, yielding a response rate of 32.3%. This response rate is deemed acceptable for industry-based survey research, where participation is often constrained by the availability of practitioners. More so, respondents were informed to relate their responses to selected projects (i.e., existing conventional buildings and sustainable buildings) that they have been involved in. This is the case because the findings of the study were intended to provide context-specific insights rather than support broader statistical generalisations to a larger population. Therefore, the responses were deemed reliable as they reflect the perspective of experienced professionals. Consequently, the quality and relevance of responses are more critical than the number of respondents.

high operating costs, reduced marketability, poor IEQ, and rapid deterioration of interior materials in existing conventional buildings. Although the study provides valuable insights into industry perceptions, the findings are limited to the NMBM context and reflect practitioners' perspectives rather than direct performance measurements. Therefore, the results should not be interpreted as universally generalisable.

4 Findings and Discussion

Table 1 indicates the extent to which eleven factors contribute to higher operating costs in existing conventional buildings in terms of percentage responses to a scale of not at all to a very large extent, and MSs ranging between 1.00 and 5.00. It is notable that 8 / 11 (72.7%) MSs exceed the midpoint of 3.00, which indicates in general the factors contribute to high operating costs in existing conventional buildings to a large, as opposed to a limited extent. Furthermore, it is notable that none of the MSs are > 4.20 ≤ 5.00. However, 7 / 11 (63.6%) of the MSs are > 3.40 ≤ 4.20, which indicates the factors contribute between a moderate to a near large / near large extent. Only 2 / 11 (18.2%) MSs are > 2.60 ≤ 3.40, namely outdated lighting systems, and older water fixtures, indicating they contribute to higher operating costs between a near limited to a moderate extent / moderate extent. The MSs of high insurance premiums, and lack of structured waste management systems are > 1.80 ≤ 2.60, indicating they contribute to higher operating costs between not at all to a near limited / a near limited extent.

Table 1: The extent to which eleven factors contribute to higher operating costs in existing conventional buildings

Factor	U	Response (%) Not……Very					MS	Rank
		1	2	3	4	5		
Occupant behaviour	0.0	0.0	9.5	14.3	28.6	47.6	4.14	1
Frequent repairs or replacement of building systems	0.0	0.0	9.5	23.8	42.9	23.8	3.81	2
Dependence on grid electricity	0.0	0.0	9.5	28.6	47.6	14.3	3.67	3
Inefficient or outdated HVAC systems	0.0	0.0	19.0	14.3	47.6	19.0	3.67	4
Lack of renewable energy integration	0.0	0.0	14.3	33.3	28.6	23.8	3.62	5
Poor thermal insulation of building envelopes	0.0	0.0	14.3	38.1	19.0	28.6	3.62	6
Absence of automation for monitoring and controlling energy and water use	0.0	4.8	19.0	19.0	23.8	33.3	3.62	7
Use of outdated lighting systems	0.0	0.0	19.0	33.3	38.1	9.5	3.38	8
Use of older water fixtures that consume excessive water	4.8	0.0	19.0	14.3	42.9	19.0	2.65	9
High insurance premiums from increased risks of fire, flooding, or other damage	4.8	0.0	23.8	28.6	19.0	23.8	2.45	10
Lack of structured waste management systems	4.8	4.8	19.0	33.3	19.0	19.0	2.30	11

A measure of central tendency in the form of a mean score (MS) was computed for each variable to determine the relative significance of each variable. Then the variables were ranked in descending order based on their MSs, to identify the key contributors to

In terms of the mean ranking, occupant behaviour was ranked first, followed by frequent repairs or replace of building systems, dependence on grid electricity, and insufficient or outdated HVAC systems. These findings are consistent with the literature. Concerning occupant

behaviour, a previous study conducted by Delzendeh et al. (2017) indicates that inefficient usage patterns contributed to substantial energy waste due to unoccupied buildings. Nonetheless, Chen et al. (2021) revealed that while smart HVAC systems and lighting systems can improve efficiency, the gap between predicted and actual energy use in buildings associated with behavioural factors remains underexplored. With regard to dependency on grid electricity, Alberini (2018) opined that energy inefficiency directly increases utility costs through higher electricity and fuel consumption. In the developing countries context, the situation is compounded by higher electricity tariffs due to energy supply constraints and infrastructure deficits. In alignment with insufficient or outdated HVAC systems, Shuja, Gardezi and Idrees (2021) and Berardi (2017) contend that many buildings continue to rely on outdated systems with minimal integration of energy-efficient technologies, contributing to higher operational costs.

Table 2 indicates the extent to which eight factors negatively affect the marketability of existing conventional buildings in terms of percentage responses to a scale of minor to major, and MSs ranging between 1.00 and 5.00. It is notable that 4 / 8 (50.0%) of the MSs are > 3.00, indicating the factors have a major as opposed to a minor negative effect on marketability of existing conventional buildings. It is notable the MS of lower resale / rental value is > 4.20 ≤ 5.00, which indicates the factor has between a near major to a major / major negative effect on marketability. The MSs of outdated design and overall energy efficiency of building are > 3.40 ≤ 4.20, indicating between a moderate to a near major / near major negative effect on marketability. Then, 2 / 8 (25.0%) MSs are > 2.60 ≤ 3.40, indicating between a near minor to a moderate / moderate negative effect - absence of formal building certification ranked fourth followed by perceptions toward inefficient buildings. Then, 2 / 8 (25.0%) MSs are > 1.80 ≤ 2.60, namely absence of visible sustainability features ranked sixth followed by ineligibility for tax incentives, which indicates between a minor to a near minor / near minor negative effect on marketability. The MS of absence of automation is > 1.00 ≤ 1.80, indicating between a minor to a near minor / near minor negative effect on marketability.

The findings in relation to the top ranked factors, such as the lower resale / rental value relative to conventional buildings, outdated design or lack of modern visual appeal, and overall energy efficiency of the building, are in consonance with the literature review and corroborated by Hossain *et al.* (2023) and Zhang *et al.* (2018). For instance, Hossain *et al.* (2023) stated that in most cases, conventional buildings are characterised by poor building design, inefficient technologies, and inadequate energy management, which has a negative effect on the marketability prospects of the property. In contrast, Zhang *et al.* (2018) argue that sustainably constructed buildings have been shown to achieve rental premiums and improved asset value, thereby enhancing their marketability prospects.

Table 3 indicates the extent to which eight factors influence the IEQ and occupant health in existing

Table 2: The extent to which eight factors negatively affect the marketability of existing conventional buildings

Factor	U	Response (%) Minor……Major					MS	Rank
		1	2	3	4	5		
The lower resale / rental value relative to conventional buildings	0.0	4.8	0.0	9.5	28.6	57.1	4.33	1
Outdated design or lack of modern visual appeal	0.0	4.8	0.0	33.3	28.6	33.3	3.86	2
Overall energy efficiency of the building	0.0	0.0	4.8	33.3	38.1	23.8	3.81	3
Absence of formal building certifications	0.0	14.3	14.3	38.1	14.3	19.0	3.10	4
Perceptions of buyers, tenants, and investors toward inefficient buildings	4.8	4.8	14.3	4.8	28.6	42.9	2.95	5
Absence of visible sustainability features	4.8	4.8	9.5	33.3	28.6	19.0	2.50	6
The ineligibility for tax incentives or rebates	4.8	9.5	9.5	28.6	28.6	19.0	2.40	7
The absence of automation for building systems	4.8	14.3	23.8	38.1	14.3	4.8	1.70	8

Table 3: The extent to which eight factors influence IEQ and occupants' health in existing conventional buildings

Factor	U	Response (%) Minor……Major					MS	Rank
		1	2	3	4	5		
High humidity levels leading to dampness or mould inside the building interior.	0.0	4.8	4.8	4.8	33.3	52.4	4.24	1
Ventilation rate and air circulation of ventilation system installed.	0.0	4.8	4.8	9.5	33.3	47.6	4.14	2
Inconsistent indoor thermal comfort due to poor thermal control.	0.0	9.5	9.5	14.3	42.9	23.8	3.62	3
Ability of the building to provide and maintain adequate indoor lighting conditions.	0.0	14.3	4.8	28.6	23.8	28.6	3.48	4
The acoustic design (noise pollution control) of the building.	0.0	14.3	9.5	33.3	19.0	23.8	3.29	5
The lack of automated systems for monitoring and controlling indoor air quality.	0.0	14.3	19.0	14.3	33.3	19.0	3.24	6
Build-up of indoor dust and particles from poor filtration.	4.8	9.5	4.8	9.5	33.3	38.1	2.90	7
Use of interior finishes / material releasing harmful emissions (e.g. VOC's).	4.8	4.8	9.5	19.0	33.3	28.6	2.75	8

conventional buildings in terms of percentage responses to a scale of minor to major, and MSs ranging between 1.00 and 5.00. It is notable that 6 / 8 (75.0%) of the MSs are > 3.00, which indicates in general the factors have a major as opposed to a minor influence on IEQ and occupant health. It is notable 1 / 8 (12.5%) MSs is > 4.20 ≤ 5.00, indicating that high humidity levels leading to dampness has between a near major to a major / major influence. Then, 3 / 8 (37.5%) MSs are > 3.40 ≤ 4.20, indicating between a moderate to a near major / near major influence - ventilation rate and air circulation ranked second, followed by inconsistent indoor thermal comfort, and provision of adequate lighting conditions. Furthermore, acoustic design ranked fifth, followed by lack of automated air quality monitoring, build-up of indoor dust, and use of interior finishes releasing harmful emissions all have MSs > 2.60 ≤ 3.40, indicating they have between a near minor to a moderate / moderate influence on IEQ and occupant health. The findings are aligned with previous studies conducted by Valderrama-Ulloa *et al.* (2020), Emetere *et al.* (2024), and Kurmanbekova *et al.* (2025). For instance, poor IEQ in conventional buildings may affect occupant health and productivity and may lead to SBS (Valderrama-Ulloa *et al.*, 2020; Emetere *et al.*, 2024). Kurmanbekova et al. (2025) note that this situation is exacerbated due to reliance on outdated ventilation systems and materials with higher VOCs.

Table 4 indicates the extent to which nine factors contribute to the rapid deterioration of interior building materials and finishes in existing conventional buildings in terms of percentage responses to a scale of not at all to a very large extent, and MSs ranging between 1.00 and 5.00. It is notable that 4 / 9 (44.4%) MSs are > 3.00, indicating in general the factors contribute to a large as opposed to a limited extent to rapid interior material deterioration. It is notable 1 / 9 (11.1%) MSs is > 4.20 ≤ 5.00, indicating the quality of workmanship during installation of the material contributes between a large to a very large / very large extent towards rapid deterioration of interior building materials. Conformance to standards ranked second, followed by resistance to moisture exposure, and frequency of maintenance have MSs > 3.40 ≤ 4.20, which indicates they contribute between a moderate to a large / large extent. In addition, 4 / 9 (44.4%) MSs are > 2.60 ≤ 3.40, indicating the factors contribute between a limited to a moderate / moderate extent - compatibility with indoor conditions ranked fifth, followed by time elapsed since installation, compatibility of protective coating, and resistance to chemical exposure. Resistance to mechanical stress has a MS > 1.80 ≤ 2.60, indicating it contributes between not at all to a limited / limited extent.

In terms of the top ranked factors, the findings are similar to previous studies. Conventional materials commonly used in developing countries are vulnerable to environmental degradation. For this reason, material durability is a key determinant of lifecycle performance and maintenance costs (Phillipson, Emmanuel & Baker, 2016; Ferrara, La Noce &Sciuto, 2023). Hence, the quality of workmanship during installation of the

Table 4: The extent to which nine factors contribute to rapid deterioration of interior materials in existing conventional buildings.

Factor	U	Response (%) Not……Very					MS	Rank
		1	2	3	4	5		
The quality of workmanship during installation of the material.	0.0	4.8	0.0	14.3	28.6	52.4	4.24	1
The conformance to standards of the interior construction material.	0.0	4.8	0.0	19.0	47.6	28.6	3.95	2
The resistance of the interior construction material to moisture exposure.	0.0	4.8	9.5	19.0	42.9	23.8	3.71	3
The frequency of maintenance and repairs required for the material (e.g., concrete, timber, clay bricks).	0.0	4.8	23.8	23.8	19.0	28.6	3.43	4
The compatibility of the interior material with the indoor environmental conditions.	4.8	4.8	0.0	23.8	38.1	28.6	2.90	5
The time elapsed since the installation or replacement of the original interior construction material.	4.8	0.0	0.0	38.1	33.3	23.8	2.85	6
The compatibility of protective coating, sealants or treatment applied with the indoor environmental conditions.	4.8	9.5	0.0	23.8	28.6	33.3	2.80	7
The resistance of the interior construction material to chemical exposure.	4.8	4.8	9.5	28.6	28.6	23.8	2.60	8
The resistance of the interior construction material to mechanical stresses.	4.8	4.8	4.8	33.3	38.1	14.3	2.55	9

material and conformance to standards of building material are important aspects in reducing the cost of maintenance throughout the building life cycle

5 Conclusions and Recommendations

This study examined the performance limitations of existing conventional buildings in the NMBM to inform the adoption of non-demolition sustainable transformation practices. The findings confirm that continued reliance on conventional building approaches results in measurable economic, environmental, and health-related inefficiencies that undermine the long-term performance of buildings. The study determined that high operating costs are primarily driven by inefficient occupant behaviour, outdated HVAC systems, dependence on grid electricity, and the absence of automation. These factors collectively increase energy consumption and a building's lifecycle expenditure. From a market perspective, buildings with no sustainable features experience reduced resale and rental values, and financial performance emerges as the main element for competitiveness. Which places sustainable transformation of existing conventional buildings not only as an environmental consideration but as a strategic economic necessity to ensure building value retention.

The study further establishes a clear relationship between poor IEQ and increased likelihood of SBS symptoms. High humidity levels, inadequate ventilation, and inconsistent thermal comfort were identified as key contributors to occupant discomfort and potential health risks. In addition, rapid deterioration of interior building materials was found to be strongly associated with poor workmanship, non-compliance with South African National Standards (SANS), and exposure to moisture, leading to a shortened service life and increased maintenance demands. Overall, the findings confirm that non-demolition sustainable transformation practices are essential to improve energy efficiency, enhance market competitiveness, protect occupant health, and extend building longevity. The takeaway is that delaying sustainable transformation interventions preserves building inefficiency and loss of building value, whereas proactive transformation of the existing buildings can present a pathway toward improved performance, economic strength, and environmental sustainability within the NMBM.

5.1 Theoretical contributions, practical implications, and policy contributions

In terms of the theoretical contribution, the study adds to the body of knowledge regarding building performance and sustainability by providing empirical evidence associated with the multi-dimensional limitations of conventional buildings from four perspectives, namely, economic, market, health, and material performance.

Concerning practical and industry implications, the findings of the study offer valuable insights for professionals within the construction and real estate sectors. First, it provides evidence of key economic inefficiencies associated with conventional buildings and demonstrates how poor IEQ and unhealthy building conditions can influence occupant well-being and productivity. Second, the study provides empirical evidence that highlights material performance deficiencies and how they influence the marketability of conventional buildings in terms of property attractiveness, occupancy rates, and asset values. Subsequently, these findings will enable stakeholders to make informed investment and design decisions.

Regarding policy contributions, the study provides evidence-based insights that can support policymakers, regulators, and professional bodies within the built environment by promoting sustainable development through strengthening building regulations and performance standards relating to energy efficiency, indoor environmental quality, material sustainability, and retrofitting of existing buildings.

5.2 Recommendations

Further research should focus on conducting detailed lifecycle cost analysis and post-occupancy evaluations to quantify the economic, environmental, and health benefits of sustainably transforming existing conventional buildings. Empirical measurement of energy saving, improvements in IEQ, and reductions in maintenance frequency would strengthen the business case for transformation. For stakeholders, including property owners, developers, and facility managers, immediate action is required to improve the performance of existing buildings. Priority should include conducting energy and IEQ audits to identify inefficiencies, integrate automation and monitoring technologies to manage resource consumption, and enforce strict compliance with construction materials SANS to enhance interior material durability. Provincial and municipal authorities can strengthen policy support mechanisms by introducing targeted incentives, technical guidelines, and monitoring frameworks that encourage sustainable transformation over continued conventional practices.

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A Scoping Review: Policy "Pull" and Diffusion of Green Building Certification Across Africa

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Abstract

Green building adoption is part of a global response to the environmental impacts of construction. However, the literature shows low adoption rates for green certification in developing African countries due to various challenges, including fragmented policy approaches. This scoping literature review explored how policy instruments influence the adoption and diffusion of green building certification across African countries. Using the PRISMA framework, 28 studies were selected from 113 identified across 3 databases, including Scispace, Google, and Google Scholar. The results demonstrate that the green building policy landscape in Africa is underdeveloped, with many countries lacking defined policies to guide sustainable practices. However, adoption of international green certification systems is prevalent on the continent due to the lack of local rating systems and cohesive policy frameworks. Notable policy gaps driving stakeholder interests include the need for technical training, public awareness initiatives, regulations by green building councils, the creation of green financial instruments, and government interventions. Unlike other studies that focus on cost perceptions and lack of technical skills, this study explored how policy instruments influence the adoption and diffusion of green building certification across African countries.

Keywords: Green building, Green Certification, Policy Instrument, Africa, Scoping Review, Certification, Rating Systems, Regulation.

1. Introduction

In recent years, there have been concerted efforts advocating sustainability and green practices in the built environment. Studies like Gelan (2022) assert that the built environment contributes up to 39% of global carbon emissions and 40% of global energy consumption. As a result, green building has been proposed as a critical strategy to reduce the negative impacts of construction activities on the environment. This has led to the adoption of green certification systems like the LEED, BREEAM, and the South African Green Star as standards for demonstrating environmental compliance and contribution to sustainability (Adegbile, 2012; Bharat et al., 2013; Wyk, 2014; Balapgol, 2022). However, adoption remains limited in many developing countries and across Africa despite growing energy needs.

In Figure 1, the global demand for electricity across the globe has proceeded on an upward trajectory. However, in Africa, this demand has remained relatively

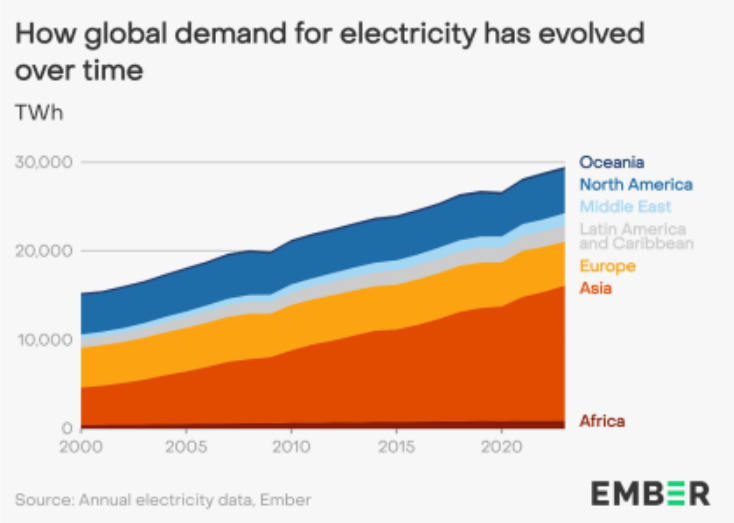

Figure 1: Global Demand for Electricity (Ember, 2024).

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consistently low. Africa's electricity demand increased from little under 2% in 2023 to an anticipated 3.4% in 2024. This growth is expected to continue over much of the continent between 2025 and 2027, averaging 5% annually (ESI Africa, 2025). As demand for development increases, energy demand may not remain low. As Ayoade (2019) rightly put it, large-scale energy production and consumption are now the foundation of prosperity as well as the source of 80% of carbon dioxide (CO2) emissions and around 75% of all greenhouse gas emissions. Meanwhile, African nations have committed to core climate change agreements, including the UN Framework Convention on Climate Change (UNFCCC) 1992, the Kyoto Protocol 1997 and the Paris Agreement 2016. With growing advocacy for certification of green buildings, policy diffusion and its influence on adoption potentially offer insight into how the built environment responds to climate change in developing African contexts.

This study seeks to answer the question: How do policy instruments influence the adoption and diffusion of green building certification across African countries? This main question is further addressed through the following sub-questions:

1. What are the extant green policies adopted across Africa?
2. Which green certification systems are widely adopted in Africa?
3. Which policies influence stakeholders in the adoption of green certification systems across the continent?

2. Literature Review

Green building has in recent years emerged as a strategic response to the environmental impact associated with the housing or construction sector (Bogdana, Dacian and Raluca, 2009). Across sub-Saharan Africa, studies (Adegbile, 2012; Victoria et al., 2022; and Maria, Sambo and Dave, 2022) have shown that green building practices have limited adoption and reach. This suggests that despite the growing importance of a green housing sector, there are still several limitations and challenges limiting the reach and adoption of green buildings. Regulation and compliance through certification remain largely underexplored in literature.

2.1. Green Building Certification

Green building certifications emerged as a response to the need for standardization in the adoption of green practices. Some of the common and leading certifications present across the continent include the BREEAM (developed in the UK) and LEED (in the USA), Grean Star (South Africa). Studies (Velişcu, 2009; and Güngör, 2015) describe in detail the development of various certification or rating systems like LEED Leadership in Energy and Environmental Design (LEED) in North America, Building Research Establishment Environmental Assessment Method (BREEAM) in the UK, HQE in France, Casbee (Japan), Nabors in Australia, HK-Beam in Hong Kong, etc. These not only help to monitor and assess green or sustainable practices uniformly but also reduce the risk of greenwashing (Oladeji and Okoro, 2024). While there are studies that highlight the scope and application of certifications in individual countries, there is no comprehensive synthesis of literature capturing the certification types within Africa. This creates a policy gap for promoting or advocating green building certification, without understanding the different regulatory approaches dominating different countries, might yield limited results.

2.2. Green Policy Diffusion

There are different positions on Africa's approach to addressing environmental impacts in the housing sector. Some of these different positions are influenced by differing geopolitical policies across Northern African countries and Sub-Saharan Africa. Others are reflected in the difference between regional dynamics across Southern Africa, East Africa, and West Africa.

In the literature, Northern Africa's green or sustainability policies and diffusion are explored as a part of the MENA (Middle East and North Africa) grouping (Redouan et al., 2022). This suggests strong policy influences from Middle Eastern regions on the adoption and reach of sustainability interventions in North Africa (Yakouta, Michele and Ouassila, 2023). Furthermore, the environmental risks across the MENA region are scarcely uniform across more than 20 countries (Isaac et al., 2013). These realities constitute significant differences that might inhibit shared sustainability goals without a cohesive framework.

Across Sub-Saharan Africa as well, countries like Nigeria, Ghana, Kenya, and South Africa, have adopted different regulatory or certification systems (Khaemba and Mutsune, 2014; and Darko, 2019). Some of these are adapted to local realities, while others are mere replications of systems created for more developed economies.

2.3. Policy Stakeholders

Nduka and Olabode (2015) argue that the extra cost of making housing sustainable is often perceived as out of reach for many people. Meanwhile, other studies insist that the long-term benefits of green buildings outweigh the initial costs (Matsila, 2013; Martin and Sarmad 2013); Windapo, 2014). This implies that ongoing development, rising energy demand, and the need to expand cities will increase demand for green buildings across the continent. However, these studies have only provided limited coverage on policy diffusion and how

it contributes to green building certification. This represents a significant gap in understanding the green and sustainability adoption challenges in developing African contexts.

3. Methodology

To assess how policy instruments influence the adoption and diffusion of green building certification across African countries, this study adopts a pragmatic philosophical stance. The pragmatic worldview recognises that knowledge can be contextual and not limited to structured and empirical information (Saunders, Lewis and Thornhill, 2023). Across African countries, green building policy and evidence are often dispersed across policy documents, institutional reports, industry practices, and academic scholarship. Therefore, a conceptual synthesis offers a critical foundation to further quantification or empirical studies. This study applied an inductive approach to allow themes to emerge from fragmented literature across the continent, which is appropriate where research and data are limited (Ibrahim and Raji, 2018). A scoping literature review is conducted to explore the literature, chart and summarize the evidence, and inform future research. This study adopted the 5-step framework by Arksey and O'Malley (2005). For the transparency of the identification and selection process a PRISMA 2020 flow diagram was used (Haddaway et al., 2022).

3.1. Study Selection

As seen in Figure 2, of the 113 identified studies, 46 were selected from 3 databases, including Scispace, Google, and Google Scholar, which offered a robust selection of referred journal articles. Studies that were not focused on African countries were excluded. Language was also a basis for excluding some studies. Only studies using the English language were included in the selection due to the limited timeframe for the study and the extensive need for translation that would be required to include studies in other languages, like French or Arabic.

3.2. Charting the Data

The information extracted from the studies included the country, the existing green building policy focus in the identified country, the green building rating or certification system, and policy influences on stakeholders. This data was tabulated using Excel spreadsheets.

3.3. Collating, summarising, and reporting.

Results for 28 studies were summarized, collated, and reported. These results were representative of regions within Africa including West Africa, South Africa, North Africa, and East Africa. Furthermore, the content analysis includes a table consisting of the Author, Country, Existing Green Policy, Certification System, and Policy diffusion level. The content analysis was conducted manually by reading through the selected studies.

4. Results

In Table 1 (Appendix 1), twenty-eight studies offering a comprehensive synthesis of green building policy direction are analyzed. The results include information spanning nine countries across various regions, including West, East, North, and Southern Africa. The content analysis included published sources from 2011

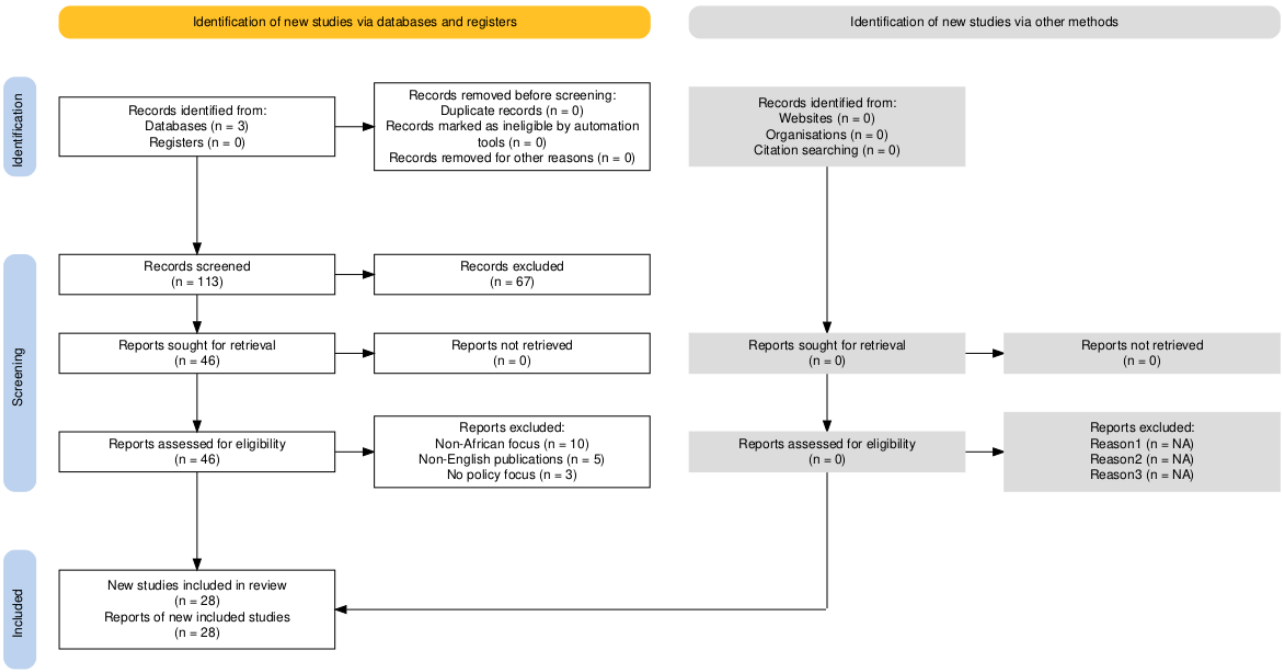

Figure 2: PRISMA Flow Chart (Author's own work).

to 2022, with an outlier from 1970. Table 1 outlines the existing green building policy in each identified country, the green building rating system, and the policy influences on stakeholder engagement.

Across the literature analysed in table 1, studies report a lack of specific policy instruments driving the adoption of green building certifications. There are, however, a few related policies that have been identified as guidelines for certain countries. In Ghana, Agyekum et al. (2022) noted the ISO 14000 environmental management systems and frameworks. Meanwhile, in Egypt, there are some influences of the energy efficiency (EE) policies governing the MENA region (Osama and Omar, 2019). Across the literature, an emerging policy position is that there needs to be government intervention in the form of mandatory policy and regulations to enforce green building standards. This might be explained by the limited success recorded through voluntary green building implementation (Isaac et al., 2013). The results also recommend key policy gaps to be filled, including green tax incentives, localized rating, financing, awareness, guidelines, tools, and techniques. While there are increasing influences from Middle Eastern policies in North Africa, the results also found strong influences from Asian countries like India and Malaysia in West Africa. This suggests broader international influences and interests in the green building market across the continent.

This study also identified certification and rating systems that exist across the continent. Some of the leading certifications include LEED, BREEAM, and the South African Green Star. While these certification systems are adopted from the U.S., U.K., and Australia respectively, there is a broad advocacy for localized green building rating systems. In Egypt, Osama and Omar (2019) reported the development of a local rating system called Green Pyramid Rating System (GPRS). However, due to ongoing political and economic reforms, the rating system had not been used at the time of the study. Of all the international rating systems, the LEED was reported to have a wider coverage of most regions of the continent. It is also significant to note that the South African Green Star rating has been adopted by some developers in Nigeria (Onuoha et al., 2017), which demonstrates cross-border collaborations.

To evaluate the influences of policy in driving diffusions across the continent, the study also explored policy stakeholder involvement. Overall, the interest of stakeholders can be grouped as follows:

1. Government or public institutions: private institutions require policy interventions that inform priority locations for green buildings, utility concessions, financial incentives, training, and awareness.
2. Built-environment professional institutions: Professional bodies are increasingly developing awareness and interest in incorporating green principles in practice.
3. Financial institutions: Banks and other development financers with an interest in developing financing instruments require regulation, education and training for financing decisions.
4. Green building councils: There is a limited presence of established bodies to document, advocate, regulate and promote green building practices.
5. Contractors and building artisans: The lack of trained experts or technical skills for the use of green building materials is also a challenge for widespread adoption (Fanie and Roneesh, 2011).
6. Building users and investors: Public awareness is reported as significantly low across the continent.

A conceptual framework for the contributions of policy diffusion to green building certification is illustrated below in figure 2.

In Figure 3 (Appendix 1), the conceptual framework illustrates the study's contribution in identifying policy mechanisms and their influence on the adoption of green building certification by identified housing stakeholders. For example, the role of Government officials in addressing needs for green incentives and concessions contributes to green certification adoption. Professional institutions seek to translate green policy into practice. Financial institutions developing green finance instruments and education adopt certification for compliance and standards. Green building councils seek to advocate and promote green building practices. Contractors and artisans need technical training to implement sustainable practices. Building Users and investors need more awareness on benefits of green buildings. This conceptual framework would benefit from further research and development including survey data to validate the policy drivers and their contribution to the green certification market.

5. Conclusion

This paper examined how policy instruments influence the adoption and diffusion of green building certification across African countries. First, the findings show that the green building policy landscape is significantly underdeveloped. Most African countries lack a clearly defined green building policy to guide the adoption and implementation of sustainable building practices. However, diverse international institutions are influencing awareness and advocacy for policy adoption. This distinctly demonstrates the role of global institutions and mandatory regulation for policy development and sustainability adoption.

Second, adopting international green certification or rating systems has evolved as the most common approach to regulation across the continent. Which policymakers must recognize as a limited approach that requires robust local replacement through policy. The LEED from the United States and South Africa's Green Star are considered the most popularly used rating system across the continent. However, the diverse local realities of construction and housing markets require green implementation to be locally relevant to guarantee wider adoption.

Thirdly, many stakeholders have differing sustainability interests, which green building policies must address. Some of these policy gaps include the need for policy-driven technical training for skilled workers, public awareness for users and investors, regulation by green building councils, the development of green financial instruments, and government-led interventions or concessions.

The study recommendations include:

1. Country-level green building agendas driven by government ministries that directly serve the construction and housing sectors.
2. Development of local rating systems that extend the existing international standards.
3. Widespread introduction of green standards to built environment professional bodies.
4. Partnerships between the governments and financial institutions that develop green building financial instruments and concessions.

While this study has provided an insight into the policy landscape in extant literature, it is limited by the lack of primary data. This offers an opportunity for further research to examine stakeholders' interest and commitment in adopting a comprehensive green building policy. Further research should explore the potential use of local standards and measures to assess green practices and determine compliance.

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Appendix 1

Table 1: Content Analysis for Green Building Policy Diffusion in Africa

Author	Country	Existing Green Building Policy	Green building rating system	Policy diffusion level
Gelan (2022)	Ethiopia	NA	LEED - Limited	Minimal
Chan et al. (2018), Darko (2019), Agyekum et al. (2019), Addy et al. (2020), Ampratwum et al. (2021), Agyekum et al. (2022), Anzagira et al. (2022), Victoria et al. (2022),	Ghana	Related environmental policy	LEED, IFC Edge, and South Africa's Green Star.	Minimal
Department of Environmental Affairs and Tourism (DEAT) (2009), Mpakati-Gama, Wamuziri and Sloan (2012), Windapo (2014), Windapo and Goulding (2015), Simpeh et al. (2023), Oladeji and Okoro (2024)	South Africa	Regional and national building regulations	The South African Green Star.	Significant
Isaac et al. (2013), Assadiki et al. (2022)	North Africa	Related energy policy	LEED and limited use of the BREEAM.	Moderate
Nduka and Olabode (2015), Onuoha et al. (2017), Ibrahim and Raji (2018), Ola and Adjekophori (2018)	Nigeria	NA	LEED and the South African Green Star.	Minimal
Matsila (2013)	Botswana	NA	NA	NA
Khaemba and Mutsune (2014)	Kenya	Yes	Limited LEED rating system.	Minimal
Claude, Siddig and Blaise (1970)	Cameroon	Related local planning policy	NA	NA
Abdel Aleem, Balci, and Sakar (2015), Osama and Omar (2019)	Egypt	Related energy efficiency (EE) policies.	Green Pyramid and LEED.	Moderate
Fanie and Roneesh (2011)	Mauritius	NA	LEED.	Moderate
Ebekozien et al. (2024), Ntombela and Okoro (2024)	Multiple African Countries	Significant green building policy advances from South Africa	South African Green Star, Kenyan Green Mark.	Minimal

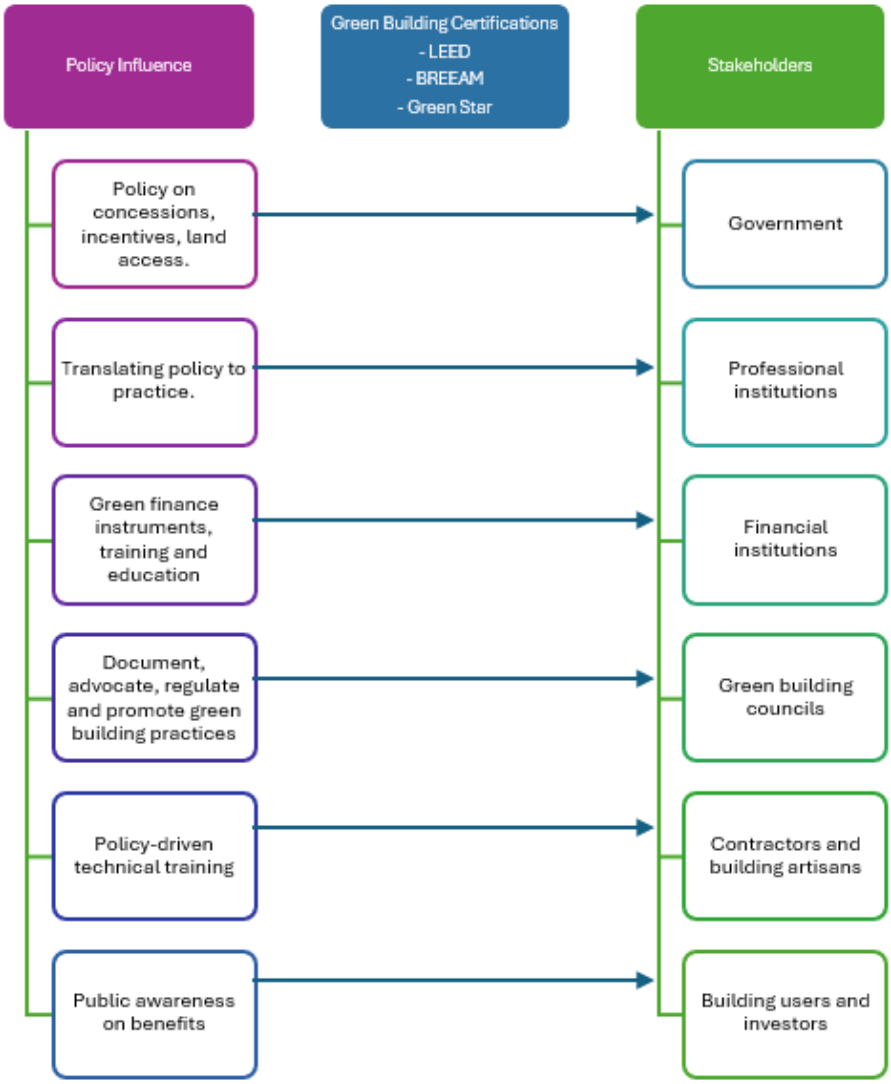

Figure 3: Proposed Framework: Policy Influences Driving Green Building Certification Adoption. Source**:** Author's Own Work.

Effects of Government Policies on the Provision of Housing in Nigeria: An Empirical Analysis of Akure North Local Government Area

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Abstracts

This study examined the effects of government policies on the provision of housing in Akure North Local Government Area, Ondo State, Nigeria. A mixed-methods approach was adopted, utilising both quantitative data from 120 structured questionnaires and qualitative insights from interviews, observations, and field photographs. Respondents were drawn from five communities: Oke-Ijebu, Igoba, Ita-Ogbolu, Oba-Ile, and Osi, using a stratified random sampling technique to ensure proportional representation. The findings revealed that while a majority of residents live in moderately adequate housing with basic sanitation, they still face common challenges such as poor electricity, leaking roofs, and inadequate plumbing. Land availability was generally rated as adequate; however, land costs remain a constraint, particularly for low-income earners. Perceptions of government housing policies were mixed, with 30% of respondents reporting negative impacts and only 28.3% perceiving a positive influence. The study concluded that existing policies have not sufficiently addressed housing affordability, infrastructure provision, or access to land. It recommends improved policy implementation, regular maintenance programs, and affordable land pricing schemes to enhance housing delivery and residents' well-being in Akure North.

Keywords: Government Policies, Effect, Housing Policies, Housing Provision

1. Introduction

Housing represents a basic human necessity and a crucial element for sustainable development (United Nations Human Settlements Programme, 2015). Suitable housing offers refuge, safety, and seclusion, and it is crucial for the well-being and dignity of individuals and families (UN-Habitat, 2020). Nonetheless, in numerous regions of Nigeria, accessing decent and affordable housing continues to be a substantial obstacle, especially for low-income households (Ibem & Amole, 2013). Schwartz (2015) stated that adequate housing is a multifaceted challenge that necessitates the involvement and coordination of numerous entities. It encompasses governmental bodies at various levels, whose policies, regulations, and initiatives play a pivotal role in shaping the housing landscape. Additionally, Schwartz (2015 stated that private real estate developers and construction firms are crucial stakeholders, responsible for undertaking housing projects and contributing to the overall supply. Financial institutions, such as banks and mortgage lenders, are instrumental in providing the necessary financing options to make housing accessible and affordable. Furthermore, the community itself, including residents, civic organisations, and advocacy groups, plays a vital role in voicing concerns, shaping priorities, and contributing to the development and implementation of housing solutions, according to Schwartz (2015).

The government plays a crucial role in shaping housing policies and creating an enabling environment for housing development. In Nigeria, various housing policies and programs have been implemented over the years to address the housing deficit and improve access to affordable housing (Federal Ministry of Works and Housing, 2022). Akure North Local Government, a peri-urban region within Ondo State, Nigeria, faces a growing housing crisis. This crisis is characterised by a shortage of affordable and adequate housing units, overcrowding, and poor living conditions (Adewale & Ajayi, 2021). The local government has implemented various housing policies and initiatives aimed at addressing the housing needs of its residents. However, the effectiveness of these policies and their impact on housing provision in the area remains unclear. It is essential to evaluate the effects of government policies on housing provision to identify areas that require improvement and to inform future policy decisions

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(Ibem et al 2017, Aluko 2024). The Nigerian government's National Housing Policy, which aims to provide affordable housing for all citizens, has largely fallen short of its goals. Despite the policy's intentions, little progress has been made in its implementation, leaving many Nigerians disillusioned and frustrated (Adejumo, 2008). In 1996, a United Nations study highlighted increasing worries about the worsening state of housing in urban areas of developing countries (Aribigbola, 2011). In response to these mounting concerns and to address the various housing issues prevalent in developing nations, the global community took action. They established the Habitat Agenda during a conference in Istanbul. This initiative had multiple objectives: to ensure shelter for all people, to promote sustainable urban development, and to assign primary responsibility for implementing the agenda's goals. (Aribigbola's 2011)

Adejumo (2008) also stated that while the government periodically introduces new policies and programs to tackle housing issues in Nigeria, there appears to be a lack of systematic evaluation of these initiatives. The absence of a robust review process hinders the assessment of policy effectiveness and prevents the application of lessons learned to future housing strategies or other sectors. Implementing such reviews could facilitate ongoing improvements in housing policy and allow for the transfer of successful approaches to other areas of governance. This research aims to examine the effects of government policies on the provision of housing in Akure North Local Government, while the objectives are to i) determine the housing conditions of the study area; and ii) examine the factors affecting housing provision in the study area.

2. Literature review

2.1. Concept of Housing

Grimes & Orville (1976) explain that, in the past, the concept "housing" was associated with a physical phenomenon, and the policies of countries for its provision are mostly related to construction costs that may largely vary depending on the type of construction, material, various housing standards and construction quality. Housing can be rated or judged as excellent, good, fair or poor based on the infrastructural facilities, government policies and other factors (Owolabi, 2014). Within the framework of housing policy, Torgersen (1987) explains the concept "housing" as the wobbly pillar under the welfare state because, in contrast to the health and education provision, the state does not see its role as the main service provider in this field. Housing is a fundamental concept that encompasses the provision of shelter, security, and personal space for individuals and families. This essential aspect of human life has evolved significantly throughout history, reflecting changes in societal structures, technological advancements, and cultural norms (Clapham, 2019). At its core, housing serves to protect individuals from external elements and provide a sense of belonging; its implications are far-reaching and complex (Kemeny, 1992; Aluko, 2024).

The physical structures that comprise housing have adapted over time to suit environmental conditions, available resources, and technological capabilities. From ancient mud huts to modern skyscrapers, the evolution of housing reflects human ingenuity and adaptability (Oliver, 2007). The concept of housing continues to evolve in response to contemporary challenges such as urbanisation, demographic shifts, and technological advancements. Madeddu *et al.* (2015) explore emerging trends including smart homes that integrate advanced technologies for improved efficiency and comfort, co-living spaces that address changing social dynamics and housing affordability, and adaptive reuse of existing structures to meet new needs while preserving architectural heritage. Sideḷska (2014) uses the concept "housing" as real estate or its part in the building, including non-residential buildings that are used for dwelling purposes all year round. The problem of housing provision in Nigeria started in the 1970s when the government shifted its focus from rural development to urbanisation, which led to a high influx of people into urban areas. The government's inability to provide adequate housing for its citizens has resulted in a deficit of over 20 million housing units (Yao, 2009).

Schwartz (2015) notes that it is often the largest single investment an individual or family makes, influencing wealth accumulation and economic stability. The housing market has significant implications for national and global economies, with fluctuations in property values and construction activity having far-reaching effects. A study carried out by Blessing (2016) observes that governments worldwide grapple with issues such as affordable housing, homelessness, and sustainable urban development. These policies shape the physical landscape of cities and towns, as well as the social and economic opportunities available to residents. The functions of housing extend far beyond providing basic shelter, encompassing a wide range of social, economic, and psychological roles crucial to individual and community well-being (Clapham, 2005). At its most fundamental level, housing offers physical protection from environmental elements, fulfilling a basic physiological need as described in Maslow's hierarchy of needs (Maslow, 1943). Adequate housing is essential for maintaining physical health and preventing issues associated with substandard living conditions (Gao and Ho, 2021). Housing plays a vital role in fulfilling social and psychological needs, providing a space where individuals construct their identities and develop a sense of belonging (Easthope, 2004). It offers privacy, a sense of control over one's environment, and serves as a foundation for family life (Clapham, 2005). In the context of community

development, housing patterns and neighbourhood structures play a crucial role in shaping social cohesion and community formation (Forrest and Kearns, 2001).

2.2. Concept of Government Policy

The provision of affordable and adequate housing, recognised as a fundamental human right, remains a significant challenge in numerous developing nations, including Nigeria (UN-Habitat, 2014). Akure North Local Government, like many other regions in the country, has implemented various government policies aimed at enhancing housing provision for its citizens (Akinluyi *et al.,* 2018). However, the efficacy of these policies in addressing the housing needs of the population continues to be a subject of debate among researchers and policymakers (Ibem and Amole, 2010). This section aims to present a theoretical framework examining the relationship between government policies and their impact on housing provision within Akure North Local Government (Olotuah and Bobadoye, 2009). By analysing these policies and their outcomes, we can gain insights into the complexities of housing provision in this region and potentially identify areas for improvement (Makinde, 2014). This theoretical approach will help contextualise the challenges and opportunities in implementing effective housing policies in Akure North Local Government, contributing to the broader discourse on housing provision in developing urban areas (Owoeye and Omole, 2012; Aluko, 2024). Government policies exert a profound influence on housing provision within societies. According to McDermott *et al.* (2008), these policies can be broadly categorised into supportive or restrictive. Supportive policies aim to stimulate both private and public investment in housing, fostering an environment conducive to affordable housing development. Conversely, restrictive policies create obstacles that hinder the availability of affordable housing, particularly impacting low-income individuals.

In Nigeria, numerous government policies have been implemented to enhance housing provision. For instance, the Federal Government introduced the National Housing Policy (FHNHP) in 1991 with the goal of ensuring affordable housing for all Nigerians (Medugu *et al.,* 2008). This policy framework encompasses aspects such as housing finance, construction, and maintenance. In Akure North Local Government, specific policies such as land reforms, infrastructural development, and housing subsidies have been instituted to expand access to affordable housing (Daramola et al., 2008). Government policies aimed at improving housing provision have faced significant challenges in Nigeria, as highlighted by Figueiredo (2008). Despite these efforts, the country continues to grapple with a substantial housing deficit, largely due to policies that have not effectively addressed underlying issues like poverty and inadequate infrastructure. Moreover, the lack of robust implementation and monitoring mechanisms has further hindered the ability of these policies to offer sustainable solutions to housing problems. In Akure North Local Government, the impact of government housing policies remains ambiguous. For instance, critiques levelled by Medugu *et al.* (2008) suggest that subsidised housing initiatives have been insufficient and poorly targeted. Furthermore, the local government area suffers from inadequate infrastructure, including deficient roads, water supply, and electricity, which significantly hampers the construction of affordable housing. These infrastructural challenges have underscored the limitations of existing housing policies in the region.

The Study Area

Akure North LGA is a prominent local government area situated in the heart of Ondo State, Nigeria. It encompasses the bustling city of Akure, which serves as the state capital, and its surrounding environs. This strategic location has positioned Akure North as a significant administrative, commercial, and educational hub within the region. Spanning an area of approximately 331 square kilometres, Akure North LGA is bounded by Akure South LGA to the south, Ifedore LGA to the north, Ose LGA to the east, and Idanre LGA to the west. At the centre of Akure North LGA lies the vibrant city of Akure, which has experienced rapid growth and urbanisation in recent years. This expansion has been fueled by the influx of people seeking opportunities in the state capital, leading to a significant increase in population density (Okosun et al 2024). While official census figures from 2006 estimated the population to be around 360,000, the current figures are believed to be much higher due to the continued migration and natural population growth.

The economy of Akure North LGA is multifaceted, with a blend of commercial activities, public service, and agriculture. The city of Akure serves as a major commercial hub, bustling with markets, banks, and various businesses catering to the needs of the local and surrounding communities. Additionally, the presence of government offices and institutions, such as ministries and agencies, contributes significantly to employment and economic activities within the area. Agriculture remains an important sector, particularly in the rural areas of Akure North LGA. Farmers cultivate a variety of crops, including cocoa, palm produce, maize, yam, and cassava, which not only contribute to the local economy but also serve as a source of food and livelihood for many families. In terms of infrastructure, Akure North LGA has witnessed notable developments in recent years, with improvements in road networks, water supply, and electricity distribution. However, the rapid urbanisation has also brought challenges, with some areas still lacking adequate infrastructure to meet the growing demands of the population.

3. Research Methodology

The study adopted a mixed-methods research design, combining both quantitative and qualitative approaches to examine the effects of government housing policies on housing provision in Akure North Local Government. This methodology, supported by Creswell and Creswell (2018) and Johnson and Onwuegbuzie (2004), enables the integration of numerical data from structured surveys with rich contextual insights from interviews and observations. A sequential explanatory design was used; quantitative data collection and analysis were followed by qualitative inquiry, helping to interpret and deepen the understanding of the statistical findings. Primary and secondary data served as the foundation of the research. Primary data were obtained from residents through structured questionnaires, direct interviews, field observations, and photographs of housing conditions. Secondary data included journals, theses, reports, books, and government documents related to housing and urban development. The study area comprised five major communities: Oke-Ijebu, Igoba, Ita-Ogbolu, Oba-Ile, and Osi, which were mapped using GIS tools to guide sampling and building enumeration. A stratified random sampling technique was applied to select 120 buildings out of 4,468 across the five communities. The sample size represented 2.7% of the total building stock, ensuring proportional representation from each community while minimising bias. The allocation of questionnaires was based on each area's building density, with Ita-Ogbolu receiving the highest (42) and Osi the least (5). Each building was randomly selected using a number generator, providing fair geographic and demographic representation for analysis.

In terms of data collection and analysis, several instruments, including reconnaissance surveys, structured questionnaires, photographs, and field observations, were employed to gather comprehensive information. The quantitative data were coded and analysed using SPSS version 22, where descriptive statistics such as frequencies and percentages were used. Microsoft Excel was used for tabular presentation, and bivariate analysis was employed to test hypotheses, providing insights into the relationships between government housing policies and the housing realities experienced by residents in Akure North, Nigeria.

4. Findings and Discussion

The findings of the effects of government policies on the provision of housing in Akure North Local Government Area, Nigeria are presented below.

4.1. Average Monthly Household Income Level

Table 1 shows the income levels of respondents in Akure North. The largest group, 36.7% (44 respondents), earns between ₦50,000 and ₦100,000 per month. Another 31.7% (38 respondents) earn more than ₦100,000, while 26.7% (32 respondents) earn less than ₦50,000 per month. A small group, 5% (6 respondents), falls into an "others" category, meaning their income is irregular or doesn't fit the main groups. The group earning ₦50,000-₦100,000 is likely made up of skilled workers, small business owners, and professionals who have a stable income but may struggle with housing costs.

4.2. Type of housing

Figure 1 illustrates the types of housing occupied by respondents in Akure North Local Government, which includes areas like Oke-Ijebu, Igoba, Ita-Ogbolu, Oba-Ile, and Osi. Among the 120 respondents surveyed, a significant majority, 81.7% (98 individuals), live in

Table 1: Average Monthly Household Income Level

Income level	Frequency	Percentage %
under 50,000	32	26.7
50,000 - 100,000	44	36.7
Above 100,000	38	31.7
Others	6	5.0
Total	**120**	**100**

Source: Author's Field survey, 2024

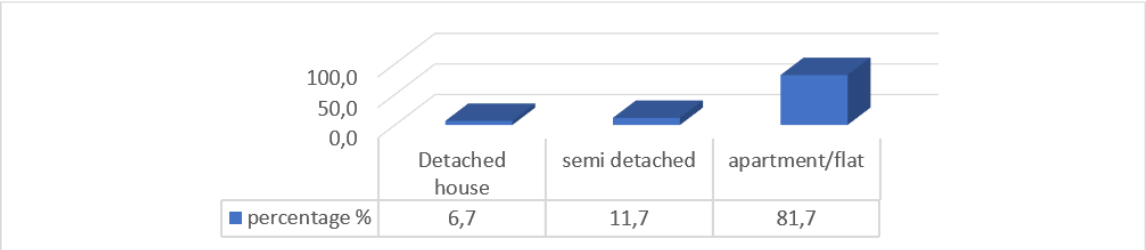

Figure 1: Types of Housing

apartments or flats, indicating that multi-family housing is the most common option. A smaller portion of respondents, 11.7% (14 individuals), live in semi-detached houses, which offer a middle ground between affordability and privacy. This type of housing is popular among families and individuals seeking more space.

4.3. Condition of current housing

Figure 2 illustrates how residents in Akure North Local Government, which includes areas like Oke-Ijebu, Igoba, Ita-Ogbolu, Oba-Ile, and Osi, perceive the overall condition of their housing. Out of 120 respondents surveyed, 41.7% (50 individuals) rated their housing as good, indicating a significant level of satisfaction with their living conditions. This suggests that many residents have access to adequate infrastructure and maintenance. To maintain this positive perception, housing policies should focus on regular maintenance programs, basic service provision, and infrastructure upgrades. 36.7% (44 individuals) rated their housing condition as fair, suggesting that while their homes are liveable, improvements are needed. According to Owolabi(20124), houses can be rated as excellent, good, fair or poor based on the facilities and government policies and other factors responsible for the construction and provision of houses.

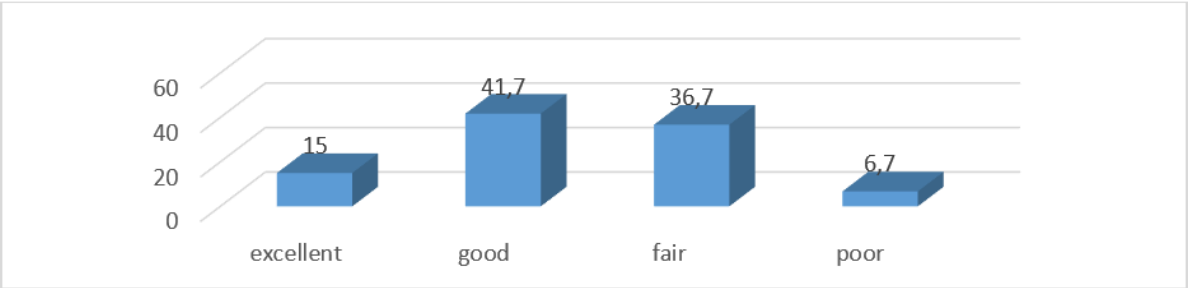

Figure 1: Conditions of current housing
Source: Author's Field survey, 2024

4.4. Adequacy of sanitation facility in homes

In terms of adequacy of sanitation facilities in homes within Akure North Local Government, among the 120 respondents, 56.7% (68 individuals) rated their sanitation as adequate, and 18.3% (22 individuals) said it was very adequate. However, 20.0% (24 individuals) reported inadequate facilities, while 5.0% (6 individuals) had no sanitation facilities at all. Most respondents, 56.7%, feel their sanitation needs are being met, reflecting positively on the local government's efforts to provide functional facilities, which help improve hygiene and reduce disease risk. A smaller group, 18.3%, indicated that their sanitation facilities were very adequate, suggesting they have better-quality systems, likely due to higher income or better housing conditions. On the other hand, 20.0% of respondents reported inadequate facilities, indicating issues like poorly maintained toilets, which can lead to health problems such as cholera and diarrhoea. Targeted government action is needed to improve sanitation in these areas. The 5.0% of respondents without any sanitation facilities is concerning, as it points to a public health risk due to open defecation. Immediate measures are necessary to ensure these households have access to at least basic sanitation services.

4.5. Common housing issues faced by respondents

The main housing problems faced by respondents in Akure North Local Government include areas like Oke-Ijebu, Igoba, Ita-Ogbolu, Oba-Ile, and Osi. The most common issue, reported by 55.0% of respondents, is electricity problems. Other problems include leaking roofs (13.3%), poor ventilation (11.7%), plumbing issues (11.7%), and cracked walls (6.7%). Only 1.7% of respondents reported no housing issues. The electricity problems, affecting over half of the respondents, indicate a major challenge with power supply. This could be due to frequent outages or an unstable power grid, making daily life difficult. Addressing this issue will require improvements to the local power infrastructure and exploring alternative sources like solar energy. Leaking roofs, reported by 13.3%, suggest issues with poor roofing materials or lack of maintenance. This is especially concerning during the rainy season, as it can lead to other problems like dampness or structural damage. Poor ventilation, affecting 11.7% of respondents, can lead to health issues, especially in overcrowded or poorly designed homes. Better housing designs with larger windows and better air circulation are needed to address this. Plumbing issues, also reported by 11.7%, include problems with leaks, poor drainage, or blocked pipes, which can disrupt daily life and cause damage to homes. Cracked walls, affecting 6.7%, point to structural issues, likely due to poor construction or wear over time, which can pose safety risks (Okosun *et al,* 2024). Only a small percentage (1.7%) reported no housing problems, suggesting these respondents live in newer or better-maintained homes.

4.6. Availability of land for housing in Akure North, Nigeria

Table 2 presents data on how respondents view the availability of land for housing in Akure North Local Government, including areas like Oke-Ijebu, Igoba, Ita-Ogbolu, Oba-Ile, and Osi. Out of 120 respondents, 55.0% (66 people) believe that land availability for housing is adequate. Meanwhile, 28.3% (34 people) feel that it is inadequate. A smaller group, 15.0% (18 people), consider land availability to be very adequate, and only 1.7% (2 people) reported that there is no land available at all. The majority of respondents (55.0%) say that land for housing is generally accessible in Akure North. This suggests that while land is available, there may be limitations in terms of its desirability or proximity to infrastructure. Urban planning and zoning regulations, as well as population growth, likely affect land availability for housing development in the area. However, 28.3% of respondents find land availability inadequate, pointing to barriers like high land prices, limited infrastructure, or challenges with land acquisition, especially for lower-income groups. These factors might make it difficult for many residents to secure land for housing, especially in desirable locations. A smaller percentage (15.0%) believe that land availability is very adequate, possibly in less populated areas or areas farther from urban centres where competition for land is lower.

Table 2: Influence of government policies on housing provision

What is the influence of government policies on housing provision	Frequency	Percentage%
very positive	12	10
positive	34	28.3
negative	36	30
very negative	16	13.3
no influence	22	18.3
Total	**120**	**100**

Source: Author's Field survey, 2024

In response to respondents' views on land costs in Akure North, most respondents (51.7%) said land is moderately expensive, meaning it's accessible but still a financial burden for some, especially those with lower incomes. This is likely due to factors like location and development in the area. About 23.3% of respondents said land is expensive, likely due to rising urbanisation and speculation, making it harder for many to afford. However, 20% found the cost affordable, likely those with higher income.

4.7. Influence of government policies on housing provision

Table 2 shows how respondents in Akure North view the impact of government policies on housing. The responses are mixed. 30% believe government policies have hurt housing. This likely reflects frustration with issues like slow processes, high taxes, or ineffective housing programs. Many may feel policies favour the wealthy, leaving lower-income residents behind. 28.3% say government policies have had a positive impact. They may appreciate efforts like affordable housing projects or infrastructure improvements, which have helped them access housing more easily. 18.3% feel policies have had no impact.

5. Conclusion and Further Research

The study revealed that housing conditions in Akure North Local Government are varied, with a majority of residents living in moderately adequate housing supported by basic sanitation, but still facing major challenges such as poor electricity supply, leaking roofs, and plumbing issues. Land availability for housing is generally rated as adequate, though the cost remains a barrier for many. Importantly, the impact of government policies on housing provision is perceived by many as either negative or negligible, suggesting a gap between policy intent and implementation. The findings highlight the need for more inclusive, accessible, and efficient housing strategies that directly address the real needs of residents while removing systemic barriers such as affordability, infrastructure deficits, and poor enforcement of planning standards.

Addressing these challenges requires a coordinated effort among government agencies, industry professionals, and other stakeholders to create a sustainable housing provision framework that is both practical and enforceable. Without decisive action, the Nigerian housing sector/industry risks lagging in global sustainability efforts, impacting environmental and economic progress.

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Comparative Performance of Alternative building technologies vs convential in Reconstruction and Development Programme RDP Housing Construction

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Abstract

This study evaluates the suitability of alternative building technologies (ABTs) for the delivery of Reconstruction and Development Programme (RDP) housing in South Africa. The research responds to the persistent housing backlog, poor workmanship, recurring defects, and the labour-intensive nature of conventional brick-and-mortar construction. The aim was to determine which alternative construction method meets or exceeds conventional methods in terms of time, cost, and quality. A mixed-methods design was adopted, supported by literature review, questionnaires, interviews with contractors, regulators, end-user input, and observation through a site visit. The study examined three ABTs: Moladi Construction Technology, Hydraform Interlocking Brick Technology, and Sandbag Construction Technology. Findings show that all three alternatives offer relevant options to conventional methods, particularly through faster delivery, reduced dependence on highly skilled artisans, and potential improvements in sustainability and community participation. Among 23 contractor respondents, Sandbag Construction Technology was the most selected preferred ABT at 30%, while 17% selected Moladi and 17% selected Hydraform; however, the broader comparative assessment identified Moladi as the leading option overall in terms of time, cost, and quality. In addition, 39% of contractors indicated that end-user opinion is an important factor in deciding whether ABTs should be adopted. Responses from 8 end-users also suggest a generally positive attitude toward alternative methods when safety, performance, and access to housing are assured. The study concludes that ABTs, especially Moladi, can support faster, more cost-effective, and more sustainable RDP housing delivery in South Africa.

Keywords: Alternative building technologies, Moladi Construction Technology, Hydraform Interlocking Brick Technology, Sandbag, Affordable housing.

1. Introduction

Since the end of apartheid and the transition to democracy in 1994, the South African government has pursued the Reconstruction and Development Programme (RDP) as a key intervention for addressing the housing needs of previously disadvantaged communities. The programme was introduced to provide low-cost housing to families living in informal settlements and to improve their socio-economic conditions through access to basic services such as water and electricity, while also contributing to broader community upliftment (Greyling, 2010; Gabula, 2012; Amoah, 2019).

Despite the positive impact of the RDP housing programme over the past decades, its objectives have not been fully achieved. One of the major challenges has been the persistent housing backlog, which continues to affect a significant number of South Africans (Amoah, 2019). The backlog has been linked to several chronic impediments, including fraud, corruption, delays, absentee contractors, ghost houses, and poor workmanship, all of which undermine the effective delivery of housing (Manomano, 2018).

A central concern within the RDP housing programme is the poor quality of many completed houses. Defects in low-cost housing have resulted in substantial additional expenditure by government on rectification works (Buys and le Roux, 2013). More broadly, in the first 15 years of the programme, government spent R836.9 million to rectify 131,000 defective homes, while more than 5,000 defective houses were repaired during the 2010/2011 infrastructure boom at a cost of R971.1 million (Amoah, 2020). These defects are often associated with poor-quality workmanship, inadequate contractor selection, and weak quality inspection processes.

The current construction method used for RDP housing relies on conventional materials such as concrete, brick, mortar, and wood (Windapo, 2021). While widely used, this method is labour intensive and depends heavily on skilled artisans, who are in limited supply in South Africa (Windapo, 2021). As a result, conventional construction has contributed to inefficiencies in delivery and has not sufficiently incorporated sustainable building technologies. For an RDP house to be fit for habitation, it must satisfy criteria such as structural stability, effective drainage, lack of

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dampness, adequate piped water supply, and sufficient heating, lighting, and ventilation; failure to meet these standards renders the house defective (Buys and le Roux, 2013).

Given these challenges, there is a strong case for considering alternative building technologies in the delivery of RDP housing. To improve sustainability and cost effectiveness, alternative methods should be assessed against the conventional approach using time, cost, and quality as key performance criteria. Among the alternatives identified are Moladi housing technology, Hydraform interlocking bricks, and sandbag building technology. These methods present possible solutions to the ongoing challenges of backlog, cost, and quality in South Africa's low-cost housing sector.

2. Literature Review

The conventional brick/block-and-mortar method is identified as the dominant form of RDP house construction in South Africa. This system relies on strip footings, brick or block masonry, mortar joints, timber roof trusses and conventional plastered finishes, and is widely used because it is familiar within the industry (Mabuya and Scholes 2000; Janek 2013; Ryan 2022). Yet this method is labour intensive, highly dependent on skilled artisans and not well aligned with the realities of many RDP projects, where contractors are often required to draw labour from local communities with limited prior training (Windapo, 2021; Manomano and Tanga 2018). Typical RDP houses range from 36 m² to 45 m², and province-level cost figures indicate a rough construction cost of about R4 000–R5 000 per square metre, excluding land and some services (Tshangana 2018).

The weaknesses of the conventional method are a central concern. Five broad defect categories are identified: design of the houses, materials used, construction of the houses, maintenance of the houses, and limited beneficiary involvement (Buys and Le Roux, 2013). These problems do not operate independently; rather, they overlap and compound one another. The scale of the problem is demonstrated by expenditure on rectifying badly built houses between 2011/2012 and 2013/2014, with a total of R2.129 billion spent on fixing 341 625 units (Bailey 2017). In design terms, many RDP houses are criticised for poor orientation, insufficient weather protection, a lack of gutters, and in some cases the absence of ceilings, all of which undermine thermal comfort and increase exposure to environmental damage (Manomano, 2013; Ratshitanga 2017; van der Watt 2022). Material choices also contribute to poor performance. Hollow blocks are associated with damp penetration and mould in wet climates, while light metal door and window frames are prone to distortion and poor sealing. Construction problems extend beyond physical defects to management issues, contractor selection and weak training of local labour, which together reduce workmanship quality and shorten the effective life of houses that should otherwise last much longer (Buys and Le Roux 2013; Manomano and Tanga 2018; van der Watt 2022). The literature further notes that limited maintenance support and low beneficiary participation weaken both long-term performance and community satisfaction (Gabula 2012; Windapo and Goulding 2013; Amoah, Kajimo-Shakantu et al. 2022).

Against this background, the literature turns to alternative building technologies (ABTs) as potential means of improving RDP housing delivery. Three technologies are prioritised including Moladi Construction Technology, Sandbag Construction Technology and Hydraform Interlocking Building Technology. These are selected because the literature suggests that they offer advantages in time, cost, quality, sustainability and opportunities for community engagement. Moladi is described as a South African technology based on reusable lightweight plastic formwork that is assembled on a raft foundation and filled with a specially modified mortar to cast the wall structure in situ (moladi 2022). The system is notable for repeat use of formwork, limited waste and the possibility of constructing the superstructure within a single day once the mould is assembled and filled. Sandbag technology uses eco-beams and stacked geo-fabric sandbags filled with sand, including excavated material from site where suitable, then finished with mesh and plaster or similar cladding. its simplicity, thermal and acoustic properties, low waste and reduced need for highly skilled labour make it ideal (Kracht 2009; EcoSteps 2022; Windapo, Jarratt et al. 2022). Hydraform technology, by contrast, uses interlocking soil-cement blocks that are dry stacked and self-aligning, which reduces mortar use and simplifies wall construction (Uzoegbo and Ngowi 2003; Deepak 2011).

The important performance advantages to these ABTs. In relation to time, Moladi is presented as the fastest system because the walling structure can be completed through a fit-fill-strip process that takes roughly 12 hours in total for a 45 m² unit, excluding foundation curing time (Moladi 2022). Sandbag construction is also considered faster than conventional masonry because it avoids mortar-setting constraints and can proceed by stacking and plastering once bags are prepared (Strydom 2022). Hydraform blocks similarly reduce construction time because they are dry stacked and not limited by mortar drying; reported labour output is 7.05 m² per hour compared with 3.30 m² per hour for conventional concrete block construction, suggesting a 54% higher output (Aligamhe, Kaseem et al. 2020). Cost comparisons are more uneven, but sandbag construction is reported at approximately R3 500/m², below the conventional R4 000–R5 000/m² range (Strydom 2022; Tshangana 2018). For Moladi

and Hydraform, yet both systems are described as offering savings through lower skilled-labour requirements, reduced waste, reusable or locally sourced materials, and lower transport needs (Deepak 2011; moladi 2022).

In terms of quality and standards, it was acknowledged that the conventional construction benefits from established SANS guidance, notably SANS 10400 and SANS 10500 (Janek 2013), whereas the ABTs do not always have equivalent compliance standards framed in the same way. Even so, important approval pathways and quality assurances are already underway. Moladi's modified mortar and reusable formwork are presented as compliant through SABS-related approval and NHBRC acceptance, while sandbag and Hydraform technologies are associated with NHBRC and Agrément South Africa approval for use in housing contexts. Regarding sustainability advantage, Moladi reduces waste through reusable formwork; sandbag and Hydraform reuse site-derived materials and reduce reliance on conventional high-input materials; and all three systems potentially reduce long-term maintenance burdens compared with poorly executed conventional houses. Finally, community engagement is presented as a significant comparative advantage of ABTs. Because they are simpler to teach and less dependent on highly skilled artisans, Moladi, sandbag and Hydraform systems create greater scope for the involvement of local labour and skills development than conventional construction, which tends to concentrate power and technical knowledge in contractors and officials (Adedeji and Fa 2012; Sekoboto and Landman 2019).

The comparative synthesis presented in Table 1 draws these findings together by evaluating ABTs against conventional construction across six indicators: construction process, time, cost, quality/applicable standards, sustainability and community engagement. Overall, the literature review establishes a strong basis for investigating whether ABTs can meet or exceed conventional performance requirements in RDP housing delivery, particularly where backlog reduction, quality improvement and broader developmental value are central concerns.

3. Methodology

This study adopted a mixed-methods design within a positivist research paradigm to evaluate whether selected alternative building technologies could meet or exceed the performance of conventional construction methods used in Reconstruction and Development Programme (RDP) housing in South Africa.

The study population comprised three stakeholder groups directly linked to RDP housing delivery and use, including contractors, regulators, and end-users. Contractors were purposevely selected because of their industry experience and practical knowledge of working with the South African government in RDP housing delivery. Regulators were included to explore possible resistance to the implementation of alternative building technologies within the RDP housing sector. Finally, End-users captured the social acceptance of alternative methods without shifting attention away from the central focus on time, cost, and quality. The final sample consisted of 23 contractors, 11 government respondents, and 8 end-users.

Data were collected using instruments including questionnaires, interviews, and a site visit observation. questionnaires were developed on Google Forms, each tailored to a specific respondent group. The online format allowed the questionnaires to be emailed and forwarded, thereby increasing circulation and the potential number of responses. Contractors and regulators received the questionnaire links by email, while end-users in Khayelitsha were engaged in person because email access was not considered a viable means of obtaining sufficient responses. Their answers were recorded directly on the Google Form, and assistance with translation was provided where language barriers existed. The end-user questionnaire focused on acceptance of alternative construction methods.

Data analysis was descriptive and comparative(Bhatia 2018). Responses from the three respondent groups formed the data pool for analysis. Qualitative data were analysed using content analysis to identify recurring themes and patterns (Williams 2007). Results were

Table 1: Comparison between the performance of ABTs with conventional construction

Performance Indicators	Moladi	Sandbag	Hydraform	Conventional Technology
Construction Process	Insitu-based	Insitu-based	Insitu-based	Insitu-based
Time	2 m³ of concrete/hr	8 m²/hr	7.05 m²/hr	3.30 m²/hr
Cost	-	R3500/m²	-	R4000–5000
Quality – Applicable Standards	No compliance standard; Agrément South Africa approved; Approved by NHBRC; Styrofoam formwork SABS approved	No compliance standard; Approved by NHBRC	No compliance standard; Approved by NHBRC; Machinery SABS approved	SANS 10500; SANS 10400
Sustainability	Formwork reusable (50 times); low maintenance	Reuse of site soil; sandbags made from recycled material	Reuse of site soil; limited use of cement; low maintenance	High maintenance
Community Engagement	High (unskilled workforce)	High (unskilled workforce)	High (unskilled workforce)	Low (skilled workforce)

presented in both textual and diagrammatic form, including pie charts, bar graphs, and frequency diagrams. This analytical approach supported the comparison of the three alternative technologies with conventional RDP housing construction.

The study's reliability and validity was achieved through the use content and face validity (Mohajan, 2017). Ethical considerations included informed consent, privacy and confidentiality, and ethical clearance obtained from the University of Cape Town's Research Ethics Committee.

4. Results

4.1. Current construction methods

The results show that conventional methods dominate RDP housing construction, with 15 contractors using the standard block-and-mortar method and 3 contractors using the standard brick-and-mortar method. In contrast, alternative methods remain limited, with only 1 contractor reporting the use of Moladi and 1 contractor each reporting sandbags and Ecobeams, Sandbag, and Sandbag Construction. The detailed breakdown is presented in Table 2.

4.2. Drawbacks of current methods

The results show that the main drawbacks of current RDP construction methods relate to time and long-term quality. As shown in Table 3, 8 contractors identified time constraints as the main disadvantage, while 5 reported long-term quality deficiencies. Other concerns included under-allocation of resources, identified by 3 contractors, as well as unskilled labour, worker training requirements, and corner cutting, each identified by 1 contractor.

4.3. Willingness to adopt alternative building technologies

Contractor willingness to adopt alternative technologies was mixed but not strongly negative. Of the 23 contractors, 9 respondents (39.1%) indicated that they would still participate in RDP projects if ABTs were required, 8 respondents (34.8%) selected "maybe," and 6 respondents (26.1%) selected "no." These results suggest that most contractors were either willing or potentially willing to participate, although a sizeable minority remained resistant.

4.4. Familiarity with alternative building technologies

Figure 1 shows that contractors had some awareness of alternative building technologies, although familiarity varied by method. Sandbag technology was the most recognised option, with 5 respondents familiar with sandbag only, while 3 respondents were familiar with Moladi only and 2 respondents with Hydraform only.

Table 2: Construction methods used in RDP housing projects

Construction method used in RDP housing projects	No. of responses
Standard block and mortar method	15
Standard brick and mortar method	3
Sandbags and Ecobeams	1
Sandbag	1
Sandbag Construction	1
Moladi	1
Not involved in the construction of RDP housing	1
Total	23

Table 3: Drawbacks/downfalls experienced by contractors using current methods in RDP projects

Disadvantages of the building technology	No. of responses
Time constraints	8
Quality deficiency in the long term	5
Under-allocation of resources	3
No drawbacks/downfalls	2
Other: Unskilled labour force	1
Other: Training of workers	1
Other: Corner cutting	1
Other: Planning of fill and quantities	1
Quality deficiency in the short term	0

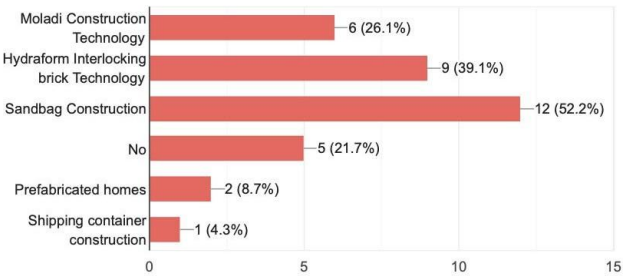

Figure 1: Bar Chart Showing the ABT's with which contractors have experience

However, 5 respondents had no prior familiarity with any of the technologies, suggesting that awareness of ABTs exists but remains uneven among contractors.

4.4.1. Comparative performance of alternative building technologies

Table 4 shows that all three ABTs were perceived positively when compared with standard technologies. Moladi recorded the highest total score (18), followed closely by sandbag and Hydraform, each with a score of 17. Moladi was rated better in terms of time by 7 respondents, cost by 5 respondents, and quality by 6 respondents, with no negative ratings for time or cost. This suggests that Moladi emerged as the strongest overall alternative when time, cost, and quality were considered together.

4.5. Implementation concerns, standards, and economic implications

Contractor concerns about ABT implementation

Contractors' main concerns were practical rather than cost related. As shown in Table 5, quality assurance was the most frequently reported concern, identified by 12 respondents. This was followed by possible initial delays in project completion, identified by 10 respondents, the effort required to train workers, identified by 9 respondents, and the unavailability of resources, identified by 8 respondents. Only 3 respondents considered ABTs too expensive. Regarding compliance with National Building Regulations, 11 respondents (47.8%) believed that ABTs could meet the requirements, 10 respondents (43.5%) were uncertain, and 2 respondents (8.7%) did not believe that they would. Overall, contractor hesitation was mainly associated with quality control, transition challenges, training and resource availability rather than outright rejection of ABTs.

The responses concerning National Building Regulations indicate that contractors were not strongly opposed to the possibility that ABTs could satisfy requirements for strength, stability, serviceability and durability. Nearly half of the respondents believed that ABTs could meet the requirements, while a similar proportion remained uncertain. Only a small minority expressed a negative view. This pattern suggests conditional acceptance, with confidence likely depending on clearer evidence of testing, approval and quality assurance.

Economic benefits of ABTs

The perceived economic benefits of ABTs were mixed. 11 respondents indicated that ABTs offered no benefits, while another 11 respondents identified shortened project completion time as a benefit. In addition, 7 respondents believed that ABTs could improve structural quality, while 4 respondents identified lower cost implications. These results show that although some contractors were unconvinced, others recognised potential benefits, especially in relation to time savings and quality improvement.

4.6. End-user influence and contractor preference

Contractors were divided on whether end-user opinion should influence the choice between traditional and alternative methods. Nine respondents (39.1%) answered "yes," 8 respondents (34.8%) answered "no," and 6 respondents (26.1%) selected "maybe." The written responses in Table 6 show a similar division: 10

Table 4: Comparative assessment of ABTs in terms of time, cost and quality

Alternative Building Technology	Better in terms of time	Better in terms of cost	Better in terms of quality	Worse in terms of cost	Worse in terms of time	Worse in terms of quality	Total score
Moladi	7	5	6	0	0	N/A	18
Sandbag	9	5	6	-2	-1	N/A	17
Hydraform	8	4	6	-1	0	N/A	17

Table 5: Contractor concerns with the implementation of ABTs

Concerns with implementation	No. of responses	%
Inability of quality assurance	12	52%
New methods would have a negative effect on project completion time initially	10	44%
Too much effort to train workforce	9	39%
Unavailability of resources	8	35%
Other	7	30%
Too expensive	3	13%

Table 6: Table showing whether end-users opinion on the finished produce would be a large contributing factor

Contractor view on end-user opinion	No. of responses
End-user opinion should be considered	10
End-user opinion should not be considered	7

of the 17 respondents who provided qualitative answers believed that end-user opinion should be considered, while 7 believed that it should not. This suggests that ABT adoption is not only a technical issue but also depends on how contractors view beneficiary involvement.

Figure 2 shows that contractors' preferences were divided across the three ABTs. Sandbag was the most selected option, with 7 respondents, followed by Moladi and Hydraform with 4 respondents each. However, 8 respondents selected none of the listed alternatives. This suggests that although sandbag was the most preferred ABT, contractor preference did not fully match the performance comparison, where Moladi scored highest overall.

4.7. End-user Results

Figure 3 shows that end-users were generally open to alternative construction methods. The eight end-users surveyed in Khayelitsha expressed acceptance of ABTs, especially where the house would be safe, available, and better performing than existing RDP houses. Some responses linked ABTs to improved safety, reduced moisture and cracking problems, and shorter waiting times for housing. This suggests that end-users were not resistant to ABTs and, in some cases, viewed them as potentially better than conventional RDP housing.

4.8. Regualtors Results

Regulator respondents viewed SABS approval as a possible barrier to ABT implementation. Of the 11 respondents, 5 (45.5%) answered "yes," 5 (45.5%) answered "maybe," and only 1 (9.1%) answered "no." This suggests that most regulators either recognised or suspected that certification requirements could affect the adoption of ABTs. Content analysis further showed that 6 of the 8 respondents who explained their views linked SABS approval to testing, while 2 were uncertain about the process. Testing was therefore seen as the main route to approval, although uncertainty remained about the exact procedure. Figure 4 shows that regularors hesitation toward ABTs was linked to several factors, including resource availability, possible end-user resistance, initial delays, cost, and concerns

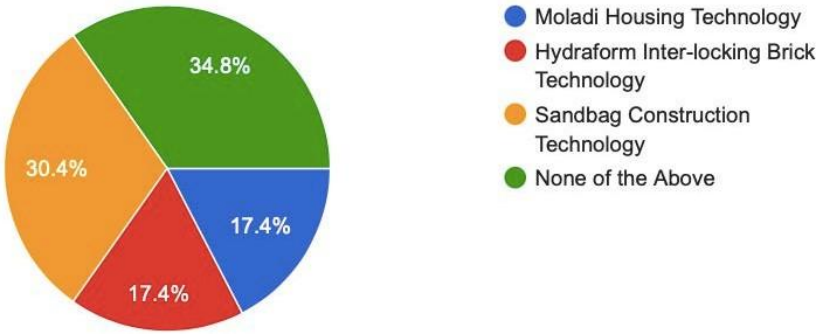

Figure 2: Pie chart showing the preference of contractors between ABT's

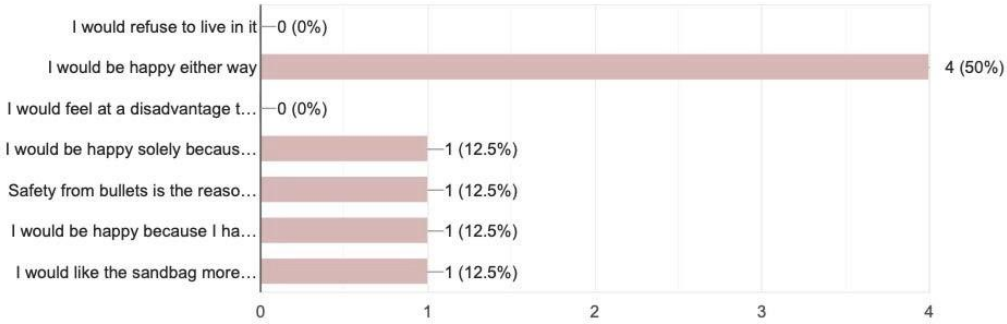

Figure 3: Bar chart showing whether end-users are concerned with the method of construction of their RDP home

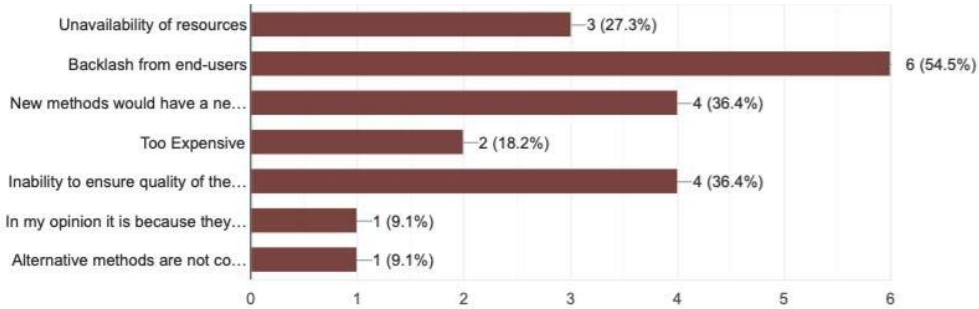

Figure 4: Bar chart showing why the SA government has been avoiding the use of ABT's in RDP projects

about structural quality. The written comments also suggest that ABTs are not yet well known or commonly used in South Africa. Overall, the results indicate that regulators reluctance is mainly shaped by limited familiarity, institutional caution, and quality assurance concerns rather than complete rejection of alternative methods. The Khayelitsha site visit further supported this finding. Although the sandbag dwelling was reported to be more expensive per square metre than a comparable double-storey traditional RDP house, it showed advantages in community involvement, sustainability, and perceived wall strength. Overall, the results suggest that all three ABTs have potential, with Moladi performing strongest on time, cost, and quality, while sandbag remained attractive because of its social and practical benefits.

5. Discussion

The findings show that ABT performance in RDP housing depends on more than technical efficiency alone. It is shaped by the interaction between construction performance, contractor confidence, regulatory approval, and end-user acceptance. This supports the literature, which shows that RDP housing problems are linked to workmanship, materials, maintenance, beneficiary involvement, and delivery management (Buys and Le Roux, 2013; Manomano, 2013; Ratshitanga, 2017). Within the study's time-cost-quality framework, Moladi emerged as the strongest overall alternative. recent studies described Moladi as a system that uses reusable plastic formwork, simplified wall construction, and rapid production, thereby reducing labour intensity and potential workmanship errors (moladi, 2022; Manomano and Tanga, 2018; van der Watt, 2022). It is certainly based on these characterists that respondents found it to be more beneficial than other alternative.

However, the findings also show that the highest-performing technology is not always the most preferred by contractors. Although Moladi ranked highest in the comparative assessment, Sandbag construction was the most preferred named ABT. This suggests that contractor preference may also be influenced by familiarity, perceived simplicity, sustainability, and community participation. Literature supports this interpretation by presenting Sandbag construction as a relatively simple method using eco-beams, geo-fabric bags, and locally available sand, while also offering benefits such as material reuse, sound insulation, fire resistance, and weather resistance (Strydom, 2022; EcoSteps, 2022; Kracht, 2009).

conventional brick/block-and-mortar construction is labour intensive and dependent on skilled artisans, while poor workmanship contributes to defects and costly rectification works (Windapo, 2021; Buys and Le Roux, 2013; Amoah, 2020). The mentioned facts corroborate with the fundings of this investigstion, showing that conventional RDP delivery remains constrained by slow construction, scarce skilled labour, resource limitations, and long-term quality problems. Observed contractor concerns about ABTs were therefore not mainly based on rejection of innovation, but on uncertainty about quality assurance, training, certification, and implementation risk. Regulators concerns about SABS approval reinforce this point, suggesting that regulatory clarity remains central to ABT adoption.

Finally, the end-user and site-visit findings show that ABTs must also be assessed through social acceptance and community value. Although contractors were divided on whether end-user opinion should influence construction-method selection, end-users were generally receptive to alternative methods when linked to safety, strength, reduced cracking, and shorter waiting times. Beneficiary involvement and satisfaction are important in RDP housing performance, especially because end-users value physical, functional, maintenance, and sustainability outcomes (Windapo and Goulding, 2013; Juta, Moeti et al., 2014; Kakaza, 2009). Overall, Moladi offers the strongest option under the time-cost-quality criteria, while Sandbag and Hydraform remain important because they address sustainability, community participation, and practical implementation concerns.

6. Conclusion

This paper examined the potential of alternative building technologies to improve South African RDP housing delivery by comparing Moladi Construction Technology, Sandbag Construction Technology, and Hydraform Interlocking Brick Technology with conventional brick/block-and-mortar construction. The comparison was based on time, cost, quality, standards, sustainability, and community engagement. The findings show that conventional RDP delivery continues to face challenges related to slow production, dependence on scarce skilled labour, and quality defects. They also show that contractors are not entirely resistant to alternative methods, although concerns remain regarding quality assurance, training, and implementation risk.

The paper concludes that Moladi offers the strongest overall alternative when assessed against time, cost, and quality. Its value lies in simplifying wall construction, reducing workmanship-related errors, accelerating delivery, and supporting repeatable production for mass housing. However, Sandbag and Hydraform also remain relevant, particularly in relation to sustainability, material reuse, and community participation. Overall, the study concludes that ABTs should be assessed through an integrated time-cost-quality and implementation lens, with Moladi offering the clearest pathway for more efficient low-cost housing delivery.

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Evaluating Compliance Levels of Informal Housing Construction Practices with Building and Environmental Regulations in South Africa

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Abstract

South Africa's rapid urbanization and economic struggles have led to informal settlement growth. While informal housing provides shelter, construction practices often do not comply with building and environmental regulations, causing safety, health, and sustainability concerns. This study aims to determine compliance levels of informal settlement construction practices with these regulations. The research uses a qualitative approach, collecting data on construction practices, materials, builders' skills, and regulatory awareness through observations, interviewsin Khayelitsha, Gugulethu, Langa, and Ocean View, while the focus group included informal builders from various locations. Data is analyzed using thematic analysis to identify compliance-related patterns, challenges, and opportunities. Key findings show that residents and informal builders have limited understanding of and adherence to regulations due to socioeconomic constraints, lack of formal training, and the informal nature of settlements. Non-compliant practices create environmental, health, and safety risks. The study highlights the need for context-sensitive policies addressing non-compliance causes such as poverty, lack of affordable housing, and low institutional capacity. Recommendations include improving builders' access to quality materials and training, supporting community-driven initiatives, and implementing flexible approaches to informal settlement upgrading. The findings contribute to knowledge on enhancing living conditions and promoting sustainable urban development in South Africa's informal settlements.

Keywords: informal settlements, construction practices, building regulations, environmental regulations, alternative building technologies

1. Introduction

Building and environmental regulations are important because they establish minimum standards for safe, healthy, and sustainable construction. In South Africa, building regulations include the National Building Regulations and Building Standards Act 103 of 1977, which sets requirements related to structural integrity, fire safety, sanitation, ventilation, energy efficiency, and accessibility (Gazette, 1985; Cecilia, 2020). Environmental regulations, including the National Environmental Management Act 107 of 1998 and the National Environmental Management: Waste Act 59 of 2008, are intended to ensure that construction activities align with environmental protection and sustainability goals (Gazette, 1999; Gazette, 2009; Zhang et al., 2021). Compliance with these regulations is therefore central to protecting occupants, builders, surrounding communities, and the environment.

However, informal housing construction often takes place outside formal systems of approval and inspection. The shortage of affordable formal housing forces many low-income households to build dwellings in informal settlements (Hasgül, 2016). These structures are commonly built using salvaged materials such as corrugated metal, wood, and plastic, while builders often rely on rudimentary techniques and trial-and-error methods rather than formal construction standards (Frediani, Cociña & Roche, 2023; Hasgül, 2016). Consequently, there is limited understanding of the quality of materials used, the construction practices followed, the specifications applied, and the extent to which these practices comply with building and environmental regulations.

This lack of knowledge creates an important research gap. Without clear information on informal housing construction practices, it is difficult to assess whether these dwellings are safe for occupants, builders, and surrounding communities. It is also difficult to determine whether the construction process creates wider health and environmental risks. Therefore, this study investigates the compliance levels of informal housing construction practices with building and environmental regulations in South Africa. By examining the construction methods, materials, builder skills, and working and living conditions in informal settlements, the study seeks to provide insights that can support safer, healthier, and more sustainable informal housing interventions.

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2. Literature Review

Informal construction practices reflect these socio-economic and spatial conditions. Informal dwellings are commonly built using salvaged or low-cost materials such as corrugated metal sheets, wood, plastic, and scrap materials (Frediani et al., 2023; Milford et al., 2019). These materials are accessible and affordable for urban poor communities, but they contribute to substandard and hazardous living conditions (Milford et al., 2019). Builders often rely on rudimentary methods and trial-and-error approaches rather than recognised construction standards (Hasgül, 2016; Milford et al., 2019). The construction process is often incremental, with rooms or portions added as needs arise and as resources become available (Milford et al., 2019). Common challenges include the absence of proper foundations, inadequate roof support, poor ventilation, and limited professional design input, all of which affect safety and habitability (Milford et al., 2019).

Builder skills and training are central to compliance. Most informal settlement builders acquire skills through observation, imitation, and hands-on learning within communities (Hasgül, 2016). Although such knowledge may respond to immediate shelter needs, it does not necessarily align with formal regulations or best practices. The absence of formal training and certification raises concerns about quality, safety, and sustainability because builders often depend on personal judgement, estimation, and available materials rather than standard plans and regulations (Kovacic et al., 2019). Limited awareness of safety protocols, including personal protective equipment and the handling of hazardous materials, also creates risks for builders and occupants (Kovacic et al., 2019). Efforts such as the People's Housing Process have provided construction skills training, project management training, and social support to low-income households, but their reach has been constrained by inadequate resources, weak coordination, and the scale of the informal housing challenge (Department of Human Settlements, 2009;Chege et al., 2021).

2.1. Comparison to formal housing practices

Informal construction differs sharply from formal housing construction. Formal housing projects are subject to building standards and regulations covering structural integrity, fire safety, sanitation, and environmental impacts (Kovacic et al., 2019). They also involve architects, engineers, building inspectors, quality materials, specialised equipment, and skilled labour, which support durability and safety (Kovacic et al., 2019). Informal housing, by contrast, is usually produced outside the formal regulatory framework with limited professional input or oversight (Kovacic et al., 2019). This can result in structurally unsafe dwellings, poor ventilation, fire and flood vulnerability, inadequate foundations, weak roof support, and poor drainage (Hasgül, 2016; Milford et al., 2019; Kovacic et al., 2019). The layout of informal settlements can also be dense and unplanned, with irregular access routes and limited open spaces, which may restrict emergency access and increase public health risks (Kovacic et al., 2019).

2.2. Overview of key standards and regulations

Building regulations provide the formal benchmark against which informal construction practices can be assessed. South Africa has a system of building regulations and standards intended to protect the safety, health, and well-being of occupants and builders while supporting sustainable development and environmental preservation. The primary legislation is the National Building Regulations and Building Standards Act 103 of 1977, which sets minimum requirements for the design, construction, and maintenance of structures in South Africa. The National Building Regulations cover structural stability, fire safety, sanitation, ventilation, lighting, and energy efficiency, and are supported by South African National Standards that provide technical specifications for construction components such as concrete, steel, masonry, and timber. Other relevant instruments include the Occupational Health and Safety Act 85 of 1993, which addresses worker safety, personal protective equipment, safe work practices, and hazardous material management, and the National Environmental Management Act 107 of 1998, which addresses environmental sustainability in construction.

The implementation of building regulations is generally the responsibility of local authorities such as municipalities and city councils (Khumalo and Choga, 2019). The process includes submission of building plans, assessment by building control officers, regular inspections during construction, final inspection, and the issuing of an occupancy certificate where compliance is achieved (Windapo and Rotimi, 2012; Watermeyer and Milford, 2003). However, implementation is constrained by limited resources, lack of technical capacity, corruption, and political interference (Windapo, 2016). These challenges are especially serious in informal settlements because illegality, insecure land tenure, lack of formal planning, and inadequate infrastructure make it difficult to monitor construction and enforce compliance.

2.3. Challenges and barriers to compliance

Barriers to building regulation compliance include socio-economic constraints, institutional capacity, technical knowledge, and cultural norms. Poverty, unemployment, high housing costs, insecure tenure, and the threat of eviction limit residents' ability and willingness to invest in compliant materials and construction practices (Marutlulle, 2021; Lemanski,

2009; Durand-Lasserve and Royston, 2002). Local authorities may lack the staff, resources, and technical expertise needed to supervise construction activity in informal settlements (Windapo, 2016; Khumalo and Choga, 2019). Builders often lack formal construction training and professional support, which contributes to substandard materials, poor workmanship, and weak awareness of structural stability, fire safety, and ventilation requirements (Hasgül, 2016; Milford et al., 2019; World Bank, 2020). Cultural norms and traditional construction methods may also conflict with formal regulatory requirements (Maluleke et al., 2021; Massey, 2013). Table 1 shows Environmental regulation that adds a further compliance dimension. Also, Table 2 presents factors influencing compliance.

absent, low-quality materials are used, settlements expand into natural areas, and waste accumulates in open spaces and waterways (Mararakanye and Le Roux, 2012; Sibanda, 2022).

Environmental compliance is constrained by limited awareness of environmental regulations, weak institutional capacity, socio-economic pressures, and settlement location. Residents and builders may not understand technical regulations related to waste, water, and air quality (Zhang et al., 2021; Sibanda, 2022). Environmental authorities may also have limited presence in informal settlements and may struggle to respond to rapid settlement growth (Kovacic et al., 2019). Poverty and lack of basic services push residents to prioritise immediate survival needs such as shelter,

Table 1: Different Environmental Regulations to be considered in a construction project

Environmental Regulation	Description	Purpose	References
The National Water Act (Act No. 36 of 1998)	Governs water resource use and management on a project, including pollution control and aquatic environment protection if the project is going to affect the oceans	To ensure sustainable and equitable use of water resources while protecting the aquatic environment	(Department of Water and Sanitation, 2021)
The National Environmental Management: Waste Act (Act No. 59 of 2008)	Establishes regulations for waste minimization, reuse, recycling, and safe disposal of waste materials on and off-site, including waste from construction and demolition on a project	To promote sustainable waste management practices and minimize the environmental impact of waste generated by construction activities	(Department of Environment, Forestry, and Fisheries, 2021)
The National Environmental Management: Air Quality Act (Act No. 39 of 2004)	Regulates air pollution emissions and sets environmental air quality requirements, including dust and other emissions from construction operations	To prevent and control air pollution and maintain acceptable air quality standards during construction activities	(Department of Environment, Forestry, and Fisheries, 2021)
The National Heritage Resources Act (Act No. 25 of 1999)	Seeks to protect and manage cultural heritage resources such as archaeological and paleontological sites, graves, and historically significant structures in South Africa	To conserve and protect the nation's cultural heritage resources and ensure their responsible management during construction projects	(South African Heritage Resources Agency, 2021)

Table 2: Factors Influencing Compliance and Non-Compliance.

Factor	Description	Reference
Political will and commitment	The level of political will and commitment to solve the issues of informal housing and urban poverty in order to prioritize the interests and rights of marginalised groups	(Lombard, 2021)
Legal and administrative support	The availability and accessibility of legal and administrative support for resolving disputes and conflicts relating to land, housing, and the environment to maintain the rights and interests of informal settlement residents	(Durand-Lasserve and Royston, 2002)

Informal construction can create environmental impacts at local and global scales. Local impacts include soil erosion, water pollution, air pollution, biodiversity loss, and waste generation, especially where vegetation is cleared, sanitation systems are

food, and water over environmental considerations (Marutlulle, 2021; Kovacic et al., 2019). Many informal settlements are also located in floodplains, wetlands, steep slopes, and other sensitive or hazardous areas, despite regulatory restrictions and environmental

risks (Pharoah, 2014; Satterthwaite et al., 2020; Kovacic et al., 2019).

The literature therefore shows several gaps. There is limited clear information on the extent and causes of non-compliance, insufficient attention to residents' lived experiences and behaviours. Thereforeinvestigation that includes deeper case studies, adequate theoretical integration, understanding of actual compliance levels and implications, sufficient investigation of barriers and effective responses, and a lack of comprehensive policy analysis becomes a need. These gaps justify further research into the compliance of informal housing construction practices with building and environmental regulations in South Africa.

3. Methodology

This study adopted a constructivist research philosophy to examine the compliance levels of informal housing construction practices with building and environmental regulations in South Africa. Constructivism was appropriate because the study sought to understand informal housing practices through the experiences, perceptions, values, and social contexts of stakeholders involved in informal housing and construction (Guba & Lincoln, 1994; Schwandt, 2000). The study used a qualitative research approach, suitable for exploring the lived experiences and practices of builders, occupants, and surrounding community members in relation to regulatory compliance (Williams, 2007; Manomano, 2013).

The research was conducted in informal settlements in South Africa Cape Town (including community members from Khayelitsha, Gugulethu, Langa, and Ocean View, while the focus group included informal builders from various locations), where inadequate infrastructure, limited services, environmental risks, and substandard living conditions are common (UN Habitat, 2015; Govender et al., 2011; Ziblim et al., 2013). The study population included informal builders, residents, and members of surrounding communities. Participants were selected using purposive sampling, supported by criterion and snowball sampling. Criterion sampling ensured that participants were directly involved in, affected by, or knowledgeable about informal housing construction, while snowball sampling helped identify additional participants within hard-to-reach communities (Patton, 2015; Palinkas et al., 2015; Noy, 2008). The final sample comprised 15 interviews and one focus group discussion, at which point data saturation was reached (Saunders et al., 2018).

Data were collected through participant observations, semi-structured interviews, and focus group discussions. Observations allowed the researchers to document construction practices, materials, and site conditions in their natural setting (Emerson et al., 2011; DeWalt & DeWalt, 2011). Semi-structured interviews enabled participants to explain their experiences, knowledge, and perceptions of informal housing construction and regulatory compliance (Kallio et al., 2016). Focus group discussions provided collective insights from informal builders regarding construction practices and compliance challenges (Morgan, 1996; Krueger & Casey, 2015).

The data were analysed using thematic analysis, supported by NVivo software. The process involved familiarisation with the data, coding, theme development, theme review, and reporting of key patterns (Braun & Clarke, 2006; Saldaña, 2015; Woolf & Silver, 2017). Trustworthiness was strengthened through triangulation, audit trails, and reflexivity (Patton, 2015; Denzin, 2017; Carcary, 2009; Berger, 2015). Ethical considerations included informed consent, confidentiality, anonymity, secure data handling, and participants' right to withdraw.

4. Results

4.1. Interviewee and Observation Profiles and descriptive result

This section presents the findings from interviews and observations conducted in the informal settlements of Khayelitsha, Langa, and Gugulethu in Cape Town. The study focused on evaluating the compliance levels of informal housing construction practices with building and environmental regulations. Respondents included occupants of informal housing, members of surrounding communities, hardware-related respondents, and informal builders. Fifteen individual interviews and one focus group discussion were conducted. The individual interviews lasted about ten minutes, while the focus group discussion lasted approximately one hour. The data were analysed thematically around construction practices, material use, safety, environmental awareness, and regulatory compliance as summarized in Table 3 and 4

Table 3: Different types of people profiles

Group	Role	Perspective
Occupants	Residents living in informal settlements	Challenges face in compliance with building and environmental regulations
Surrounding	Residents	Impacts of informal housing
Informal builders	Builders involved in informal construction	Practical construction methods, awareness of regulations, and barriers to compliance
Field Observation	Observing construction practices	Firsthand observation of building processes, materials used, and compliance challenges

Table 4: Codes of interviewees and profiles

Code	Location	Role	Gender	Professional Background
K1	Khayelitsha	Occupant	Female	Creditor's cleck
K2	Khayelitsha	Occupant	Female	Cleaner
K3	Khayelitsha	Occupant	Female	Nanny
K4	Khayelitsha	Surrounding community	Male	Pastor
K5	Khayelitsha	Surrounding community	Male	Professional Builder
M1	Khayelitsha	Hardware owner	Male	Self-employed
M2	Khayelitsha	Hardware worker	Male	Shop keeper
G1	Gugulethu	Occupant	Female	Self-employed
G2	Gugulethu	Occupant	Female	Nanny
G3	Gugulethu	Occupant	Male	Security guard
G4	Gugulethu	Occupant	Male	Freelance photographer
L1	Langa	Occupant	Female	Street vendor
L2	Langa	Occupant	Female	Street vendor
L3	Langa	Occupant	Female	Cleaner
O1	Oceanview	Occupant	Female	Unemployed
F1-F10	Various Locations	Informal Builders	Male	Informal Builders

Participants represented different perspectives on informal housing. Occupants described the lived experience of informal dwellings and the challenges of maintaining homes under limited resources. Surrounding community members explained broader safety and environmental impacts. Informal builders described construction methods, material availability, building knowledge, and awareness of regulations. Field observation in Khayelitsha provided direct evidence of the techniques, materials, and compliance challenges visible during construction.

The interview profiles show that most respondents were occupants or community members from Khayelitsha, Gugulethu, Langa, and Ocean View, while the focus group included informal builders from various locations. The informal builders had construction experience acquired through informal and community-based learning rather than formal training. The findings therefore reflect both practical construction knowledge and lived experience.

The first finding concerns the naming of informal housing types. Respondents used terms such as Umkhukhu, Ityotyombe, and Hoki to describe shack dwellings. Although names varied, they referred to similar informal dwellings made from accessible materials such as corrugated iron and wood. Respondents explained that the names may differ according to size, sturdiness, or local expression, but the underlying housing condition remains largely the same. The dwellings are usually small, quickly constructed, and shaped by immediate need rather than formal design.

4.2. Materials Used

The most common construction materials were corrugated iron sheets, wooden planks, plastic sheeting, cardboard, and other scrap materials. Corrugated iron was preferred for walls and roofs because it was considered relatively strong and weather resistant. However, most sheets were obtained second-hand from scrapyards, demolition sites, or residents and were often rusted or damaged. Plastic and wood were therefore used to patch defects, reducing the structures' durability and weather resistance.

Wood was primarily used for the structural frame. Although strong timber was considered necessary for stability, its cost limited access. Builders consequently used second-hand planks and leftover timber. Cardboard, blankets, chipboard, and other makeshift materials were used to cover gaps when proper materials were unavailable. These practices demonstrated residents' resourcefulness but also explained the difficulty of meeting construction standards.

4.3. Construction methods

Construction methods were informal, rapid, and based on improvisation. Builders learned through observation and experience without formal manuals, templates, or approved specifications. Construction generally started with a timber frame, with wooden members placed directly into the ground without a formal foundation. Uneven ground was addressed by adjusting timber lengths or digging parts of the site. Corrugated iron sheets were then nailed or tied to the frame.

The primary objective was to provide immediate shelter, with many shacks completed within one or two days. However, rapid construction often resulted in leaks, cracks, unstable walls, and loose roofs. Corrugated iron roofs were secured using nails or wire to resist Cape Town's strong winds. Windows and other openings were improvised and sometimes covered with clear plastic, resulting in limited ventilation and natural light.

Builders relied on experience and community knowledge rather than building plans or official guidance. Each dwelling was adapted to the available space, land slope, materials, and the household's financial capacity. Although this flexibility enabled rapid construction, it placed the structures outside formal regulatory and inspection systems.

4.4. Building Regulation knowledge and challenges

Respondents had limited knowledge of formal building regulations but understood practical risks such as fire, inadequate sanitation, unsafe electrical connections, structural weakness, and poor waste management. Fire was considered a major danger because shacks were closely spaced and residents commonly used candles, paraffin stoves, and unsafe electricity connections. Although builders sometimes attempted to maintain spaces between structures, overcrowding and housing demand made this difficult.

Most shacks lacked private toilets, proper sewage systems, and drainage. Residents depended on communal facilities, while rainfall and flooding created additional health risks. Weak materials and informal construction methods also affected structural safety. Builders used additional timber, plastic, and available materials to reinforce structures, but recognised that these measures were temporary and vulnerable to storms.

Although residents understood the environmental harm caused by burning and dumping waste, formal waste-management services were limited or irregular. Plastic, metal offcuts, timber, and other construction waste were commonly left on sites, dumped in open areas, or burned. Environmental compliance was therefore difficult despite respondents' awareness of pollution and health risks.

The main construction challenges were financial constraints, limited access to quality materials, overcrowding, harsh weather, and inconsistent local-authority support. Financial limitations influenced dwelling size, material quality, and repairs. Residents understood that better materials would improve safety and durability but could not afford them. Limited land also increased fire risks by forcing structures to be built close together, while rain and wind caused flooding, leaks, roof damage, and instability.

Common post-construction problems included leakage, instability, and poor durability. Leaks resulted from old or poorly sealed corrugated sheets, while instability was associated with uneven ground, weak timber, thin metal sheets, and absent foundations. Residents reported shaking roofs and unstable walls during strong winds. Builders attributed these problems mainly to low-quality materials and clients' inability to afford stronger alternatives.

4.5. Observation of Construction Process in Khayelitsha

he Khayelitsha observation confirmed the interview findings. Three local builders constructed a shack using salvaged and second-hand materials. They had no formal training and had acquired their skills through community experience. The structure was completed in approximately four hours but was built directly on sandy ground without a foundation or insulation. Corrugated iron sheets, wooden beams, and nails were used, while improvised tools were adopted when proper equipment failed.

The site had no formal boundaries, management arrangements, safety equipment, or waste-disposal system. Builders handled sharp materials without helmets, gloves, or protective clothing. Scrap materials were left around the site, and excess waste was commonly burned or dumped. Although the completed shack provided immediate shelter, it remained vulnerable to leakage, temperature changes, strong winds, and movement because it lacked a foundation and insulation.

5. Discussion

The findings from interviews and observations in Khayelitsha, Gugulethu, and Langa show that compliance with building and environmental regulations in informal housing construction is shaped by linked material, safety, environmental, regulatory, and socio-economic constraints. The discussion is organised around five themes: access to materials and financial constraints, safety and structural integrity, environmental awareness and waste management, knowledge of regulations and compliance gaps, and social and economic pressures.

First, limited access to good-quality building materials emerged as a central barrier to compliance. Builders and residents reported that financial constraints forced them to rely on second-hand, cheap, or salvaged materials, even when they understood that stronger and more durable materials would improve housing quality. This finding reflects Durand-Lasserve and Royston's (2002) argument that limited access to formal housing markets and financial resources pushes informal settlements toward makeshift construction. In this context, non-compliance is not simply a technical failure but is connected to poverty and limited material choices.

Second, safety and structural integrity were major concerns. Builders acknowledged that shacks were vulnerable to collapse, fire, and weather-related damage, especially during Cape Town's rainy season. Site observations in Khayelitsha showed that some structures were built without foundations, leaving them exposed to shifting, flooding, and wind damage. These findings are consistent with Patton (2015), who

identifies fire hazards and structural failures as common features of overcrowded and unregulated informal settlements. They also support Denzin (2017) view that the absence of foundations increases collapse risks in informal settings.

Third, environmental awareness existed, but practical waste-management options were limited. Builders and residents recognised that burning or dumping waste was harmful, yet they reported that formal systems for waste collection, recycling, and disposal were absent or inadequate. This finding aligns with Carcary (2009), who notes that informal settlements often lack formal waste-management systems, and with Berger (2015). argument that environmental degradation in such areas is linked to neglect by local authorities.

Fourth, the study found a gap between awareness of regulations and the ability to comply with them. Builders and residents knew that formal rules existed, particularly regarding safety and environmental protection, but viewed these regulations as designed for formal housing rather than informal settlement conditions. This supports Huchzermeyer's (2008) argument that formal housing frameworks often fail to respond to the realities of informal settlements, creating a disconnect between legal requirements and what residents can practically achieve.

Finally, social and economic pressures were found to drive non-compliance. The need for immediate shelter, overcrowding, unemployment, and poverty meant that residents prioritised short-term survival over long-term safety or sustainability. This reflects Moola and Kotze (2021) view that economic survival strategies shape urban informal development. Overall, the findings show that non-compliance is produced by structural constraints rather than by a lack of concern for safety or the environment.

6. Conclusion

The study concludes that non-compliance with building and environmental regulations is widespread in informal settlements. This is mainly linked to financial constraints, lack of access to compliant materials, limited formal infrastructure, overcrowding, and the urgent need for shelter. Builders often rely on cheap, second-hand, or salvaged materials that do not meet required standards for structural safety or environmental sustainability. As a result, many homes remain vulnerable to collapse, fire hazards, extreme weather, leaks, and frequent repair needs. The findings also show that informal builders generally do not use formal building templates or guides. Although some builders and residents are aware of safety and environmental risks, compliance remains difficult because regulations are viewed as unattainable within their economic and spatial conditions. Improper waste disposal and the burning or dumping of leftover materials further contribute to environmental degradation. The study therefore recommends improving access to affordable and compliant building materials, establishing practical training and capacity-building programmes for informal builders, and introducing waste management systems and environmental awareness programmes. It also recommends context-sensitive regulations that reflect the realities of informal housing construction, supported by government incentives, microloans or grants, and collaborative policy development involving community leaders, builders, NGOs, private-sector actors, and government authorities.

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ACADEMIC PAPERS: THEME 4 -
Health, Safety, Wellbeing, Inclusion and Workforce Culture

SMART CONSTRUCTION TECHNOLOGIES APPLICATION TO IMPROVE HEALTH AND SAFETY IN THE SOUTH AFRICAN CONSTRUCTION INDUSTRY: A SYSTEMATIC REVIEW

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Abstract

Purpose: The South African construction industry continues to experience persistent health and safety challenges despite regulatory frameworks. This study systematically reviews the application of smart construction technologies and their potential to improve occupational health and safety outcomes within the South African construction context.
Design/Methodology/approach: A qualitative systematic literature review guided by the PRISMA framework was adopted. Peer-reviewed journal articles, conference papers, and industry reports published between 2015 and 2025 were sourced from Scopus, Web of Science, and SA ePublication databases. A total of 113 eligible studies were analysed using thematic analysis.
Findings: The findings reveal that smart construction technologies—including IoT devices, wearable sensors, BIM, drones, and automated systems—significantly enhance real-time hazard detection, worker monitoring, emergency response, and safety management. However, adoption remains limited due to high initial costs, inadequate technical skills, resistance to change, insufficient infrastructure, and weak regulatory support.
Practical implications: The study highlights the need for targeted training programmes, supportive government policies, and strategic investment to encourage widespread adoption of smart safety technologies across the South African construction industry.
Research Limitations and Implications: The review relies solely on secondary data and reports findings for only one research objective due to space limitations. Future empirical studies are recommended to validate these findings within live construction projects.

Keywords: Construction industry, health and safety, smart construction technologies, South Africa

1. Introduction

The global economy depends heavily on the construction sector, which propels growth and permits the development of infrastructure. However, it is mostly a dangerous field, with a high frequency of serious occurrences and a steady high incidence rate (Hinze, Thurman and Wehle, 2013). There are more than 60,000 construction workers killed worldwide each year, with roughly eight deaths occurring in South Africa's construction sector each month. Occupational health and safety deficiencies, together with problems like inadequate training and noncompliance with rules, are the primary cause of the tragic incidents (Department of Labour 2024). (Zhou, Irizarry and Li, 2013) and (Okpala, Nnaji and Karakhan 2020) argue that safety will continue to exist in the construction industry unless radical mitigations are implemented. It is therefore crucial to establish effective safety management systems and to innovate ways of mitigating risks, thus ensuring workers' safety, and promoting sustainable practices. The Architecture, Engineering and Construction (AEC) industry is still relying on conventional methods for overseeing health and safety, and this is a huge challenge as manual observation and inspection can be tough since it is difficult to observe the whole construction place and all employees at once (Gao et al. 2022; Guo, Zou and Chen 2018).

Traditional ways of ensuring safety have relied on the vigilance, intuition, and knowledge of the safety manager. Likewise, traditional safety training programs have multiple shortcomings that make them ineffective (Akinradewo, Aigbavboa and Oke, 2020). Most of the time construction workers rely on their experience to identify and respond to safety risks. Hence, a significant challenge for workers is to identify and react when they encounter potential dangers and risks that are hard to anticipate, as these threats are hard to manage and can undermine an effectively structured safety programme (Afzal, Shafiq and Jassmi 2021). Due to the urgent necessity to enhance working conditions and safety outcomes, numerous researchers have investigated the application of technologies in contemporary construction to impact safety on construction sites (Okpala, Nnaji and Karakhan 2020). Currently, a diverse arrangement of safety technologies

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is available for implementation at construction sites (Teizer, Cheng and Fang, 2013). Existing research has indicated that the adoption of various safety technologies during the construction phase yields considerable benefits. Specifically, monitoring systems, alerts systems, and computer vision technologies have proven its effectiveness in enhancing safety through the delivery of prompt information and notifications about potential dangers (Wang and Razavi, 2016; Son et al., 2019).

This study investigates innovative technology to enhance conventional safety management procedures to reduce some of the issues regarding construction safety. Modern safety methods entail the use of technologies like wearable technology, drones, the Internet of Things (IoT), and big data analytics (Fang et al., 2018). According to existing research, implementing creative solutions can lower workplace accidents and enhance worker safety. However, the adoption of smart construction technologies in South Africa is still limited (Yap *et al.* 2022b). This study will fill the knowledge gap that exists in construction safety field by examining smart construction technologies application to South African Construction to enhance safety. The outcome of this research will improve knowledge capacity and skills of construction professionals on how technology can be applied in different tasks to keep construction sites safe. This research will also show how new technologies are changing and shaping the future of safety within the construction field.

2. Research Methodology

Research methodology refers to the procedures and strategies adopted to conduct a study and achieve its objectives (Kumar, 2019). This study adopted a qualitative research approach because it relied on a desktop-based systematic literature review (SLR) to examine the application of smart construction technologies for improving health and safety in the South African construction industry. Qualitative research enables the exploration of experiences, meanings, and contextual interpretations presented in existing literature (Busetto, Wick and Gumbinger, 2020; Bryman, 2016). Creswell and Creswell (2018) further noted that qualitative approaches allow researchers to capture contextual influences and nuanced perspectives that cannot easily be quantified.

A systematic literature review was employed as the primary methodological framework because it provides a structured and transparent process for synthesising evidence while minimising bias (Haddaway et al., 2022). Unlike traditional literature reviews, SLRs follow clear and replicable procedures for identifying, screening, and synthesising studies, thereby improving research rigour and reliability (Oke, Aghimien and Aigbavboa, 2021). Kahale et al. (2022) also emphasised that systematic reviews enhance credibility through the consistent application of inclusion and exclusion criteria. To ensure transparency and fairness, the review followed the Preferred Reporting Items for Systematic Reviews and Meta-Analyses (PRISMA) framework during the identification, screening, eligibility, and inclusion stages (Haddaway et al., 2022). Studies were selected based on predefined criteria, including relevance to the research objectives, publication date, and academic credibility. The review focused on literature published between 2015 and 2025 to ensure contemporary and relevant findings (Figure 1).

Data were collected from secondary sources, including peer-reviewed journal articles, conference proceedings, editorials, books, websites, online repositories, and professional publications (Afzal, Shafiq and Al Jassmi,

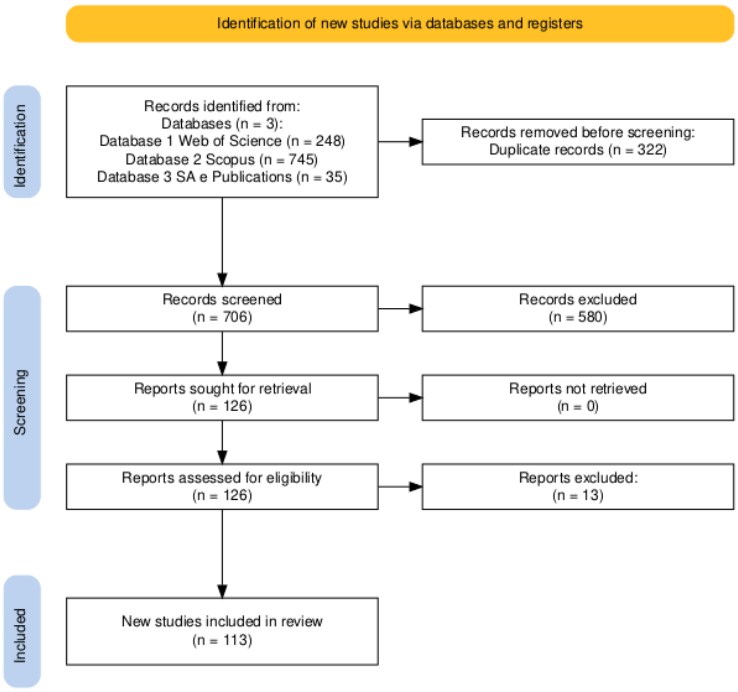

Figure 1: PRISMA flow for article selection

2021). Searches were conducted across databases such as Scopus, Web of Science, and SA ePublication using keywords including "smart construction," "construction 4.0," "digital safety management," "digital construction," "construction technology," "construction innovation," "safety," "health," "occupational health and safety," and "OHS." The initial search identified 1,028 studies. After removing 322 duplicate records, 706 articles remained for screening. Titles and abstracts were reviewed to assess relevance to the study objectives, particularly factors influencing the application of innovative construction technologies for safety improvement, the effects of non-application, and mitigation strategies. Consequently, 580 articles were excluded for lacking sufficient focus on smart construction technologies and safety improvement. The remaining 126 articles underwent further eligibility assessment through detailed abstract and topic evaluation. Full-text reviews were subsequently conducted to ensure relevance, resulting in a final sample of 113 articles for thematic analysis. The collected qualitative data were analysed using thematic analysis techniques to identify recurring themes, patterns, and insights related to smart construction technologies and occupational health and safety practices in the construction industry.

3. Results

The Table 1 shows the analysis of database sources used for the study. The results indicate that the literature reviewed came from different sources,13% percent of the literature was published in conference papers and written by researchers from various countries. The conference papers have produced numerous reports detailing the benefits of smart technologies, their efficiency and sustainability in the construction industry. The conference papers also indicate the positive impact of smart construction technology application to improve safety in South Africa. A further 12% of the literature came from MDPI Buildings journals. These sources provided valuable data on the regulatory and economic frameworks governing smart construction technologies in South Africa, particularly emphasizing the role of government policies, education, and encouraging sustainable building practices. 59% of the sources came from Professional engineering bodies, policy organizations, such as the Engineering, Construction, and Architectural Management Society, the Automation in Construction, and Construction. The process entailed using Smart construction to identify, analyse, and report patterns or themes in the data, carefully selecting those that relate to the research questions and overall theoretical framework.

The remaining 16% of the literature was derived from institutions such as the Journal of Building Engineering, Construction Economics and Building, Journal of Scientific Research and Reports, International Journal of Building, Journal of Materials Engineering, Structures and Computation, Journal of the Institution of Engineers (India) Series A. These institutions contributed critical peer-reviewed studies on the long-term economic effects of sustainable smart construction technology in improving the health and safety in the construction industry in South Africa. From the total of 113 publications that contributed to the accomplishment of the three main objectives of the main study. Of these, 48% contributed to the first objective, which was to examine the factors causing lack of smart construction technologies applications in

Table 1: Frequency of selected paper from the database used in this study

No	Publishers	No of Articles
1	Conference Paper	15
2	MDP I(Buildings)	14
3	Engineering, Construction and Architectural Management	9
4	Automation in Construction	5
5	Journal of Science Safety	3
6	Journal of construction engineering and management	3
7	Journal of Building Engineering	3
8	International Journal of Construction Management	3
9	Journal of smart and sustainable Built Environment	2
10	MDPI (Engineering Proceedings)	2
11	International Journal of Building Pathology and adaption	2
12	Journal of Civil Engineering and Management	2
13	Journal of engineering, project and production management	2
14	University of Johannesburg	2
15	Malaysian Construction Research Journal	2
16	Computers in the industry	2
17	Journal Frontiers in Built Environment	2
18	Others	1 each
19	**TOTAL**	**113**

improving health and safety in the South African construction industry. Additionally, 25% contributed to the second objective, which was to identify the effects of non-application of smart construction technologies to improve health and safety in the South African construction industry 27% contributed to the third objective, which was to determine the available mitigating strategies of smart construction technologies in the construction industry to improve health and safety in the South African construction industry. However, due to constraint of space only the findings on the first objective were reported in this article.

A primary finding of the review is that the adoption of smart construction technologies in South Africa's construction industry is progressing slowly and unevenly across all nine of its provinces. Although international studies report significant improvements in safety and productivity through these technologies, local research identifies challenges related to organisational structures, financial constraints, and regulatory frameworks that hinder implementation. The most prevalent barriers include high initial investment costs, a shortage of skilled labour, resistance to change among stakeholders, inadequate infrastructure, and the absence or ambiguity of relevant regulations and policies. The researchers discovered that the lack of application of smart construction technologies to improve health and safety on construction sites is caused by multiple interrelated factors. High initial costs make it difficult for companies to invest in new technologies. Additionally, the absence of government legislation and commitment during the procurement process limits formal encouragement and mandate for technology use. A lack of technical training further hinders workers' ability to effectively utilize these innovations (Oke, Aghimien and Aigbavboa, 2021).

This finding is confirmed by Yap et al. (2022a) who confirms that concerns about data security and cybersecurity, along with a lack of top management and leadership support, reduce confidence in adopting these tools. Smart technologies often suffer compatibility issues with existing procedures, and poor cooperation among built environment professionals obstructs integrated implementation. Moreover, a lack of practical strategies, industry complexity, low digital literacy among some professionals, and limited access to suitable technology and frameworks contribute to slow adoption. Uncertainty about technological outcomes, unclear profit benefits, and environmental factors such as poor weather conditions further diminish enthusiasm. Other challenges include poor data quality, reliability, insufficient awareness, weak inter-organisational integration, lack of vendor support, contractors' limited knowledge, and individual attitudes. Collectively, these factors create significant obstacles to the widespread use of smart construction technologies for health and safety improvements on construction sites.

Figure 2 indicates the percentage contribution of the factors affecting the non- application of smart construction technologies to improve health and safety

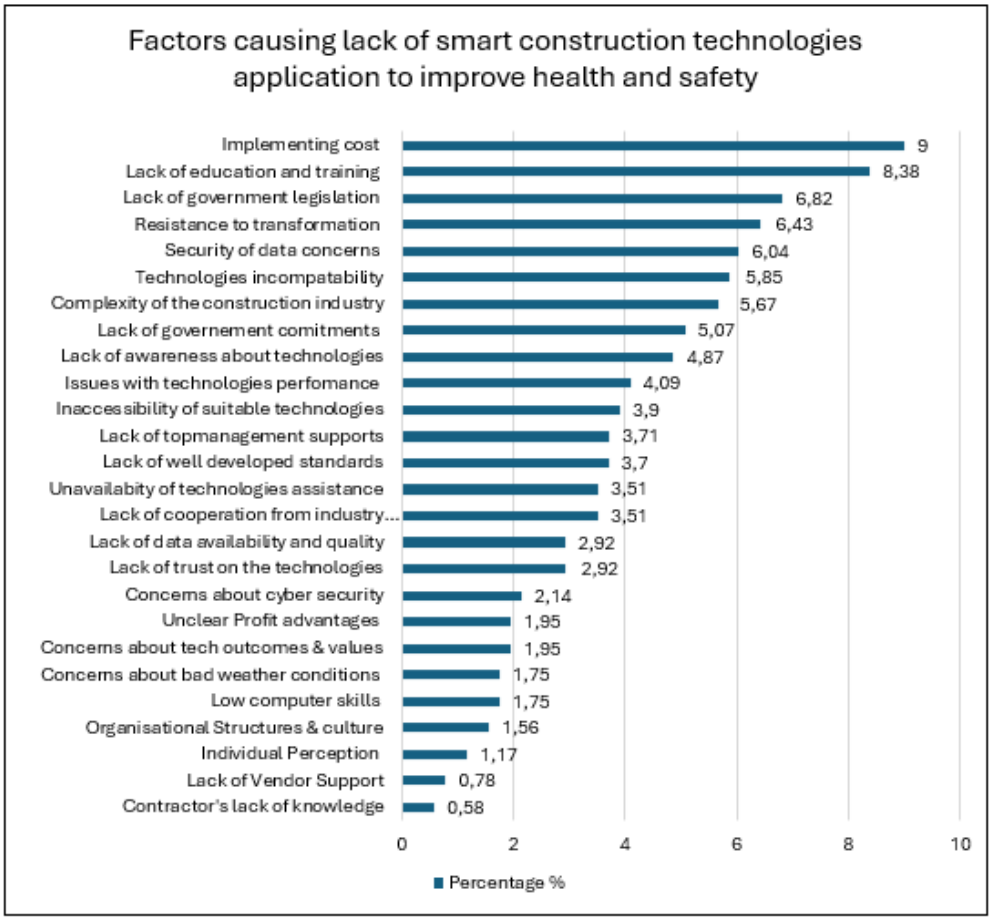

Figure 2: Lack of smart construction technologies application

in the South African construction industry. These range from high implementation cost to purchase the technologies being the most frequently mentioned, making 9 % of the total in different papers. These is also confirmed by Okpala, Nnaji and Karakhan 2020; Malomane, Musonda and Okoro (2022) who also have high initial cost as their top factor causing lack of smart technologies, lack of education and training is the second most common factor accounting to 8.38 % as confirmed by Okpala, Nnaji and Karakhan 2020 who has need for training ranked No.2 , followed by lack of government legislation contributing 6.82%, Resistance to transformation at 6.43%, the security of data concerns accounts for 6.04%, technology incompatibility accounts for 5.85%, the complexity of the construction industry accounts for 5.67%, lack of government commitment is 5. 07%, lack of awareness accrued to 4.87%, then there is concerns about the technologies performance contributing 4.09%, inaccessibility of suitable technologies at 3.90%, lack of top management supports at 3.71%, lack of well d developed standards at 3.70%, unavailability of technology assistance at 3.51%, lack of cooperation on built professions at 3.51%, lack of data availability at 2.92%, lack of trust on the technologies at 2.92%, concerns about cyber security at 2.14%, unclear profits at 1.95%, Concerns about technologies outcome and values at 1.95%, concerns about bad weather conditions at 1.75%, low computer skills at 1.75%, organisational structure at 1.56%, individual perception at 1.17%, lack of vendor supports at 0.78% and the least mentioned factor is contractor's lack of knowledge indicating that while these are recognised, they have less frequency as compared to others which make that the least contributory factors.

4. Conclusion

This study examined the application of smart construction technologies for improving health and safety in the South African construction industry through a systematic literature review. The findings demonstrate that smart technologies have considerable potential to address long-standing safety challenges by enabling proactive hazard identification, continuous worker monitoring, and enhanced safety decision-making. International evidence consistently shows improvements in safety performance and productivity; however, South Africa continues to experience slow and uneven adoption across its provinces.

The review identified high implementation costs, skills shortages, weak regulatory enforcement, resistance to change, and poor technological infrastructure as the most critical barriers to adoption. These challenges are interrelated and collectively undermine efforts to modernise safety management practices. The persistence of traditional, manual safety approaches further limits the industry's capacity to leverage digital innovations effectively. Despite these challenges, the study confirms that smart construction technologies represent a viable pathway for improving occupational health and safety outcomes. Their integration can significantly reduce accidents, enhance compliance, and promote sustainable construction practices. By consolidating existing knowledge, this study contributes to the growing body of literature on construction digitalisation and safety management in developing economies. Based on the findings, the study recommends that government agencies strengthen regulatory frameworks and embed smart technology requirements within procurement and safety policies. Construction firms should prioritise investment in digital infrastructure and continuous professional training to enhance technological competence among workers and managers. Industry stakeholders should also foster collaboration between professionals, technology vendors, and academic institutions to improve awareness, interoperability, and innovation. Future research should adopt empirical methods, such as case studies and field experiments, to assess the real-time effectiveness, cost–benefit implications, and contextual adaptability of smart construction technologies in South African construction projects

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Leadership Practices Supporting Workforce Engagement and Inclusion in Western Cape Construction Firms: A Principal Component Analysis

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Abstract

This study identifies leadership practices perceived to support workforce engagement and inclusion in construction project delivery in the Western Cape Province, South Africa. A quantitative questionnaire survey was administered to leaders in cidb Grade 6–9 general building firms, and 64 valid responses were analysed using descriptive statistics, Cronbach's alpha, and principal component analysis. The instrument's reliability was high ($\alpha = 0.910$). Five components were extracted, namely inclusive workplace support, employee empowerment, social support, participative leadership, and workplace clarity, explaining 57.094% of the total variance. The highest-ranked practices were enabling peer support (MV = 4.59) and leadership engagement and visibility (MV = 4.51). The study provides preliminary evidence on leadership-related practices associated with engagement and inclusion in Western Cape construction firms. However, because productivity was not directly measured and the study was limited to one province and a modest sample, the findings should be interpreted with caution.

Keywords: construction management, inclusion, leadership, project delivery, workforce engagement, and the Western Cape

1. Introduction

The construction industry is very important to a country's economic and infrastructure development (Atiku *et al*., 2024; Osunsanmi *et al*., 2018; Moyo *et al*., 2021). The construction industry contributes significantly to job creation and GDP, but still faces several challenges, including low productivity, inefficiencies, and workforce diversity (Bailey *et al*., 2017; Dithebe *et al*., 2022). Empirical evidence from the study conducted by Osunsanmi *et al*. (2018) shows that the construction industry is an important sector for South Africa's economic growth and performance, as it employs more than 1.4 million people, lowering the unemployment rate.

According to Mahamid (2013), citing Chitkara (2004), the construction industry accounts for 6% to 9% of total GDP in several countries. According to recent research by Alaloul et al. (2021), the construction business is worth USD 1.7 trillion globally, with most nations accounting for 5-7% of total GDP. According to Tucker *et al*. (2015), construction projects in the Western Cape Province contribute significantly to urban development and meet the rising need for housing, infrastructure, and economic growth to achieve sustainable development goals. Despite these contributions, the construction industry faces several barriers to workforce engagement and inclusiveness (Osunsanmi *et al*., 2018). Cultural issues, organisational structure, limited chances for underrepresented groups, and ineffective leadership practices (Mishra, Boynton & Mishra, 2014). According to Cole *et al*. (2012), these issues frequently result in low morale, high turnover rates, and a lack of integration between individual and construction business goals, reducing workforce productivity (Alam *et al*., 2024).

Inclusive leadership has become increasingly prevalent due to factors such as communication barriers, resistance to change from employees and management, unconscious bias, limited leadership competencies, and difficulties building trust among team members (Obeng *et al*., 2024; Mishra *et al*., 2014). As a result, inclusive leadership enables contractors to achieve success in construction projects. Furthermore, Shaik *et al*. (2020), Mahamid (2013), Moyo *et al*. (2021) and Chitkara (2004) reveal that the construction industry's capacity to achieve construction project delivery needs depends on developing a motivated and inclusive workforce to enhance productivity at the project level. According to Moyo *et al*. (2021), the construction industry is overlooked due to low productivity growth resulting from inadequate adoption of a diverse and inclusive workforce. Against this background, the research question for this study is as follows:

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- *What are the leadership practices influencing workforce engagement and inclusion to enhance team and individual productivity in construction project delivery?*

This study aims to provide evidence-based insights into how engagement and inclusion practices influence contractors' workforce productivity and to identify actionable practices to achieve productivity at the project level. This study contributes to the larger discussion on workforce productivity and sustainable development in the construction industry (Shaik *et al*., 2020). The following sections include a literature review relevant to the study, the research methodology used to achieve the study's aims, the findings, the analysis and discussion of the results, conclusions and recommendations.

2. Literature Review

2.1. Leadership practices in construction

Leadership practices in the construction industry are essential for ensuring effective project delivery, workforce management, and contractors' business success (Kalambayi *et al*., 2021). Furthermore, leadership practices increasing recognition in project management research underscore the significance of competencies such as leadership, results orientation, assertiveness, reliability, and efficiency, all linked to improved project delivery (Rehan, Thorpe & Heravi, 2024). Wu, Li and Fang (2017) highlight that construction leaders are responsible for coordinating diverse teams, managing resources, maintaining safety standards, and addressing project challenges in dynamic and often uncertain environments. Effective leadership practices include clear communication, employee empowerment, collaborative decision-making, conflict resolution, and the promotion of a positive safety culture (Rehan *et al*., 2024). A research conducted by Kalambayi et al. (2021) reveals that these leadership practices directly impact employees' performance, productivity, and commitment and they can positively or negatively affect a team.

2.2. Workforce engagement in the construction industry

As workplace diversity evolves, many employees experience exclusion, and many feel they are not considered integral parts of the organisation (Goswami & Goswami, 2018). Worker engagement refers to employees' level of involvement and dedication to their organisation (Jerónimo *et al*., 2022; Goswami & Goswami, 2018; Brooking, 2021; Ly, 2024). Thus, to increase employee engagement, the workplace needs to promote safety, meaningfulness, and availability (Jeronimo *et al*., 2022). Among other individual employee behavioural phenomena, research has shown that proactive individual work engagement significantly affects both individual and organisational performance (Gupta and Sharma, 2016). Adaptability, flexibility, and tailored responses to changing environments are essential qualities for organisations in a competitive environment (Uddin, Mahmood & Fan, 2018).

2.3. Inclusion in diverse construction workforces

An inclusive leader is characterised by participation, empowerment, open communication, collaboration, trust, and respect for diverse perspectives (Rehman, 2020). Ding, Ren and Lin (2024) add that leaders are able to realise teams' full potential by embracing diversity in all forms, including gender, race, age, and skill set. In a field where collaboration across disciplines is crucial, such as engineering, architecture, and labour, inclusive leadership ensures that all voices are heard and diverse viewpoints are integrated into problem-solving (Fu *et al*., 2022). Khan *et al*. (2020) reveals that this strategy improves teamwork, resulting in better project outputs, fewer misunderstandings, and a stronger feeling of shared purpose.

2.3.1. The role of leadership in enhancing engagement and inclusion

Inclusive leadership plays a key role in improving employees' engagement and inclusion in the organisation during the delivery of a construction project (Goswami & Goswami, 2018). Furthermore, Rehman (2020) reveals that an inclusive leader offers employees an environment that causes them to feel appreciated, respected, and able to add value to the goals of the organisation. Rehman (2020) highlights that inclusive Leaders value and respect differences, embrace equity opportunities, and fairly treat all employees, irrespective of their backgrounds. However, research conducted by Tims et al. (2013) and Aragon and Kim (2021) also reveals that cultural biases, limited development opportunities for minority-represented workforce groups, and workforce disengagement are a few obstacles faced by contractors that require effective leadership practices. Furthermore, Ding, Ren and Lin (2024), Rehman (2020), and Moss (2019) add that construction leaders who embrace workforce diversity and inclusion programmes can drive and improve workforce morale and align workforce goals with project objectives, thereby enhancing workforce productivity. Therefore, leadership development programmes that promote diversity awareness enable contractors to maintain an inclusive and engaging workplace (Gerritsen, 2020; Jerónimo, Henriques & Carvalho, 2022; Nishii & Leroy, 2022). Cole et al. (2012) indicate that inclusive leaders enable trust, encourage collaboration, and establish a sense of psychological safety, which can lead to greater employee engagement, satisfaction, and performance. Consequently, leadership is a critical determinant of inclusion and engagement and helps create motivated and resilient employees.

2.4. Productivity in construction project delivery

Productivity in the construction business is a vital indicator that directly impacts project success, profitability, and industry growth (Shinde & Hedaoo, 2017). In the construction industry, productivity is commonly defined as the ratio of outputs (such as completed work) to inputs (such as labour, materials, and time) (Crawford & Vogl, 2006; Ghodrati *et al*., 2018; Choudhry, 2017). Almamlook et al. (2020) reveal that high productivity in construction is critical for completing projects on time and within budget, which is especially vital in an industry defined by tight deadlines and financial constraints. However, the construction sector faces hurdles to achieving optimal productivity, such as project complexity, labour shortages, and the need for effective coordination among a wide range of stakeholders (Durdyev & Mbachu, 2011). According to Ghodrati *et al*. (2018), the experience and skill level of the workforce are important; a skilled and trained labour force is more productive and reduces errors and rework. An inclusive leader leads to effective resource management and project planning, which are also essential. Inadequate resource allocation or planning can result in cost overruns, delays, and disruptions that harm output (Assaad & El-Adaway, 2021). Moreover, external variables that can cause unpredictability and reduce efficiency, such as weather, regulations, and market swings, frequently affect building projects (Naoum, 2016). Because of these considerations, construction managers need to put plans in place that not only reduce risks but also optimise operations (Shinde & Hedaoo, 2017).

3. Research Methodology

3.1. Research design

This study adopted a quantitative research approach to assess inclusive leadership practices enabling contractors project success. Creswell and Creswell (2018) state that this method involves gathering numerical data through surveys, tests, or pre-existing datasets to lay the groundwork. This makes it possible for researchers to evaluate correlations between variables, analyse trends, and gauge the frequency of particular variables (Richey & Klein, 2014). 154 structured survey questionnaires were distributed to the respondents employed by contractors registered under cidb grades 6 to 9.

3.2. Population and sample size

This study focused on construction professionals involved in the delivery of construction projects. The selected population enabled the researchers to better understand the unique obstacles and challenges they face in promoting an inclusive workplace. A diverse range of leadership roles, such as construction managers, site agents, quantity surveyors, team leaders, and owners, ensures a thorough awareness of perspectives across the construction hierarchy registered between grades 6 and 9. The population size for this study comprises 206 contractors registered between grades 6 and 9, with 90 contractors registered in grade 6, closely followed by 69 contractors registered in grade 7. While 25 and 22 contractors were registered under grades 8 and 9, respectively. This study adopted probability sampling using random sampling.

To achieve the objectives of this study Singh and Masuku (2014) equation was adopted ($n = N.Z^2 p.q. (1-P) / e^2.(N-1)+ Z^2.p.q$), where n is the sample size, N is the population size, Z is based on the desired confidence level (95%), e is the margin of error, p is the estimated proportion of an attribute that is present in the population, and q is 1-p. Using this equation, the sample size for the study was determined as 154 contractors registered in cidb Grade 6 to 9.

3.3. Data collection

154 survey questionnaires were sent to contractors registered under cidb Grade 6 to 9. 98 survey questionnaires were sent out to participants via email. Twenty-eight (28) of the 98 were correctly filled out and returned. A total of fifty-six (56) survey questionnaires were physically given to contractors in the Western Cape Province. Thirty-six (36) of the fifty-six (56) survey questionnaires were answered accurately by the respondents. 64 surveys were correctly completed, resulting in a 41.6% response rate. According to Hwang et al. (2018), most construction-related studies consider a response rate of between 20 to 30% acceptable. A five-point Likert scale was adopted in this study, namely: 1 = Never, 2 = Rarely, 3 = Sometimes, 4 = Often, and 5 = Always. Furthermore, the respondents were informed to note the unsure response, and the inclusion of an "Unsure" option enabled respondents to express uncertainty rather than being forced to select a never or always response that might not accurately reflect their views. According to Joshi et al. (2013) and Emerson (2017), Likert scale questions offer respondents a range of options to indicate their degree of agreement or disagreement with a particular statement, enabling researchers to quantify subjective opinions.

3.4. Data analysis

For quantitative results, descriptive and inferential statistics were used. Furthermore, the Likert-scale survey questionnaires were tested using Cronbach's alpha coefficient to assess the internal consistency of the quantitative items, with values ranging from 0 to 1.0; adequate reliability is 0.7 or greater (Cronbach, 1951). To ensure the reliability and validity of the results, Cronbach's alpha was used. The results show the reliability of the results with an average of 0.910, indicating the internal consistency of the results. Cronbach's alpha is a crucial statistic for evaluating the validity of scales and surveys in a variety of fields,

claims Taber (2018). Regarding inferential statistics, this study employed PCA to reduce the large number of variables into a smaller set. Pallant (2020) argues that PCA combines similar variables into factors, reduces the dimensionality of the data, and facilitates researchers' understanding of underlying patterns. PCA includes evaluating the data's suitability for factor analysis by assessing correlations among variables to determine whether they are sufficiently related (Pallant, 2020). This study adopted a factor loading threshold of 0.30 in the PCA, as loadings of 0.30 and above are generally considered practically significant and indicate a meaningful relationship between the variable and the extracted component (Pallant, 2020). Direct Oblimin rotation was applied as the extracted components were expected to be correlated, which is consistent with the theoretical relationships between leadership, engagement, and successful construction project delivery in the Western Cape Province. In this study, components were named based on the conceptual similarity and thematic meaning of variables with high factor loadings (≥ 0.30) on each extracted component, ensuring that each label accurately reflects the underlying construct represented by the grouped variables as recommended by Pallant (2020). The Kaiser-Meyer-Olkin (KMO) test and Bartlett's sphericity test are two commonly used metrics (Shrestha, 2021).

4. Results

4.1. Demographic profile of the respondents

This study indicated the demographic information of respondents with evidence showing that most respondents, 51.6% (33), have a degree, followed by 25.0% (16) of respondents with a diploma qualification. Additionally, 10.7%, 7.8%, and 4.7% of respondents had master's, matric, and other qualifications, respectively. This shows that most contractors' management in operation are qualified to work in the construction sector, and the majority of respondents hold tertiary qualifications. Regarding occupation, 34.4% (22) of respondents are construction managers, followed by team leaders at 29.6% (19). Furthermore, additional participants, including directors, quantity surveyors, and others, accounted for 36.0% of respondents. This suggests that construction managers or team leaders (site agents and foremen) oversee workforce productivity in construction project implementation. According to the findings, 64.0% of the respondents were construction managers and team leaders. The results show that 37.5% (24) of respondents have been in their current positions for 6 to 5 years, 29.7% (19) have been in their current positions for 11 to 15 years, 18.8% have been in their current positions for 1 to 5 years, and just 14.1% have been in their current positions for more than 15 years. These respondents have work experience in the construction industry. The results indicate that 45.3% (29) of respondents were aged between 46 and 55, and 29.6% (19) were aged between 36 and 55. 17.2% of them were in the 26–35 age range. 6.3% of respondents were above the age of 55, while only 1.6% were between the ages of 18 and 25 years. The data show that most responders were over 40 years old. Regarding respondents' gender, the results highlight that both genders are represented among the 64 respondents, with 67.2% (43) identifying as male and 32.8% (21) as female. Regarding the race of respondents, the findings show that 37.5% were of the coloured race, 31.3% were black or African, and 26.6% were White. Furthermore, only 4.7% of respondents were Indians. Table 2 shows that 31.3% of the contractors were listed in Grade 7, 26.6% of the enterprises were listed in Grade 8, 25.0% of the contractors were listed in Grade 6, and only 17.2% (11) of the enterprises were in grade 9. The majority of active contractors were in grades 7 and 8, with 57.9% of respondents working for contractors.

4.2. Ranking of leadership practices supporting workforce engagement and inclusion

This section presents leadership practices enabling workforce engagement and inclusion in the construction industry of the Western Cape Province. The results show that leadership enable peer support, and this is highest, with a mean value (MV) of 4.59. Furthermore, the results indicate that leadership engagement and visibility are ranked second with MV= 4.51 as the leadership practice supporting workforce engagement and inclusion. The third most ranked employee engagement and inclusion leadership practice was exposing employees to skills for addressing conflicts, together with promoting a sense of ownership among employees, as well as the accessibility of physical and digital tools/ resources to all employees to promote inclusion and these practices were supported by MV=4.47 as leadership practices supporting workforce engagement and inclusion. It is evident that accessibility of physical and digital tools/ resources to all employees to promote inclusion, STD = 0.642, is the third most ranked practice, followed by exposing employees to skills for addressing conflicts with STD = 0.835, and promoting a sense of ownership among employees with STD = 0.854. The least-ranked employee engagement and inclusion was prioritising employees' well-being, with MV = 3.91. Overall, these leadership practices support workforce engagement and inclusion by contractors operating in the Western Cape Province.

According to factor analysis, the results reveal a KMO score of 0.796, which exceeds the minimum of 0.60. Watkins (2021) claims that a KMO score of less than 0.6 indicates insufficient sampling and requires corrective action. A significance level of 0.001, which is less than $p<0.005$, and Bartlett's test of sphericity was 226.547. Table 1 shows the eigenvalues of a square matrix with five (5) recovered components: 2.382, 1.826, 1.376, 1.269, and 1.140. The results demonstrate

Table 1: Component Matrix[a] on leadership practices supporting workforce engagement and inclusion

	Component				
	1	**2**	**3**	**4**	**5**
Component 1: Inclusive workplace support					
Cultural awareness training	.740				
A fair hiring process that promotes a sense of belonging	.710				
Provide a support service for personal and professional challenges faced by employees	.709				
Component 2: Employee empowerment					
Promoting a sense of ownership among employees		.682			
Accessibility of physical and digital tools/ resources to all employees to promote inclusion		.609			
Promoting transparent decision-making to foster employees' trust		.562			
Regular check-in meetings with employees		.462			
Component 3: Social support					
Encouraging employees to participate in community engagement			.802		
Enable peer support			.454		
Component 4: Participative leadership					
Leadership engagement and visibility				.697	
Involve employees in decision-making				.602	
Exposing employees to skills for addressing conflicts				.357	
Component 5: Workplace clarity					
Prioritise employee's well-being					.685
Clear employee role and expectations					.437
Eigen value	2.382	1.826	1.376	1.269	1.140
Proportion of variance (%)	17.017	13.045	9.831	9.061	8.140
Cumulative variance (%)	17.017	30.062	39.893	48.954	57.094
Extraction Method: Principal Component Analysis.					
a. 5 components extracted.					

that leadership practices supporting workforce engagement and inclusion adopted by respondents accounted for 17.017% of the variation, followed by the second component at 13.045%, the third component at 9.831%, the fourth component at 9.061%, and the fifth component at 8.140%. The total extracted components account for 57.094% of the variance, making them especially essential for varied and inclusive workforce productivity in the Western Cape Province. Table 1 demonstrates that all variables have values greater than 0.30, with those less than 0.30 suppressed. In addition, leadership practices that support workforce engagement and inclusion have been discovered. The variable that represents component 1 coverage is '*inclusive workplace support*', component 2 was on '*employee empowerment*', component 3 was on '*social support*', component was on '*participative leadership*', and component 4 was on '*workplace clarity*'.

5. Discussion of findings

Component 1 (*Inclusive workplace support*) emerged as the most significant leadership practice influencing workforce engagement and inclusion, thereby enhancing team and individual productivity. It was characterised by three key practices: cultural awareness training (0.740), a fair hiring process that promotes a sense of belonging (0.710) and providing a support service for personal and professional challenges faced by employees (0.709). This component is supported by Tabassi *et al*. (2016), who concluded that inclusive workplace support adopted by contractors should incorporate interactive exercises, such as role-playing and scenario discussions, to ensure that employees can apply principles in real-world scenarios and to ensure the understanding of an inclusive workforce in the construction industry that promotes productivity in construction project delivery. Thus, employees' continuous learning opportunities, feedback mechanisms, and leadership involvement are critical for establishing a sustainable culture of inclusion (Wu *et al*., 2016).

Component 2 (*Employee empowerment*) encompasses four key features: promoting a sense of ownership among employees (0.682), accessibility of physical and digital tools/ resources to all employees to promote inclusion (0.609), promoting transparent decision-making to foster employees' trust (0.562), and regular

check-in meetings with employees (0.462). This component aligns with the descriptive findings. Promoting employee ownership is a fundamental leadership practice that influences workforce engagement and productivity during construction project delivery (Wiefek *et al*., 2019). Azila-Gbettor *et al*. (2024) and Mishra *et al*. (2014) add that employees who feel personally responsible for the success of their jobs and the entire project are more motivated to work at greater levels, take initiative, and actively participate in problem-solving. Moreover, Waller (2020) finds that in the construction industry, where teamwork and project completion are most important, developing ownership can lead to greater accountability, higher job quality, and less supervision. Hence, construction leaders may foster a sense of ownership among employees by including them in decision-making, giving meaningful responsibilities, recognising individual and team achievements, and offering chances for professional development (Shaik *et al*., 2020).

Component 3 (*Social support*) accounts for 9.831% of the total variance. It comprises two key features: encouraging employees to participate in community engagement (0.802) and enabling peer support (0.454). According to Wu, Li and Fang (2017), contractors who incorporate social support into their businesses promote a sense of purpose and responsibility for both the workplace and the larger community by applying skills gained by the workforce during project delivery to impact communities. In addition, Loosemore and Lim (2018) highlight that contractors are able to improve employee morale and teamwork by promoting volunteer programmes, sponsoring company-sponsored events, and rewarding community involvement. Thus, Loosemore and Lim (2018) conclude that this approach involves not only increasing neighbourhood links but also improving the company's brand and fostering a culture of social responsibility.

Component 4 (*Participative leadership*) is characterised by two key features: leadership engagement and visibility (0.697), involving employees in decision-making (0.602), and exposing employees to skills for addressing conflicts (0.357). According to Wu *et al*. (2017), participative leadership is crucial for developing a motivated, cohesive workforce, particularly in the construction industry. Additionally, Yunpeng and Zaman (2024) reveal that when construction leaders are actively involved and visible on-site, they foster trust, express commitment, and create a culture in which the construction workforce feels appreciated and heard. This finding aligns with the descriptive findings, with a mean value of 4.51. Additionally, the descriptive findings show that enabling peer support is one of the most significant leadership practices for enhancing workforce engagement and inclusion to enhance project delivery, with a mean value of 4.59 and this practice was ranked first. Wittenhagen et al. (2024) claim that implementing peer support in construction teams enhances workforce collaboration, skill sharing, and mutual encouragement, thereby improving both individual and team performance, contributing to workforce productivity and project success. Furthermore, Goswami and Goswami (2018) add that daily meetings, friend systems, and mentorship programmes enable the workforce to feel supported and valued, resulting in increased morale and workforce productivity, which improves project success.

Component 5 (*Workplace clarity*) accounts for 8.140% of the total variance in the study and comprises two practices: prioritising employee well-being (0.685) and clear employee roles and expectations (0.437). This component is consistent with Kowalski and Loretto (2017), who reveal that prioritising employee well-being is critical for contractors to improve workforce engagement and inclusion and an engaged and loyal team that focuses on productivity. Furthermore, organisations demonstrate their commitment to their employees' overall health and safety by providing mental health support, flexible working arrangements, and promoting work-life balance to improve workforce commitment in project delivery (Søvold *et al*., 2021).

6. Conclusion and Further Research

For more than a decade, workforce engagement and inclusion have emerged as concerns within the construction industry, particularly in the Western Cape Province. Leadership practices adopted by contractors in the Western Cape Province play a crucial role in enhancing workforce engagement and inclusion. This study aims to assess leadership practices that support workforce engagement and inclusion to enhance successful project delivery. The findings from this study reveal the following components of responsible leadership practices supporting workforce engagement and inclusion: inclusive workplace support, employee empowerment, social support, participative leadership, and workplace clarity. In conclusion, contractors who promote peer support foster camaraderie and trust, helping employees feel valued and supported by their colleagues, thereby improving productivity in construction project delivery. Also, a cultural awareness training equips employees with the skills to understand and appreciate diverse backgrounds, creating a more inclusive workplace. Encouraging a sense of ownership and community engagement inspires employees to take pride in their work and contribute positively both to the company and the community. As a result, leadership engagement, visibility, and prioritising employee well-being demonstrate a genuine commitment to employees' health and happiness, improving morale, strengthening loyalty across the organisation, and boosting workforce

productivity. Thus, this study recommends that construction leaders develop a focus on employee well-being through supportive policies and health initiatives to demonstrate the organisation's commitment to a healthy work-life balance, which can lead to improved job satisfaction, retention, and workforce productivity that leads to sustainable business performance in the construction industry of the Western Cape Province. Future research should extend this study to a broader geographical scope within South Africa and across different sectors of the built environment to enhance the generalisability of the findings. Additionally, further studies could employ qualitative or mixed-method approaches to gain deeper insights into how leadership engagement, employee well-being, and participative practices influence workforce productivity and organisational performance.

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Emotional Intelligence as a Catalyst for Resilient and Sustainable Construction Project Management in South Africa

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Abstract

The South African construction industry faces a dual challenge: the urgent need for sustainable built environments and the persistent complexity of socio-economic project volatility. While technical proficiency is well-documented, a significant knowledge gap exists regarding the specific behavioural drivers, such as Emotional Intelligence (EI), that enable Construction Project Managers (CPMs) to navigate these unique regional pressures. This study aims to evaluate the level of EI among CPMs and determine its role as a precursor to resilient project delivery. Specifically, the research objectives were to quantify current EI competencies and identify how these attributes underpin collaborative, sustainable outcomes. Guided by a positivist paradigm, the study employed a quantitative design using a structured, closed-ended questionnaire. A purposive sampling strategy targeted CPMs within the Durban metropolitan area. Of the 35 questionnaires distributed, 21 valid responses were received (60% response rate). Data were analysed using SPSS version 30 through descriptive statistical techniques. Findings suggest EI acts as a catalyst, providing the emotional infrastructure necessary to support the technical infrastructure. However, the study acknowledges the small sample size as a primary limitation; while the results provide a valuable localised snapshot, the findings lack broad generalisability. Consequently, the analysis and conclusions are presented as an exploratory foundation for larger-scale regional studies. The study concludes that integrating EI development into professional curricula and organisational strategy is essential for achieving the aim of a more resilient industry. By bridging the gap between "soft" leadership skills and "hard" sustainable outcomes, this research advances our understanding of the human-centric drivers necessary for the evolution of the South African built environment.

Keywords: construction, emotional intelligence, project managers, resilience, sustainable construction.

1. Introduction

The construction industry is widely recognised as one of the most complex and people-intensive sectors within the built environment, requiring project managers to operate in dynamic, uncertain, and multidisciplinary contexts (Aghimien & Aigbavboa, 2024; Watermeyer & Phillips, 2020). In South Africa, these demands are amplified by socio-economic pressures, regulatory shifts, and the growing imperative to deliver projects that are not only cost-effective and timely but also resilient and sustainable (Van der Waldt, 2024). Consequently, the role of the construction project manager (CPM) has evolved beyond technical and contractual proficiency to encompass broader leadership capabilities that enable effective navigation of human and organisational complexities.

Within this evolving landscape, emotional intelligence (EI) has emerged as a critical leadership competency. Defined as the ability to perceive, understand, regulate, and manage one's own emotions and those of others (Goleman, 1995), EI is increasingly linked to improved interpersonal relationships, communication, conflict resolution, and decision-making in project environments (Harinarain, 2025). These capabilities are particularly relevant in construction, where projects are characterised by diverse stakeholder groups, competing interests, and high-pressure interactions (Zhang & Hao, 2022). Empirical studies indicate that emotionally intelligent leadership enhances team cohesion, collaboration, and overall project performance (Zhang & Hao, 2022).

The relevance of EI is further heightened within the South African construction context. The industry continues to face persistent challenges, including skills shortages, labour instability, project delays, and safety concerns, alongside increasing expectations for sustainable construction practices (Harinarain, 2025; Van der Waldt, 2024). These conditions require CPMs to demonstrate resilience, adaptability, and empathy in managing project teams and stakeholder relationships.

Despite growing international recognition of emotional intelligence (EI) in project management, empirical research focusing specifically on its role among construction project managers (CPMs) in South Africa remains limited. Existing studies in the local context are relatively sparse and tend to be exploratory or narrowly focused, highlighting a broader lack of empirical

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evidence on EI within the construction sector (Aghimien & Aigbavboa, 2024; Harinarain, 2025). Furthermore, the dominant body of construction management literature in South Africa continues to prioritise technical competencies, procurement systems, and project controls, with comparatively less attention given to behavioural and emotional capabilities that underpin effective and resilient leadership (Aghimien & Aigbavboa, 2024; Smallwood et al., 2014).

Against this backdrop, this study investigates the level and perceived importance of emotional intelligence among construction project managers in Durban, South Africa. Adopting a quantitative approach, the research examines how EI manifests in practice and explores its potential contribution to key project outcomes, including productivity, stakeholder engagement, job satisfaction, and sustainable project delivery. By positioning emotional intelligence as a catalyst for resilient and sustainable construction project management, the study contributes to a more integrated understanding of how soft leadership competencies can influence hard project outcomes in the South African built environment.

2. Emotional Intelligence and Project Management

Originally conceptualised by Salovey and Mayer (1990), EI refers to the ability to perceive, understand, regulate, and utilise emotions to guide cognition and behaviour. Subsequent work by Goleman (1995) expanded the construct into leadership domains, positioning EI as a critical determinant of effective leadership performance.

Within project management, EI is increasingly recognised as a core competency that complements technical expertise. Project environments are inherently temporary, multidisciplinary, and often constrained by time, cost, and stakeholder pressures (Kerzner, 2022). These conditions demand that project managers navigate conflict, motivate diverse teams, and maintain stakeholder trust under pressure (Livesey, 2017). Empirical studies Rezvani et al. (2016) and Zhang & Hao (2022) consistently demonstrate that emotionally intelligent project managers exhibit stronger communication, improved conflict resolution, and enhanced team cohesion, all of which contribute to improved project outcomes.

In the construction industry, the relevance of EI is further amplified by its fragmented, stakeholder-intensive nature. Construction project managers (CPMs) must coordinate across professional boundaries, including architects, engineers, contractors, and clients, often in high-risk, high-pressure environments (Kerzner, 2022). As such, leadership effectiveness is not solely dependent on technical competence but also on the ability to manage interpersonal dynamics. Evidence suggests that EI significantly influences team effectiveness, collaboration, and overall project performance in construction settings (Aghimien & Aigbavboa, 2024; Zhang & Hao, 2022).

2.1. Emotional Intelligence, Resilience, and Sustainability in South Africa

Resilience has emerged as a critical concept within the built environment, traditionally associated with the capacity of infrastructure systems to withstand and recover from disruptions. However, contemporary scholarship increasingly frames resilience as a socio-technical construct that incorporates both system capabilities and human factors (Mahmud, 2017). In project contexts, resilience refers to the ability of individuals and teams to adapt, recover, and maintain performance under conditions of stress and uncertainty (Khosravi, et al., 2020).

The South African construction sector operates in a uniquely complex environment, shaped by socio-economic inequality, regulatory transformation, and industry-specific challenges such as labour unrest, skills shortages, and site disruptions (Watermeyer & Phillips, 2020). Additionally, policy imperatives, such as the Broad-Based Black Economic Empowerment (B-BBEE), require inclusive stakeholder engagement and socially responsive project delivery. These conditions necessitate leadership approaches that are both adaptive and relational. In such environments, leadership plays a pivotal role in shaping team resilience. Emotionally intelligent leaders are better equipped to regulate stress, respond constructively to conflict, and sustain team morale during periods of uncertainty ((Khosravi, et al., 2020). These capabilities enable project teams to maintain functional performance despite adverse conditions.

The relationship between EI and resilience is well established in the literature. EI enhances adaptive decision-making, emotional regulation, and relational trust, all of which are essential for resilient performance (Jordan & Troth, 2011). In construction, this linkage is particularly significant, as emotionally intelligent CPMs are more likely to demonstrate transformational leadership behaviours that foster team adaptability and long-term project sustainability (Mahmud, 2017). Accordingly, EI can be conceptualised as a human-centred resilience capability that supports both project continuity and sustainable outcomes.

Sustainability within this context extends beyond environmental considerations to include social and economic dimensions, often framed as the triple bottom line (Aghimien & Aigbavboa, 2024). However, the implementation of sustainable practices is frequently undermined by project instability and human conflict. EI plays a catalytic role in addressing these challenges

by enabling CPMs to foster collaboration, manage diverse stakeholder expectations, and maintain commitment to long-term project goals (Zhang & Hao, 2022).

Smallwood et al. (2014) and Sunindijo & Zou (2013) have also demonstrated that EI contributes to improved health and safety performance, a key dimension of social sustainability in construction. Project managers with higher EI are more effective in communicating safety protocols and cultivating a positive safety climate, thereby reducing accidents and enhancing workforce wellbeing (Sunindijo & Zou, 2013). In this sense, EI not only supports project performance but also underpins broader sustainability objectives.

By applying the WLEIS, this study moves beyond the general "soft skills" discourse and identifies exactly which emotional competencies enable CPMs to navigate the "construction mafia" and labour instability while maintaining a commitment to sustainable project delivery (Phakoana & Harinarain, 2025).

The intersection of emotional intelligence (EI), resilience, and sustainability within the South African construction sector represents a critical socio-technical nexus (Aghimien & Aigbavboa, 2024). This linkage is particularly significant, as emotionally intelligent CPMs are more likely to demonstrate transformational leadership behaviours that foster team adaptability and long-term project sustainability (Harinarain, 2025). Accordingly, EI can be conceptualised as a human-centred resilience capability that supports both project continuity and sustainable outcomes.

2.2. The Wong and Law Emotional Intelligence Scale (WLEIS)

Emotional intelligence has been conceptualised through several theoretical perspectives. Salovey and Mayer (1990) originally proposed EI as an ability involving the perception, understanding, and management of emotions. This work subsequently evolved into the Mayer-Salovey-Caruso Emotional Intelligence framework, which conceptualises EI as a set of cognitive-emotional abilities that can be objectively assessed (Mayer et al., 2004). In contrast, Bar-On (1997) views emotional intelligence as a broader emotional-social competency encompassing interpersonal skills, adaptability, stress management, and general well-being. While these frameworks have contributed significantly to the development of EI theory, the present study adopts the perspective operationalised through the Wong and Law Emotional Intelligence Scale (WLEIS) (Wong & Law, 2002). The WLEIS is grounded in the ability-based conceptualisation of EI and has been widely validated across cultural and professional contexts. It comprises four dimensions: Self-Emotion Appraisal (SEA), Others' Emotion Appraisal (OEA), Use of Emotion (UOE), and Regulation of Emotion (ROE).

The WLEIS is particularly suited to project-based environments due to its focus on how individuals perceive and utilise emotions to enhance performance and social interaction. In construction management, these dimensions can be directly linked to leadership effectiveness:

- Self-Emotion Appraisal (SEA): This refers to the CPM's ability to understand their deep emotions and express them naturally. In the volatile South African market, a CPM's ability to recognise their own stress triggers is the first step toward maintaining leadership stability (Watermeyer & Phillips, 2020).
- Others' Emotion Appraisal (OEA): This ability to perceive and understand the emotions of those around them is vital for managing diverse project teams and community stakeholders. High OEA allows CPMs to anticipate resistance or conflict before it escalates (Wong & Law, 2002).
- Use of Emotion (UOE): This involves directing emotions toward constructive activities and personal performance. For CPMs, UOE is a catalyst for resilience, enabling them to remain motivated and "bounce back" from systemic shocks, such as site disruptions or budget overruns (Zhang & Hao, 2022).
- Regulation of Emotion (ROE): This is the ability to regulate one's emotions to enable a more rapid recovery from psychological distress. ROE is arguably the most critical dimension for sustainability, as it prevents impulsive decision-making under pressure and ensures that long-term environmental and ethical goals are not sacrificed for short-term project gains.

These dimensions collectively provide a robust framework for understanding how emotional capabilities influence leadership behaviour and project outcomes. In high-risk environments such as construction, ROE and UOE are particularly critical, as they enable CPMs to maintain composure and motivation during disruptions, thereby supporting both resilience and sustainability objectives.

2.3. Knowledge Gap and Conceptual Positioning

Despite the growing international literature on EI in project management, there remains a limited empirical understanding of how these competencies manifest in the South African construction context. Professional frameworks, such as those of the South African Council for the Project and Construction Management Professions (SACPCMP), have historically prioritised technical competencies, with less emphasis on behavioural capabilities.

By integrating the WLEIS framework with resilience theory, this research contributes to a more nuanced understanding of leadership in the built environment. It

reframes resilience not only as a technical attribute of systems but also as a human capability rooted in emotional intelligence, thereby aligning with broader calls for more holistic and human-centred approaches to construction project management.

Furthermore, while the WLEIS has been widely applied in organisational research, its use within construction project management in South Africa remains limited. There is a lack of quantitative evidence on the emotional intelligence profiles of CPMs, particularly regarding resilience and sustainable project delivery. This study addresses this gap by advancing the argument that emotionally intelligent CPMs are better equipped to foster communication, manage conflict, sustain team cohesion, and build stakeholder trust. In doing so, EI serves as a catalyst that translates technical project plans into effective, sustainable execution.

3. Research Methodology

This study was underpinned by a positivist research paradigm (Creswell & Creswell, 2023). Given the study's objective of assessing the level and perceived importance of emotional intelligence among construction project managers, a quantitative research approach was considered most suitable. This approach enabled the researcher to collect standardised data and identify measurable patterns related to emotional intelligence within the selected professional cohort. Consequently, a deductive approach was adopted, testing the theoretical constructs of the Wong and Law Emotional Intelligence Scale (WLEIS) (Wong & Law, 2002) using a structured, closed-ended questionnaire as the primary data collection instrument. The WLEIS is a validated emotional intelligence instrument that measures four dimensions of emotional intelligence, namely self-emotion appraisal, others' emotion appraisal, use of emotion, and regulation of emotion. The use of an established instrument enhanced the content validity and reliability of the study.

The target population comprised construction project managers operating within the Durban metropolitan area. A purposive sampling strategy was employed to identify respondents with relevant professional experience and practical exposure to construction project management processes. A total of 35 questionnaires were distributed to eligible respondents. Of these, 21 valid questionnaires were returned, resulting in a 60% response rate. This response rate was considered adequate for exploratory quantitative analysis within the scope of this paper.

The completed questionnaires were coded and analysed using the Statistical Package for the Social Sciences (SPSS) Version 30. Descriptive statistical techniques were employed, including frequencies, percentages, mean scores, standard deviations, and ranking analysis. These techniques were used to summarise respondents' perceptions and identify patterns across the emotional intelligence dimensions measured in the study. Given the exploratory nature of the research and the relatively small sample size, the analysis was limited to descriptive statistics. No inferential statistical tests were conducted to establish causal or correlational relationships between variables.

Ethical integrity was maintained throughout the research process, and ethical clearance was obtained from the University's Research Ethics Committee prior to data collection. Participation was entirely voluntary, and respondents were provided with an informed consent letter outlining the study's purpose. These measures were implemented in line with standard ethical practices in social research (Creswell & Creswell, 2023).

A significant limitation of this study is the small sample size. Although 35 questionnaires were distributed, only 21 valid responses were received. While this rate is acceptable for exploratory research in the built environment, the small value limits the ability to perform complex inferential statistics. It reduces the generalisability of the findings to the broader South African CPM population. Consequently, these findings are presented as a localised study, providing a foundational evidence base for the Durban region rather than a definitive national profile.

4. Findings and Discussion

4.1. Demographic Information

The demographic profile of the participants provides essential context for the emotional intelligence (EI) scores, as factors such as age, experience, and education often influence the development of self-regulation and social skills (Wong & Law, 2002). The majority of respondents (57%) fell within the 36–50 age category, suggesting a mid-career professional cohort. Participants aged 25–35 accounted for 29%, while those aged 50+ accounted for 14%. In terms of gender, the sample remained heavily male-dominated (76%), reflecting the persistent gender disparity in South African technical and management roles in construction (Aghimien & Aigbavboa, 2024).

The sample reflected a high level of institutional memory and industry experience, with 48% of respondents having over 10 years of experience in construction project management, and 33% having 5-10 years. Only 19% were considered junior CPMs with less than 5 years of experience.

The respondents' educational level was notably high, aligning with the professional registration requirements of the SACPCMP: 52% held a postgraduate degree (Honours/Masters/PhD), 38% a degree or B-Tech, and 10% a National Diploma. The high prevalence of postgraduate qualifications suggests a cohort likely

exposed to theoretical management frameworks; however, as the literature review indicated, there remains a gap in the formal integration of psychometric training, such as the WLEIS dimensions, within these technical curricula (Table 1).

Table 1: Demographic Profile of Respondents

Variable	Category	Frequency (f)	Percentage (%)
Gender	Male	16	76%
	Female	5	24%
Age	25–35	6	29%
	36–50	12	57%
	51+	3	14%
Experience	< 5 Years	4	19%
	5–10 Years	7	33%
	> 10 Years	10	48%
Qualification	Diploma	2	10%
	Degree/B-Tech	8	38%
	Postgraduate	11	52%

4.2. WLEIS Results and Analysis

The analysis of the Wong and Law Emotional Intelligence Scale (WLEIS) provides an empirical baseline for the emotional competencies of the sampled construction project managers. The results are categorised into the four constituent dimensions of the scale.

4.2.1. Analysis of EI Dimensions

As illustrated in Table 2, the respondents demonstrated a relatively high overall level of Emotional Intelligence, though there are specific differences between "internal" appraisal and "external" regulation.

Table 2: Mean Scores and Standard Deviations for WLEIS Dimensions (n=21)

WLEIS Dimension	Mean	Std. Deviation (σ)	Ranking
Self-Emotion Appraisal (SEA)	4.12	0.58	1
Use of Emotion (UOE)	4.05	0.61	2
Others' Emotion Appraisal (OEA)	3.85	0.72	3
Regulation of Emotion (ROE)	3.62	0.84	4

Self-Emotion Appraisal (SEA) yielded the highest mean score (M=4.12). This suggests that Durban-based CPMs possess a strong ability to understand and express their own emotions. In the context of resilience, this is a foundational step; a self-aware manager is better equipped to recognise when they are reaching a state of burnout or "threat-rigidity" (Zhang & Hao, 2022).

The Use of Emotion (UOE) dimension followed closely (M=4.05). This indicates that the participants are highly capable of directing their emotions toward productive goals. This "catalytic" attribute is essential for sustainability, as it enables CPMs to remain motivated despite systemic shocks, such as supply chain disruptions (Aghimien & Aigbavboa, 2024).

Others' Emotion Appraisal (OEA) recorded a moderate-to-high mean (M=3.85). While positive, the lower score compared to SEA suggests a potential developmental gap in accurately perceiving the underlying emotional states of diverse project stakeholders. Given the socio-political complexity of South African construction sites, improving OEA is critical for mitigating conflict with local business forums and labour groups (Watermeyer & Phillips, 2020).

The Regulation of Emotion (ROE) dimension yielded the lowest mean score (M=3.62) and the highest standard deviation. This variation suggests that while many CPMs are self-aware, they struggle more significantly with the actual regulation of their emotions under duress. This is a critical finding: if a CPM cannot regulate distress during a "construction mafia" site invasion or a budget crisis, the project's resilience is compromised (Phakoana & Harinarain, 2025). The higher standard deviation indicates that emotional regulation remains a highly individualised and inconsistent skill within the profession.

4.2.2. Discussion: EI as a Catalyst for Resilience

Although the study primarily examined emotional intelligence from a project leadership perspective, the findings also have broader implications for sustainability within the built environment. Sustainable construction extends beyond environmental performance and encompasses social dimensions such as stakeholder engagement, workforce well-being, collaboration, and inclusive decision-making. The emotional intelligence dimensions identified in this study, particularly empathy, self-regulation, and social

skills, are directly relevant to these objectives. Construction project managers who demonstrate high levels of emotional intelligence are better positioned to foster positive working relationships, manage stakeholder expectations, resolve conflicts constructively, and create supportive team environments. These outcomes contribute to the social sustainability of construction projects by enhancing trust, reducing workplace tensions, and supporting long-term organisational resilience.

Furthermore, sustainable project delivery increasingly requires collaboration among diverse stakeholders with competing priorities. Emotional intelligence enables project leaders to navigate these complexities by facilitating communication and consensus-building. In this regard, emotional intelligence may be viewed as a leadership capability that supports not only project performance but also the broader sustainability agenda within the built environment.

Linking these results to sustainability, it becomes clear that technical knowledge of "green building" is insufficient if the CPM lacks the ROE to stick to these goals when a project falls behind schedule. As Wong and Law (2002) argue, EI dimensions are not static; they can be developed. Therefore, the "catalytic" potential of EI for a sustainable built environment in South Africa remains largely untapped due to a lack of formal behavioural training in the sector. The findings therefore suggest that resilient and sustainable construction depends not only on technological innovation and environmental management systems but also on the emotional and interpersonal competencies of those responsible for leading projects.

4.2.2.1 Navigating Systemic Shocks through ROE and UOE

The results indicated a high mean for Use of Emotion but a comparatively lower and more volatile score for Regulation of Emotion (ROE). In the South African context, where "construction mafia" disruptions and labour strikes are prevalent (Phakoana & Harinarain, 2025), resilience requires more than just knowing how to stay motivated (UOE); it requires the cognitive capacity to remain calm under extreme external pressure (ROE). According to Watermeyer and Phillips (2020), project failure in South Africa often stems from reactive decision-making during crises. The data suggests that while CPMs are personally driven, their ability to regulate distress, the "shield" of resilience, is the weakest link. As Wong and Law (2002) posit, leaders with lower ROE may struggle to recover from psychological burnout, which, in this study's context, directly threatens the long-term sustainability of the built environment.

4.2.2.2 Social Sustainability and the OEA Gap

Social sustainability in South Africa is defined by inclusive stakeholder management and the successful integration of local communities into the project lifecycle. The moderate score in Others' Emotion Appraisal (OEA) represents a critical bottleneck. Aghimien and Aigbavboa (2024) argue that the "human-centric" driver of construction performance is the manager's ability to read and respond to the site's emotional climate. A CPM with high OEA can detect rising resentment or anxiety among subcontractors and labourers before it manifests as a work stoppage. The findings suggest that Durban-based CPMs possess a "threshold" level of OEA. However, it has not yet reached the "catalytic" level required to fully de-escalate the unique socio-political tensions inherent in local infrastructure delivery.

4.2.2.3 The Feedback Loop: From SEA to Sustainable Outcomes

The highest score recorded was in Self-Emotion Appraisal (SEA), which aligns with the high educational and experience levels of the sample (52% postgraduate). This suggests that the sampled CPMs are highly reflective and self-aware. Literature suggests that SEA is the "engine" of the WLEIS model; without understanding one's own emotions, one cannot effectively regulate them or use them to influence others (Wong & Law, 2002). In terms of sustainability, this self-awareness enables CPMs to align their personal values with global green building standards. However, the study reveals a "decoupling" effect: while CPMs are self-aware (SEA) and motivated (UOE), the lack of consistent emotional regulation (ROE) prevents these internal values from consistently translating into resilient, sustainable external actions when the project environment becomes hostile.

4.2.2.4 Synthesis with the Knowledge Gap

These results directly address the knowledge gap identified in the introduction. While global literature (Zhang & Hao, 2022) emphasises the general importance of EI, this study localises that importance. It demonstrates that, in South Africa, EI acts as a catalyst, providing the "emotional infrastructure" necessary to support the technical infrastructure. The findings suggest that the industry's current resilience is "motivation-heavy" but "regulation-light." To achieve the aim of a truly sustainable built environment, the industry must transition from relying on individual grit among CPMs (UOE) to systematic, EI-driven conflict management and emotional regulation.

5. Conclusion and Recommendations

The primary aim of this study was to evaluate the level of Emotional Intelligence (EI) among Construction Project Managers (CPMs) in the Durban metropolitan area and to determine its role as a catalyst for resilient and sustainable project management. By applying the Wong and Law Emotional Intelligence Scale (WLEIS), the research has demonstrated that while CPMs possess high levels of Self-Emotion Appraisal (SEA) and Use

of Emotion (UOE), there is a critical deficit in Regulation of Emotion (ROE) and a moderate capacity for Others' Emotion Appraisal (OEA).

The study concludes that EI is indeed a functional catalyst for resilience; however, its current application in the South African construction sector is "motivation-heavy" but "regulation-light." In a landscape defined by socio-political volatility and the "construction mafia," the ability to remain motivated (UOE) is insufficient without the ability to de-escalate conflict (OEA) and maintain cognitive clarity under extreme duress (ROE). Therefore, achieving a truly sustainable and resilient built environment requires a shift from purely technical project management to a model that prioritises the emotional infrastructure of its leaders.

Beyond its contribution to project leadership, this study highlights the potential role of emotional intelligence in advancing the social dimensions of sustainable construction. The findings suggest that emotionally intelligent construction project managers are better equipped to create collaborative, inclusive, and resilient project environments. As the construction industry increasingly embraces sustainability principles, the development of emotional intelligence may serve as an important mechanism for strengthening stakeholder relationships, supporting workforce well-being, and enhancing the long-term sustainability of project outcomes.

The practical implications of the findings are significant for a range of stakeholders. Professional bodies, employers, construction firms, higher education institutions, and continuous professional development (CPD) providers can benefit from the results by incorporating EI-focused leadership development into training curricula and professional competency frameworks. Strengthening these competencies among current and future CPMs may improve project delivery, reduce conflict-related disruptions, and support more resilient leadership practices in the South African construction sector.

Based on the findings, the study recommends that:

- Professional councils and industry bodies such as SACPCMP should consider recognising emotional intelligence as a core managerial competency for project leadership accreditation and CPD;
- construction firms should integrate EI assessment and leadership coaching into management development initiatives;
- universities and professional training institutions within the built environment should embed emotional intelligence and resilience leadership into construction management curricula; and

While this study provides important insights, it was limited to a relatively small sample within the Durban metropolitan area. Future research should expand the scope to include other provinces and metropolitan regions in South Africa to enable broader comparative analysis.

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Assessing health and safety compliance and risk conditions in higher education buildings: A mixed-methods case study of a public university in the Free State, South Africa

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Abstract

Purpose: This study aims to assess health and safety compliance and risk conditions within buildings at a public higher education institution in the Free State Province, South Africa. Universities represent complex built environments where inadequate health and safety management can negatively affect user wellbeing, institutional performance, and regulatory compliance.
Design: A descriptive cross-sectional research design adopting a mixed-methods approach was employed to assess health and safety conditions within university buildings at a specific point in time. The mixed-methods approach integrated quantitative questionnaire surveys, qualitative semi-structured interviews, and building inspection checklists to obtain both numerical and experiential data. Semi-structured interviews were conducted with four purposively selected health and safety professionals to identify regulatory requirements, management practices, and key risk areas. Furthermore, completed questionnaires were obtained from 372 students and 235 staff members to assess perceptions of health and safety conditions within university buildings. A checklist was also used to evaluate building safety conditions.
Research Limitations and Implications: The study focuses on a single institution, which may limit generalisability. However, the findings provide context-specific insights applicable to similar public higher education institutions in South Africa.
Findings: The findings showed that while formal health and safety systems exist, their implementation across buildings is inconsistent. Key occupational hazards included blocked emergency exits, inadequate fire safety measures, poor ventilation, insufficient lighting, and ageing infrastructure. Non-compliance was associated with limited safety awareness, delayed maintenance, and weak monitoring, while management commitment supported better compliance. Existing control measures were present but inconsistently applied, reducing their effectiveness and resulting in uneven health and safety compliance across buildings.
Practical Implications: The study proposes evidence-based recommendations to strengthen health and safety management systems, enhance compliance monitoring, and support risk-informed decision-making in higher education facilities.

Keywords: Facilities governance, Institutional resilience, Occupant safety, Regulatory compliance, Risk prioritisation.

1. Introduction

Higher education institutions operate within complex environments that can handle a higher capacity of students, staff, and visitors, and they are mostly old and highly occupied structures. Becher and Kogan (2025) assert that the high capacity of the occupants presents a high risk of health and safety, which includes structural risks, fire hazards, inadequate maintenance, overcrowding, and insufficient emergency preparedness. Savolainen (2023) further indicates that these facilities accommodate large populations of students, staff, and visitors and therefore require effective health and safety management to ensure safe learning and working environments.

In South Africa, institutions are legally required to maintain safe working environments through compliance with occupational health and safety legislation. The Occupational Health and Safety Act (Act 85 of 1993) of South Africa requires employers to provide and maintain working conditions that are safe and without risk to the health of employees and other occupants (Republic of South Africa, 1993). In

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addition, the National Building Regulations and Building Standards Act (Act 103 of 1977) establishes requirements related to building safety, including ventilation, lighting, fire protection, and structural integrity (Republic of South Africa, 1977). Kovalenko *et al*. (2021) argue that despite the existence of these legislative frameworks, several higher education institutions face challenges in achieving consistent health and safety compliance within institutional buildings. Previous studies have shown that ageing infrastructure, inadequate maintenance practices, and fragmented organisational responsibilities contribute to safety deficiencies within university facilities (Loosemore *et al*., 2019).

University buildings present a wide range of potential hazards due to their diverse functions. These hazards may include slips, trips, and falls, electrical hazards, fire risks, poor ventilation, and inadequate lighting (Kong *et al*., 2013). If these hazards are not effectively managed, they may compromise the safety and well-being of building occupants and negatively affect the quality of learning environments (Almaskati *et al*., 2024). This study, therefore, assesses health and safety compliance and risk conditions within buildings at a public higher education institution in the Free State Province of South Africa. The study evaluates the current state of safety conditions, identifies hazards within institutional buildings, and examines factors influencing compliance with occupational health and safety standards.

2. Literature Review

Health and safety compliance in higher education learning buildings is critical, especially when supported by a well-structured health and safety management system and institutional leadership commitment (Mtikitiki *et al*., 2025). Universities that integrate safety into the governance structures demonstrate higher health and safety compliance because they are enforced and formalized rather than seen as voluntary. Higher education institutions with strong health and safety regulations, policies, responsibilities, and accountabilities are at the forefront of compliance. According to ISO 45001:2018, leadership commitment supports the integration of health and safety objectives into organisational strategy, resource allocation, and performance monitoring, thereby improving regulatory compliance. A Health and Safety Management System (HSMS) will help to clarify roles and responsibilities within a dynamic environment that involves various stakeholders. This will help to remove any ambiguity.

Furthermore, risk assessment and hazard identification provide the technical basis for proactive health and safety practices. Buildings in universities consist of laboratories, workshops, residences, offices, and public spaces, each of which provides distinctive hazards that consist of chemical exposure, electrical risks, overcrowding, and slips and falls. Systematic health and safety hazard identification enables the institutions to identify unsafe conditions before incidents occur and ensures regulatory compliance as per risk management requirements. Everett *et al*. (2021) state that organisations conducting regular risk assessment experience enhanced regulatory compliance since safety controls are implemented proactively rather than reactively. Furthermore, training, awareness, and safety culture also play a very crucial role in health and safety compliance. Even when the infrastructure adheres to the technical standards, non-compliance frequently arises from behavioural factors, which consist of unsafe practices, ignorance, and risk-taking attitudes. Cooper (2015) states that continuous safety education, which consists of inductions, signage, emergency drills, and student orientation, enhances shared understanding of responsibilities and enhances voluntary adherence to rules and regulations. In higher learning institutions, the transient student population makes awareness programmes particularly critical, as compliance depends on continuous awareness and participation.

The study was guided by the Plan-Do-Check-Act (PDCA) model, which served as the conceptual framework underpinning health and safety management within institutional buildings. The model supports continuous improvement through planning safety objectives, implementing control measures, monitoring compliance, and introducing corrective actions to improve institutional health and safety performance (Morgado et al., 2019).

3. Research Methodology

This study adopted a descriptive cross-sectional research design and applied a mixed-methods approach to assess health and safety conditions within university buildings. The mixed-methods approach integrated quantitative questionnaire surveys with qualitative semi-structured interviews and building inspection checklists to obtain both numerical and experiential data on health and safety conditions within institutional buildings. The research design was appropriate for assessing existing health and safety conditions within institutional buildings at a specific point in time. The cross-sectional design was appropriate because the study aimed to assess health and safety conditions and compliance levels as they existed during the period of data collection without manipulating the study environment. The research was conducted at a public higher education institution located in the Free State Province of South Africa. The campus consists of academic buildings, laboratories, administrative facilities, and student residences that are used daily by staff and students. The study population included students, staff members, health and safety professionals, and selected buildings on campus. A questionnaire survey was administered to students and staff to examine perceptions of health and safety

conditions within university buildings. The survey included 372 students and 235 staff members, representing individuals who regularly use institutional facilities. For the questionnaires, staff and students were recruited through convenience sampling while purposive sampling was used to select participants for the interviews. Semi-structured interviews were conducted with four health and safety professionals employed at the institution to explore regulatory requirements, management practices, and safety challenges affecting institutional buildings. Participants were purposively selected based on their involvement, experience, and responsibilities in institutional health and safety management practices. The study was approved by the Health Science Research Ethics Committee of the University of the Free State (UFS-HSD2024/2525/2502). Participation was voluntary, and confidentiality and anonymity of participants were maintained throughout the study. Quantitative data obtained from questionnaires were analysed using descriptive statistics, correlation analysis, regression analysis, and ANOVA tests, while qualitative interview data were analysed through thematic analysis in Atlas.ti.

4. Findings and Discussion

This section presents the findings of the study and discusses them in relation to occupational health and safety practices in higher education institutions. The findings are derived from three main data sources: questionnaire surveys administered to students and staff, semi-structured interviews with health and safety professionals, and Environmental Health and Safety (EHS) building inspection checklists conducted across selected buildings within the institution.

4.1. Observations

4.1.1. Health and Safety Compliance in Institutional Buildings

The results of the Environmental Health and Safety building inspections revealed that compliance with health and safety standards across the assessed buildings was partial rather than complete. Compliance scores ranged between 45% and 67%, indicating that several buildings did not fully meet the expected health and safety requirements.

The inspection checklist identified several recurring safety deficiencies within the buildings. These included expired fire extinguishers, blocked emergency exits, inadequate ventilation, poor lighting conditions, weak waste management practices, and insufficient safety signage. Such deficiencies pose potential risks to building occupants and highlight gaps between regulatory requirements and the actual condition of facilities (Table 1).

Table 1: Observed Safety Deficiencies in University Buildings

Safety Issue	Observed Condition	Potential Risk
Fire safety equipment	Expired or poorly maintained fire extinguishers	Increased fire risk and ineffective emergency response
Emergency exits	Blocked or poorly marked exits	Delayed evacuation during emergencies
Ventilation	Inadequate airflow in some buildings	Poor indoor air quality and discomfort
Lighting	Insufficient lighting in corridors and workspaces	Increased likelihood of accidents
Waste management	Inconsistent waste disposal practices	Environmental and health hazards

These findings indicate that although institutional health and safety systems exist, infrastructure maintenance and operational monitoring require improvement to ensure consistent compliance across buildings.

4.2. Questionnaire findings

4.2.1. Factors associated with compliance and non-compliance

The findings indicated that compliance was primarily driven by institutional conditions rather than individuals' attitudes and knowledge. Regression analysis showed that training, operational controls, and resource placement accounted for 89% of the variance in compliance. Meanwhile, perceptions like familiarity, feelings of safety, and institutional effectiveness lost predictive value when controlled for by structural variables. Tukamuhabwa (2012) asserts that compliance failures cannot be attributed to individual unwillingness but rather to insufficient institutional support and weak operational systems. Interviews corroborated these findings, with safety professionals describing leadership as reactive, communication as fragmented, committees as inactive, and follow-up on reported hazards as inconsistent. These findings suggest that the institution's governance systems were not adequately configured to support consistent compliance across buildings (Imrie & Street, 2009).

Limited engagement with students further exacerbated the compliance gap. Only 22% of students reported receiving safety training, while 89% were unaware of safe places, and 40.1% had never been informed about safety issues. Faculty-level disparities in staff perceptions and experiences, evidenced by significant ANOVA differences across measured variables, further illustrated inconsistent implementation of safety

programmes. These findings indicate that compliance was largely influenced by local management practices rather than uniform institutional standards.

4.3. Interview Findings

4.3.1. Influence and Motivation Factors for Compliance

The interviewees emphasized the impact of line managers in influencing staff compliance with safety practices, as individuals tend to follow the safety attitudes and practices adopted by line managers. This refers to a decentralised culture in which individuals are influenced by what is practised around them rather than what is practised in an organisation in general (Atkinson *et al*., 2000). Additionally, participants described compliance as largely reactive, noting that staff "become mindful only after injuries occur." This, in essence, shows a lack of proactive motivational strategies, which means that the safety behaviours are being triggered by incidents rather than reinforcement. The findings suggest that the institution is not providing sufficient positive reinforcement to sustain safety behaviours among employees. Safety is not integrated into institutional events, communication campaigns, or leadership messaging, limiting opportunities to shape user motivation (Lundgren & McMakin, 2018). The lack of behavioural reinforcement is especially detrimental when coupled with inadequate institutional controls and lack of leadership engagement. These factors, in combination, can create a situation in which motivation is lacking and a culture of episodic compliance persists.

The implications of this theme highlight the importance of cultural change and leadership modelling. Theoretically, the findings validate behavioural safety frameworks that highlight the importance of reinforcement and role modelling. In practice, safety should be incorporated into regular institutional communication, leadership briefings, and staff development activities. Policy alignment requires embedding safety expectations into managerial roles, ensuring that supervision meets OSHA requirements and conforms to ISO 45001 principles of worker participation and engagement.

5. Conclusion and Further Research

This study assessed health and safety compliance and risk conditions within buildings at a public higher education institution in the Free State Province of South Africa. The study was motivated by concerns regarding the gap that often exists between legislative health and safety requirements and the actual safety conditions experienced within institutional buildings. Factors such as leadership commitment, effective communication, availability of resources, and maintenance practices were identified as key determinants of safety performance within the institution. The results revealed that only 22% of students reported receiving safety training while the training of the staff was inconsistent. Based on these findings, institutions should implement mandatory safety training programmes for staff and students, strengthen routine building inspections, improve hazard reporting systems, and prioritise preventive maintenance to address recurring risks such as blocked emergency exits, expired fire extinguishers, and inadequate ventilation. The results of this study are expected to benefit several stakeholders within higher education institutions. University management and facilities management departments may use the findings to improve safety governance and infrastructure maintenance strategies.

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Mental Health in Construction Management: The Impact of Workplace and Organisational Culture

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Abstract

The purpose of this study was to determine how workplace and organisational cultures affected the mental health of construction managers. The study used an interpretivist paradigm and a qualitative approach to fully explore the participants' experiences concerning the phenomenon under investigation. Data were collected through semi-structured interviews with a purposive sample of 11 construction personnel working in managerial and supervisory roles on construction sites. The findings reveal that high workloads, tight deadlines, interpersonal pressures, and an organisational culture that discourages open discussions about mental health contribute significantly to stress, burnout, and emotional fatigue. The study further highlights the role of stigma and limited organisational support in exacerbating these challenges. However, the relatively small sample size limits the findings, potentially affecting the generalisability of the results. Despite this limitation, the study contributes to a growing body of knowledge about psychosocial risks in the construction industry and calls attention to the importance of organisational interventions that promote supportive work environments, improve workload management, and encourage mental health awareness.

Keywords: Construction Industry, Construction management, Mental health, Organisational Policy, Workplace Culture

1. Introduction

The construction industry plays a critical role in national economies and contributes significantly to economic growth (Adekunle et al., 2022). However, despite its importance, the industry faces a critical yet often overlooked challenge that extends beyond physical safety concerns namely, the mental well-being of construction personnels. While occupational health and safety (OHS) efforts have traditionally focused on physical hazards, increasing attention is being given to the psychological demands of construction work. For instance, Lingard & Turner, (2023) highlight that workers, particularly men, operate within a workplace culture that valorises endurance and toughness despite long hours, heavy workloads, and ongoing stress. This culture of stoicism discourages the acknowledgement of mental health challenges and contributes to outcomes such as depression and anxiety.

Construction workers experience significantly higher rates of mental health problems than national averages, with suicide rates in countries such as Australia and the United Kingdom reported to be two and three times higher, respectively (Chan et al., 2020). The causes of mental health in the construction industry could be rooted to factors such as excessive workloads, unrealistic deadlines, and job insecurity (LaMontagne et al., 2023). In South Africa, workers at moderate or considerable risk of harm were 80.0% and 77.0% less likely to present depressive symptoms, respectively (Zhang et al., 2025). It is further reported by the authors that in South Africa construction workers who were single or living with other adults without children had a significantly higher risk of depression compared to those in other forms of family relationships.

Mental health, as defined by Gautam (2024), refers to the absence of mental illness, the ability to function effectively in daily life, and a state of internal balance within one's social and physical environment. Poor mental health is associated with reduced work performance, non-compliance with safety regulations, and declining physical health (Lingard & Pirzadeh, 2025). In the construction industry, managerial roles are particularly vulnerable towards mental health. For instance, managers often face higher levels of burnout and depression than workers due to sustained responsibility, decision-making pressures, and performance expectations in construction (Tijani et al., 2021). These challenges are associated to psychosocial workplace risks, which Cox and Griffiths (2005) describe as harmful aspects of work design, organisation, and social framework. In the construction industry, such health risks include high psychological demands, time pressure, long working hours, and unpredictable schedules, all of which negatively affect job satisfaction and mental health (Lingard & Turner, 2023).

The research problem is the limited understanding of how workplace and organizational culture influence the

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mental health of construction managers. Despite increased attention to mental health in the construction industry, the specific interaction between organizational dynamics and managerial well-being remains underexplored. This study addresses the question: *"How do workplace and organizational culture in the construction industry affect the mental health of construction managers?"* Answering this question contributes to knowledge on psychosocial risks in managerial roles, informs interventions, and supports improved project performance, safety, and industry sustainability. Construction managers are critical, balancing the demands of clients, contractors, and teams while ensuring project delivery and profitability. In the South African construction industry, they face significant pressures from demanding schedules, resource constraints, stakeholder expectations, and economic uncertainties, making them vulnerable to psychosocial risks. Understanding the impact of culture on their mental health is essential, as their well-being directly influences decision-making, project performance, safety, and organizational sustainability.

2. Literature Review

In the construction industry, managers are expected to oversee demanding workloads, tight deadlines, and multiple tasks simultaneously, which places considerable pressure on their daily activities (Tijani et al., 2021). This level of demand frequently leads to high stress levels and emotional fatigue (Enshassi & Al. Swaity, 2015). According to Senaratne and Rasagopalasingam (2017), stress is intensified when managers lack adequate resources or support to meet project requirements, especially under strict deadlines and when overseeing several projects simultaneously. In addition, long working hours, broad responsibilities, and the need to coordinate different stakeholders increase the strain on managers and contribute to burnout (Selcuk, & Gundes, 2025). Taken together, these findings highlight how ongoing pressure and workload demands remain a persistent challenge for construction managers (Fisher et al., 2024).

Beyond workload, the general working conditions in construction add to the pressure experienced by managers (Zhang et al., 2020). The industry is characterized by long shifts, unpredictable working hours, and limited control over work processes, all of which contribute to fatigue, burnout, and even depression. In practice, this means that construction managers are often required to deliver results under difficult conditions, including unrealistic targets and constant time pressure. They are required to make rapid decisions, coordinate diverse teams, and manage complex stakeholder relationships, all of which can contribute to sustained mental strain over time. Consequently, the continuous demands and responsibilities associated with the role mean that project managers tend to experience higher levels of emotional fatigue than many other professionals in the industry (Wu et al., 2019).

The concept of burnout is useful in explaining the impact of these pressures. Burnout is understood as a state of emotional exhaustion, detachment from work, and a reduced sense of achievement, and it is common among construction managers and project teams (Bianchi & Schonfeld, 2025). High job demands, combined with limited organizational support and a lack of recognition, increase the risk of psychological strain and may even lead to employees wanting to leave the industry (Golzad et al., 2023). Job stress is also intricately linked to fatigue, with factors such as heavy workloads, tight deadlines, and pressure to perform identified as major contributors (Fitri & Budiyanto, 2023). These conditions demonstrate how workplace pressures can gradually affect both the mental health and overall well-being of construction professionals (Zhang et al., 2020).

Furthermore, the demanding nature of the construction industry continues to worsen mental health challenges in the industry. This is because long working hours, complex project requirements, and the constant need to meet performance expectations leave little room for rest and recovery (Wu et al., 2019). In the South African context, where additional pressures such as economic uncertainty and resource constraints may exist, these challenges can be even more pronounced. The interaction between these demanding work conditions and organizational factors, such as workplace culture and support systems, plays a significant role in shaping the mental health of construction managers. This section, therefore, demonstrates that mental health in construction is not only an individual issue but is strongly influenced by the working conditions, highlighting the need for a deeper understanding of how organizational culture and work conditions affect managerial well-being.

3. Research Methodology

3.1. Research design

Following Saunders et al., (2023), this study adopted an interpretivist research philosophy to explore the impact of the workplace and organizational culture on the mental health of construction managers. An interpretivist approach was appropriate because it allows for an in-depth understanding of participants' lived experiences, perceptions, and meanings related to workplace stress and mental well-being within the construction industry (Saunders et al., 2023). To capture rich, contextual insights from construction personnel directly involved in the construction project delivery. Thus, a qualitative research design was employed as explained by Creswell & Creswell (2023). The qualitative data were collected over two months, from August to September 2025, representing a cross-

sectional design that ensured sufficient engagement with participants to obtain detailed and reflective responses (Creswell & Creswell, 2023).

3.2. Research sampling

The research sample consisted of eleven (11) construction personnel working on construction sites in the Free State Province, the central region of South Africa. A purposive sampling strategy was used to select participants with relevant experience in managerial and supervisory roles within construction project delivery (Creswell & Creswell, 2023). The participants interviewed included a construction manager, foremen, a site engineer, a safety manager, and site supervisors, all of whom were directly exposed to the operational and organizational dynamics under investigation. To ensure confidentiality and ethical compliance, participants were anonymized and coded as P1 to P11. The selection criteria ensured that all participants possessed practical experience and decision-making responsibilities, enabling them to provide informed perspectives on workplace conditions and organizational culture (Table 1).

Table 1: Participants research sample

Code	Position	Total (No)	Percentage(%)
P1, P9, P11	Construction managers	3	27.27
P2, P8	Foreman's	2	18.18
P3	Site engineer	1	9.09
P4	Safety manager	1	9.09
P5,	Safety officer	1	9.09
P6, P10	Site agents	2	18.18
P7	Supervisor	1	9.09
Total		11	100.00

3.3. Data collection

Semi-structured interviews, as described by Saunders et al. (2023), were used to collect qualitative data, allowing participants to express their experiences and perceptions in a flexible, yet guided manner. Aligned with the research objective, interview questions explored workplace demands, organisational culture, and their influence on mental health. All interviews were conducted in a professional and confidential setting, recorded with participant consent, and transcribed for analysis. This approach ensured consistency while capturing depth and nuance in participant responses.

3.4. Data analysis

The data were analysed using thematic analysis, as recommended by Saunders et al. (2023), following a systematic process of coding, categorisation, and theme development. Initial codes were generated from the data and grouped into broader themes reflecting recurring patterns, including workload pressures, burnout, work-life imbalance, organisational culture, and interpersonal strain. To ensure traceability of responses while maintaining anonymity, participant codes (P1–P11) were used. Thematic analysis was selected for its suitability in identifying and interpreting patterns within qualitative data, especially for understanding complex social and organisational phenomena (Creswell & Creswell, 2023). This analytical approach provided a structured, yet flexible, framework to interpret how working environments and organisational culture shape the mental health outcomes of construction managers within the South African context.

4. Findings

This section uses thematic analysis to address the research question: *" How do workplace and organizational culture in the construction industry affect the mental health of construction managers?"* The first sub-question explored how high job demands and tight deadlines function as persistent sources of psychological distress. For instance, P1 stated that their role as construction manager or site agent *"affects their mental well-being in terms of managing high-pressure deadlines, ensuring safety on site, and dealing with unexpected issues like weather delays or material shortages."* P1's statement illustrates how operational pressures and uncertainty contribute to sustained psychological strain among construction managers.

P3 and P5 echoed P1's remarks, citing stress associated with coordinating multiple construction task teams, adhering to project budgets, and managing client expectations. These accounts demonstrate that operational uncertainty and constant time pressure create a construction work environment where mental fatigue accumulates, impacting managerial well-being. This assertion analytically shows how operational uncertainty and ongoing time constraints combine to produce a high-demand work environment where extended exposure to stressors causes cumulative mental exhaustion, which has a detrimental impact on construction managers' wellbeing.

Regarding the second sub-question, participants associated emotional exhaustion and burnout with long working hours and continuous performance pressure. P2, for example, explained they felt *"emotionally drained or burnt out due to work, especially during long hours on site or when projects don't go as planned."* This result indicates a close link between

work-life imbalance and these experiences; professional duties often encroach on personal time, leaving little opportunity for rest or recovery. This overlap between work and personal life underscores the intensity of occupational stress in construction management and highlights the psychological toll of prolonged exposure to high-demand roles.

The analysis also revealed that cultural attitudes and the stigma surrounding mental health significantly affect construction managers' psychological well-being. Participants indicated that the prevailing *"tough it out"* culture discourages open discussions about mental health challenges, fostering a perception of vulnerability as weakness. This is especially true for construction project leaders, who are already responsible for the project's physical and technical demands. As P4 is quoted saying, *"leadership is not very open to conversations about mental health,"* and P5 added that *"stress is seen as part of the job."* These comments suggest that organizational norms and cultural expectations actively inhibit help-seeking behaviours, leaving managers and foremen without sufficient support. The stigma associated with mental health not only hinders the recognition of stress-related issues but also can intensify emotional strain by discouraging individuals from seeking coping resources.

Interpersonal dynamics and conflict also emerged as a major source of stress. For instance, P9 is quoted saying *"dealing with conflicts between team members"* is a significant contributor to workplace strain, highlighting the complex social interactions that managers must navigate alongside their operational duties on construction sites. P9 stated that "dealing with conflicts between team members" significantly contributes to workplace stress, highlighting the complex social dynamics managers must navigate alongside their operational duties on construction sites. Construction managers are responsible for managing subcontractors, supplies, and construction personnel, as well as external stakeholders such as local government leaders and community forums.

P11 details how the combination of high-stakes responsibilities, complex coordination, and interpersonal conflict contributes to cumulative mental fatigue among construction managers. In summary, the consistent recurrence of stigma, interpersonal pressure, work-life imbalance, burnout, and excessive workload across participant interviews reveals the extent to which organizational structures and cultural norms are implicated in the mental health challenges faced by construction management. This consistency suggests that these issues are systemic, rather than isolated incidents, highlighting the need for organizational interventions within the construction industry that address work design and foster cultural change.

5. Discussion

The findings from construction personnel, as presented in the previous section, corroborate existing studies that identify high job demands and excessive workloads as major contributors to mental health challenges among construction managers (Tijani et al., 2021). Participants highlighted persistent project pressures, tight deadlines, and the responsibility of balancing client expectations with organisational profitability, reflecting the demanding nature of construction management. While previous studies have acknowledged workload-related stress, this study contributes new knowledge by contextualising these pressures within the South African construction industry, where resource constraints, economic uncertainty, skills shortages, and project delivery challenges intensify managerial stress. The findings therefore extend existing literature by demonstrating that construction managers experience a unique combination of operational, financial, and stakeholder-related pressures that increase their vulnerability to emotional exhaustion and burnout. Consequently, structured workload allocation, realistic scheduling, and effective task prioritisation are necessary to reduce excessive demands and support sustainable managerial performance (Lingard & Pirzadeh, 2025).

The study further reveals that organisational culture plays a significant role in shaping the mental well-being of construction managers. Participants described workplace environments characterised by a prevailing “tough it out” mentality, where expressing stress or seeking psychological support is often perceived as a sign of weakness. Although similar observations have been reported in international studies (Golzad et al., 2023), this research contributes new empirical evidence from South Africa, highlighting how cultural norms within construction organisations discourage discussions about mental health among managerial personnel. Importantly, the findings show that construction managers occupy a neglected position within organisational well-being initiatives, despite carrying substantial responsibility for project delivery, safety compliance, and profitability. This contribution is particularly significant because mental health research in the South African construction industry has traditionally focused on workers and safety outcomes, with limited attention given to managerial psychosocial well-being. The findings therefore underscore the need for leadership development programmes, psychological safety initiatives, regular mental health assessments, and confidential support systems tailored specifically for construction managers.

Furthermore, the study demonstrates that the mental health of construction managers is influenced by a complex interaction of workload pressures, organisational culture, interpersonal relationships, and the high-risk nature of construction projects. This

finding advances current knowledge by illustrating that managerial mental health challenges cannot be adequately addressed through workload reduction alone. Instead, they require a holistic organisational response that addresses structural, cultural, and relational factors simultaneously. The evidence suggests that conflict resolution training, team-building initiatives, improved communication channels, and formal mental health policies can help alleviate stress arising from interpersonal and organisational pressures (Wu et al., 2019). By identifying the interconnected nature of these factors, the study provides a more comprehensive understanding of psychosocial risks affecting construction managers in South Africa. This represents a meaningful contribution to the construction management body of knowledge, as it positions managerial mental health as a critical yet underexplored determinant of project performance, safety outcomes, employee well-being, and long-term industry sustainability.

6. Conclusion

This study's findings indicate that the mental health of construction managers is significantly affected by the interplay of a demanding work environment and organizational culture. Specifically, high workloads, time pressures, interpersonal strain, and the prevailing stigma against discussing mental well-being contribute to this impact. Furthermore, the study underscores the necessity of a more holistic approach to managing psychosocial risks within the construction sector. To that end, construction organizations should implement structured workload management, promote realistic project scheduling, and foster supportive leadership that encourages open communication about mental health. Providing access to employee assistance programs and counselling services is also crucial. However, this study is limited by its small sample size, potentially restricting the generalizability of its findings. Future research should, therefore, expand the sample size and incorporate diverse organizational contexts to strengthen the evidence base and offer more comprehensive insights into improving mental health outcomes in the construction industry.

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Improving Construction Education Pedagogy in South Africa

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Abstract

Globally, improving teaching and learning practices in higher education remains a priority because of the critical role graduates play in economic growth and industry development. However, there is limited empirical evidence on pedagogical strategies that effectively enhance undergraduate learning experiences in construction education, particularly within the South African Architecture, Engineering and Construction (AEC) context. This study investigated the pedagogical strategies perceived as most effective for improving teaching and learning in construction-related disciplines at the Durban University of Technology, South Africa. A quantitative research approach was adopted, using a structured questionnaire administered to 97 participants. Data were analysed using Mean Item Score (MIS) analysis to evaluate and rank the effectiveness of the identified pedagogical strategies. The findings showed that all evaluated strategies achieved mean scores above 3.50, indicating positive perceptions of their effectiveness in enhancing teaching and learning. The five highest-ranked strategies were providing students with opportunities to ask questions (MIS = 4.56), using student questions and responses to facilitate collective learning (MIS = 4.39), ensuring fairness in assessment and marking (MIS = 4.38), providing assessment plans with clearly defined deadlines (MIS = 4.26), and encouraging students to develop a deeper interest in the subject matter (MIS = 4.23). The findings highlight the importance of interactive learning, transparent assessment practices, and student-centred pedagogical approaches in strengthening construction education. The study contributes context-specific evidence to the construction education literature and offers practical insights to enhance teaching effectiveness and student learning outcomes in the AEC sector.

Keywords: Construction, Education, Learning, Pedagogical approaches, Teaching.

1. Introduction

The higher education landscape has undergone a significant transformation over the past few decades, driven by changing societal needs, technological advancements, and rising demands for graduate employability (Bennett,2019). Consequently, traditional lecturer-centred approaches, in which lecturers are regarded as the primary source of knowledge and students as passive recipients, have gradually been replaced by student-centred learning environments that emphasise active engagement, collaboration, critical thinking, and knowledge construction (Hou, Lai and Wu, 2023; Loyens and Rikers, 2011). This shift is largely influenced by constructivist learning theory, which views learning as an active process through which students develop understanding by connecting new information to prior knowledge and experiences (Bayram-Jacobs and Hayırsever, 2016). Student-centred pedagogy is commonly associated with participatory, democratic, inquiry-based, and exploratory teaching approaches that encourage learners to actively participate in the learning process rather than passively receive information (Tabulawa, 2003; Tang, 2023). In such learning environments, students assume greater responsibility for their learning, while lecturers facilitate learning through guidance, support, and the creation of meaningful learning experiences. According to O'Neil and McMahon (2015) and Harris and Cullen (2010), Lecturer-centred and student-centred pedagogies represent two contrasting educational paradigms. In lecturer-centred environments, authority and decision-making are primarily concentrated in the lecturer, whereas in student-centred environments, learners have greater autonomy, participation, and influence over their educational experiences (Tang, 2023). In student-centred learning, students are encouraged to take an active role in the learning process by engaging with materials, collaborating with peers, and interacting with instructors to construct knowledge and deepen understanding. Ideally, student-centred learning empowers students to take responsibility for their own learning by shaping aspects of their experiences, identifying learning needs, and actively participating in determining their learning pathways. This approach promotes critical thinking, independent learning, problem-solving skills, and meaningful engagement with the subject matter.

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The growing emphasis on student-centred learning reflects broader concerns regarding the preparedness of university graduates for contemporary professional environments. Employers increasingly seek graduates who possess not only disciplinary knowledge but also critical thinking, problem-solving, communication, teamwork, and lifelong learning skills (Bennett, 2019). These competencies are particularly important within the Architecture, Engineering and Construction (AEC) sector, where professionals must operate in multidisciplinary environments characterised by rapid technological change, complex project requirements, and evolving industry expectations. As a result, higher education institutions are under increasing pressure to adopt pedagogical approaches that effectively support the development of these competencies and enhance student learning outcomes (Chan et al., 2017). Although student-centred pedagogies have been widely explored across higher education, empirical research has yet to examine the pedagogical strategies that most effectively enhance teaching and learning in construction education in South Africa. Existing studies have largely focused on general higher education or engineering education contexts, with comparatively little attention given to the unique learning requirements and educational challenges associated with construction-related disciplines (McCord et al 2023).

Despite growing interest in improving higher education pedagogy, there is limited evidence regarding the pedagogical strategies that students perceive as most effective within the South African Architecture, Engineering and Construction (AEC) context. Addressing this gap is important for enhancing teaching effectiveness and graduate preparedness. This study investigates and ranks the pedagogical strategies perceived as most effective for improving teaching and learning within the AEC discipline at the Durban University of Technology, South Africa, with the aim of providing practical recommendations for strengthening construction education pedagogy and student learning outcomes.

2. Literature Review

Constructivist learning theory is a dominant framework underpinning contemporary higher education pedagogy. Unlike traditional transmission-based approaches, constructivism views learning as an active process in which learners construct knowledge through interaction, reflection, and experience, rather than passively receiving information from instructors (Bada, 2015). From this perspective, students actively participate in knowledge creation, while educators facilitate learning through guidance and the design of meaningful learning experiences (Tang, 2023). As a result, effective teaching is increasingly measured by its ability to promote student engagement, critical thinking, and knowledge construction. The application of constructivist principles has received significant attention within Architecture, Engineering and Construction (AEC) education due to growing industry demand for graduates capable of solving complex problems, collaborating across disciplines, and adapting to technological change. Gier (2008) and Hamid and Dossick (2016) argue that AEC educators should facilitate experiential learning opportunities that enable students to develop knowledge through practice and reflection, rather than relying solely on theoretical instruction. While active learning approaches are widely recognised as beneficial, their implementation and effectiveness within AEC programmes, particularly in developing countries, remain underexplored.

Experiential and collaborative learning have consistently been identified as effective strategies for improving student engagement and knowledge retention. Russell et al. (2014) found that case-based learning enhances students' understanding of real-world problems and professional practice. Similarly, Shenton et al. (2014) and Mathews (2013b) reported that team projects, online discussion platforms, and knowledge-sharing activities strengthen peer learning and classroom interaction. Collectively, these studies suggest that collaborative learning environments promote deeper learning than passive instructional approaches. However, most of this evidence originates outside South African construction education, limiting its contextual relevance. Despite increasing criticism, traditional lecturer-centred approaches remain prevalent in many educational settings. Conventional methods such as lectures, note-taking, and rote memorisation position students as passive recipients of knowledge and may limit the development of higher-order cognitive skills (Luo and Mojica Cabico, 2018). In AEC education, these approaches have traditionally focused on developing explicit knowledge through manuals, technical instruction, and standard operating procedures (Khuzaimah and Hassan, 2012; Hartless et al., 2020). Although explicit knowledge is important, Hartless et al. (2020) argue that tacit knowledge acquired through practical experience is equally essential for industry readiness, highlighting a key limitation of traditional pedagogies.

The integration of educational technologies has been proposed as a means of addressing these shortcomings. Studies have shown that technology-enhanced learning can improve student engagement, understanding, and academic performance when effectively integrated with traditional teaching methods (D'Souza et al., 2013; Turan et al., 2018; Tayeh et al., 2020; Patil et al., 2020). However, technology alone does not guarantee improved learning outcomes, as its effectiveness depends on how it supports active learning and student engagement. While existing studies support student-centred and technology-enhanced pedagogies, limited empirical evidence exists regarding the pedagogical

strategies most valued by students within South African AEC programmes. Therefore, this study investigates and ranks the pedagogical strategies perceived as most effective for improving teaching and learning within the AEC discipline at the Durban University of Technology, South Africa.

3. Research Methodology

This study began with a review of academic literature on pedagogical approaches to teaching and learning within the Architecture, Engineering and Construction (AEC) discipline. Insights from the literature informed the development of a structured questionnaire to investigate the effectiveness of pedagogical strategies in the AEC context. A quantitative research design was adopted, as the study aimed to systematically collect and analyse students' perceptions of various pedagogical strategies. Quantitative approaches are widely used in educational and social science research to measure attitudes, perceptions, and experiences across a defined population and to facilitate statistical analysis of collected data (Creswell and Creswell, 2017; Saunders, Lewis and Thornhill, 2019). The target population comprised 149 students enrolled in the Construction Studies programme at the Durban University of Technology, Midlands Campus, South Africa. A purposive sampling strategy was used because the selected participants had direct experience of the teaching and learning practices under investigation. The questionnaire was administered electronically via Google Forms and distributed to the target population. A total of 97 valid responses were received, representing a response rate of 65.1%. The questionnaire used a five-point Likert scale, where 1 = strongly disagree, 2 = disagree, 3 = neutral, 4 = agree, and 5 = strongly agree. Before the main survey, a pilot study was conducted to assess the clarity and relevance of the questionnaire items. Feedback from the pilot study led to minor revisions to improve the instrument's validity and reliability. Participation in the study was voluntary, and respondents were informed of the research purpose before completing the questionnaire. Anonymity and confidentiality were maintained throughout, and no personally identifiable information was collected. The data were analysed using the Mean Score (MS) technique to determine the relative importance of the identified pedagogical strategies. The measurement instrument's reliability was assessed using Cronbach's Alpha, which yielded a coefficient of 0.947, indicating excellent internal consistency and confirming the data's reliability. The identified pedagogical strategies were subsequently ranked by mean score to determine the most effective approaches for enhancing teaching and learning in the AEC discipline. Although Mean Score analysis was appropriate for achieving the study objective of ranking pedagogical strategies, reliance on descriptive statistics and purposive sampling may limit the generalisability of the findings. Future studies should consider broader sampling approaches and more advanced statistical analyses.

4. Findings and Discussion

Table 1 presents the demographic characteristics of the respondents. Among the 97 participating students, 50 were female, and 47 were male. The age distribution shows that 20.6% of respondents were within the 16–18 age bracket, while 79.4% were between 19 and 23 years old. This distribution reflects the typical age profile of students enrolled in Level 1 and Level 2 of the Construction Studies programme at Durban University of Technology (DUT).

Table 1: Demographic characteristics

Gender	**Freq**	**percent**
Male	47	48.5
Female	50	51.5
Age		
16-18	20	20.6
19-23	77	79.4
Total	97	100

Source: (Author, 2026)

Table 2 in Appendix 1 presents the mean scores (MS) of the variables used to evaluate strategies for improving construction pedagogy, ranked from highest to seventh. The results indicate that giving students the opportunity to ask questions recorded the highest mean score (MS = 4.56), ranking first among the evaluated strategies. This is followed by using students' questions and answers to facilitate collective learning (MS = 4.39), which ranked second. Fairness in the awarding of marks ranked third with a mean score of 4.38, while providing an assessment plan with clearly defined due dates ranked fourth (MS = 4.26). Furthermore, encouraging students' interest in learning more about the subject ranked fifth with a mean score of 4.23. Explaining the relevance of the subject to the work environment ranked sixth with a mean score of 4.15, and the educator demonstrating enthusiasm for the subject area ranked seventh with a mean score of 4.12.

The findings are consistent with previous studies that highlight the influence of lecturers' attitudes and classroom practices on effective teaching and learning.

For example, Westbrook et al. (2023) and Nkambwe and Essilfie (2022) found that lecturers who use interactive pedagogical approaches are more likely to create engaging learning environments that encourage active student participation. The high ranking of strategies such as providing opportunities for students to ask questions, facilitating collective learning through discussion, and ensuring fairness in assessment indicates that students value learning environments characterised by openness, inclusivity, and meaningful engagement. These findings support the work of Braund et al. (2013) and Chisholm and Wildeman (2013), who emphasised the importance of learner-centred approaches in improving student engagement and educational outcomes. Similarly, the findings align with those of Epstein and Yuthas(2012) and Han and Wang (2010), who highlighted the value of constructive feedback, active participation, and supportive learning environments in enhancing student learning. Within the AEC discipline, these findings are particularly important because graduates are expected to develop not only technical knowledge but also communication, teamwork, problem-solving, and critical thinking skills essential to professional practice (Butt, 2024). Strategies that encourage questioning, discussion, and active engagement help students develop these competencies and deepen their understanding of complex construction-related concepts. Therefore, the findings suggest that effective AEC pedagogy should extend beyond content delivery and focus on creating interactive learning environments that prepare students for the collaborative and dynamic nature of the construction industry.

5. Conclusion and Further Research

This study aimed to find effective ways for enhancing teaching and learning in higher education, specifically within the AEC field. The findings indicate that all proposed strategies achieved mean scores above 3.5, suggesting that respondents consider them effective for improving pedagogical practice. Therefore, the results underscore the importance of interactive, transparent, and well-structured teaching practices, including encouraging students to ask questions, using classroom dialogue to support collective learning, ensuring fairness in assessment, providing clear assessment plans, and linking course content to real-world work environments. From a practical perspective, the study revealed that lecturers can enhance student engagement and learning outcomes by adopting these strategies in their daily teaching. Creating opportunities for student participation, maintaining fairness and clarity in assessment processes, and demonstrating enthusiasm for the subject can foster a more supportive learning environment and enhance the overall quality of instruction in AEC programmes. This finding adds to the existing body of knowledge by providing empirical evidence on the pedagogical strategies most valued by students in the South African AEC context. While the findings support established student-centred learning principles, they offer context-specific insights that can inform pedagogical practice and curriculum development in construction education. However, A limitation of this study is the use of purposive sampling within a single Construction Studies programme at Durban University of Technology. Consequently, the findings may not be fully generalisable to other institutions or disciplines. Future studies should use larger, multi-institutional samples and probability-based sampling techniques.Nevertheless, the strong internal consistency of the responses and the consistently high ratings across all strategies lend credibility to the findings. Future studies should broaden their scope by including a larger, more diverse sample of students and educators across different higher education institutions and AEC programmes. Such research would provide further evidence of the relevance of these strategies and support their wider application to improve teaching and learning in higher education.

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Appendix 1

Table 2: The strategies for improving construction education pedagogy

Code	Variables	Mean score	Std D	Rank
CETL 9	Gives students the opportunity to ask questions	4.56	0.957	1
CETL 10	Uses students' questions and answers to help everyone learn	4.39	0.974	2
CETL 25	Fairness in awarding of marks.	4.38	1.103	3
CETL 19	Provides an assessment plan with due dates	4.26	1.034	4
CETL 7	Makes me want to learn more about the subject	4.23	1.036	5
CETL 6	Explains the relevance of this subject to the work environment	4.15	1.121	6
CETL 14	Educator enthusiastic about this subject area	4.12	0.982	7
CETL 21	Provides feedback within 10 working days or as set out in the study guide	4.12	1.023	7
CETL 23	Provides learning materials that help me learn	4.09	1.081	8
CETL 18	Provides clear guidelines for assessments	4.08	1.106	9

Code	**Variables**	**Mean score**	**Std D**	**Rank**
CETL 22	Provides useful feedback to help me learn	4.07	1.028	10
CETL 2	Keeps to the time allocated for the class	4.05	1.045	11
CETL 3	A thorough explanation of how the sections of the subject are linked together	4.03	1.075	12
CETL 8	Uses a style of questioning that encourages me to respond	4.02	1.181	13
CETL 24	Provides useful sources of information for reference	4.01	1.046	14
CETL 13	Educator approachable	4.01	1.094	14
CETL 5	Uses several methods of teaching to help me	4	1.19	15
CETL 12	Uses visual aids to help me learn	3.95	1.112	16
CETL 20	Uses several methods of assessment	3.94	1.116	17
CETL 4	Communicates clearly and audibly	3.92	1.196	18
CETL 1	Effective and efficient preparation for class and learning period	3.88	0.938	19
CETL 16	Educator available in consultation times outside of class	3.8	1.151	20
CETL 11	Shows me how to improve the way I learn	3.78	1.135	21
CETL 15	Gives me the opportunity to work as a member of a group or pair	3.77	1.203	22
CETL 17	Educators inform me where to get help, for example, at student counselling.	3.71	1.172	23

Source: (Author, 2026)

Integrating Human Factors into Safety, Health, Environment, and Quality (SHEQ) Management Systems to Enhance Operational Efficiency

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Abstract

This study examines how human factors, particularly leadership commitment and employee engagement, affect the operational effectiveness of Integrated Safety, Health, Environment and Quality management systems. The SHEQ management systems are structurally standardised through High-level Structures (HLS), but they often fail to reach full maturity due to an insular focus on technical compliance that excludes human-system interactions. Adopting a systematic literature review directed by PRISMA principles, this paper synthesises 35 peer-reviewed papers from Google Scholar and ScienceDirect published in the period 2014 to 2025. The thematic synthesis sets out four core pillars: structured leadership accountability, collaborative communication, participative learning cultures and cross-functional training. Premised on these findings, we propose a Human-Centred SHEQ Framework that comprises three structural dimensions. These are: the strategic levers, which include executive safety-linked accountability; the operational glue, which entails multi-employer shared communication protocols; and, lastly, the socio-technical enablers, which comprise digital learning dashboards and predictive human reliability observation metrics. This study seeks to integrate fragmented research into a practical, actionable framework specifically designed for emerging economies grappling with institutional isomorphism. This provides clear pathways to simultaneously attain regulatory compliance and operational resilience in South Africa and comparable contexts.

Keywords: Employee Engagement, Human factors, Leadership commitment, Operational Efficiency, SHEQ Management systems

1. Introduction

Human Factors has evolved from a secondary consideration in safety science to a key determinant of performance in Integrated Management Systems (IMS). Within the scope of this study, human factors (HF) are defined as the multi-dimensional behavioural, cognitive, and social interactions between individuals and the structural components of an organisation's operational design (Azman & Kelana, 2024). This definition precisely differentiates the work from the broader organisational culture studies by specifically analysing systemic touchpoints where human behaviour directly changes technical compliance outcomes, such as hazard reporting accuracy, error probability during automation and procedural adaptation during disruptions.

Despite the critical role anchored by the human factors, many South African organisations continue to view compliance with ISO 9001, ISO 14001 and ISO 45001 as an inflexibly rigid, bureaucratic auditing exercise. This focus on the technical checkboxes usually neglects human variables such as risk-based thinking, open communication and workforce morale, nourishing an operational paradox, a situation where organisations show high levels of structural compliance on paper while in fact grappling with recurrent safety failures, quality defects and high incident downtime.

Hence, this study specifically addresses this clear operational gap. Primarily, the key objective of this study is to answer the following core research question: How can factors be systematically integrated into standardised *SHEQ management frameworks to resolve the tension between structural compliance and operational efficiency?* Delving into the fragmented global and local prior studies, this research intends to provide leaders of organisations in South Africa and similar developing contexts with a contextualised, empirical framework that has the ability to transform SHEQ systems from inflexible, rigid monitoring tools into proactive drivers of socio-technical learning and organisational resilience.

2. Literature Review

2.1. Conceptual Evolution and Tensions in SHEQ and IMS

The evolution of SHEQ management has shifted significantly from the traditional mindset of rigid compliance and reactive physical inspections to a focus on organisational learning and system integration. High-income countries have historically relied on management systems such as ISO 9001 (Quality) and

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ISO 14001 (Environment) to drive performance management and accountability (Darabont et al., 2019). However, operating these systems independently often resulted in organisational silos, administrative redundancy and conflicting internal goals.

To address the structural fragmentation, the International Organisation for Standardisation introduced the High-Level Structure (HLS) in 2015. The HLS promoted alignment across different standards (ISO, 2021). While proponents see this as fostering coherence, critics argue it may undermine genuine integration if not properly assimilated (Reason, 2020; Nunes & Silva, 2023).

Evidence indicates that multi-certified organisations experience efficiency gains, but actual integration depends on workforce participation and leadership engagement (Darabont et al., 2019; Nunes & Silva, 2023). When management treats Integrated Management Systems as mere auditing tools, employees may view them as bureaucratic barriers. In contrast, organisations embracing Systems Thinking and cross-functional learning tend to achieve better quality and safety outcomes (Hollnagel, 2014; Senge, 1990). Thus, the debate highlights that IMS can serve as either a tool for compliance or a means for socio-technical learning, influenced by the integration of human factors within the organisation.

2.2. IMS Implementation in Emerging Economies

In emerging and developing economies, the adoption of SHEQ frameworks has been accelerated largely by global supply chain mandates, the pursuit of international export competitiveness, and donor-funded certification programs (Aboelsoud, 2022; Hesham et al., 2025). However, critical questions persist regarding whether these adoptions represent genuine socio-technical integration or merely surface-level administrative conformity. DiMaggio and Powell (1983) conceptualised this discrepancy through institutional isomorphism, in which organisations superficially imitate global standards solely to gain external legitimacy without any authentic intent to change their internal operational behaviours. Aboelsoud (2022) found that many hotels obtained multiple certifications without authentic participation mechanisms, and compliance was merely a response to audits. Hesham et al. (2025) noted that while some firms in North Africa and the Middle East saw initial improvements in occupational safety and health post-IMS implementation, these gains faded once external support ended.

The studies that rely on self-reported compliance metrics fail to account for cultural and behavioural factors, making efficiency claims difficult to validate. Contrary to the view that certification equals integration, scholars who oppose this view argue that true IMS maturity requires behavioural alignment, leadership, and employee engagement (Nunes & Silva, 2023; Reason, 2020).

Conversely, when emerging organisations move past inflexible and rigid Western blueprints and embed a risk-based mindset, custom training programmes and open workforce feedback directly into their operational workflows, even the resource-constrained organisations manage to secure sustainable quality improvements and incident reductions (Borzi et al., 2025).

2.3. The South African Trajectory: Governance vs. Performance Paradox

South Africa presents a highly significant regulatory environment characterised by an advanced corporate governance that coexists with severe operational fragmentation on the ground. Now, driven by the extensive mandate of the King Code IV Report on Corporate Governance, alongside critical statutory alignments with ISO 45001 and ISO 14001, key domestic organisations in the high-risk sectors, such as the mining, petrochemicals and heavy manufacturing, have developed highly advanced, multi-certified SHEQ departments.

Yet despite this structural focus on compliance, actual safety and quality efficiencies remain highly inconsistent across industries. Studies on South African public institutions and universities show that, despite maintaining robustly documented, ISO-aligned occupational health and safety frameworks, these systems suffer from underreported hazards and low employee buy-in due to inconsistent leadership visibility and weak communication pathways (Hrenov, 2023). Likewise, the domestic small and medium businesses (SMEs) routinely structure their SHEQ activities chiefly around the immediate demands of their clients rather than enhancing the broader internal organisational learning.

Encouragingly, organisations like Eskom and Sasol are making progress by integrating human reliability analysis and digital learning dashboards into their IMS frameworks. Although not fully integrated, these efforts align with Safety-II principles, promoting adaptability over strict compliance (Hollnagel, 2014). Successful implementation leads to deeper integration, which enhances overall performance.

2.4. Human Factors as Strategic Performance Drivers

Human Factors has evolved from a secondary concern in safety science to a central factor in performance within integrated management systems (IMS). It encompasses behavioural, cognitive, and social dimensions that influence the implementation, improvement, and maintenance of institutional systems. Despite recognising that people are a system's

strongest link, there is inconsistency regarding how Human Factors affect safety, health, environment, and quality (SHEQ) outcomes.

Leadership commitment is crucial to effective SHEQ systems and is viewed as their cornerstone. Globally, transformational leadership, characterised by vision and empowerment, aligns with safety performance. However, there are divergent findings on how leadership translates into measurable system maturity. While some studies advocate for visible leadership and cultural signals, others argue that mere symbolic actions are insufficient for sustainable improvement (IOSH, 2023).

In developed economies, adaptive governance has supplanted compliance enforcement, emphasising learning and foresight. Research shows that high-reliability organisations with decentralised decision-making have lower incident rates compared to hierarchical structures. In contrast, critics note that such decentralisation often relies on established resources and safety cultures, which developing economies might lack (Nunes & Silva, 2023).

In developing countries, leadership often revolves around symbolic compliance rather than real intent. For instance, hotel managers in Egypt supported ISO principles during audits but reverted to reactive problem-solving afterward (Aboelsoud, 2022). In South Africa, research shows a gap between management rhetoric on occupational safety and actual commitment, particularly in public institutions (Mtikitiki et al., 2025). Nevertheless, in sectors such as mining, incorporating accountability mechanisms into IMS has increased productivity.

Three main insights emerge from this analysis: first, integration and harmonisation are key; second, developing economies struggle with contextual translation, where regulatory compliance often overshadows genuine participatory learning; and third, despite advanced governance structures, South Africa's IMS shows uneven distribution in leadership commitment and staff engagement across industries (Mtikitiki et al., 2025).

This evidence suggests that theoretical and policy advancements have outpaced practical, human-centred implementation.

3. Research Methodology

This study adopts a qualitative desktop research design and conducts a systematic literature review strictly aligned with the PRISMA (Preferred Reporting Items for Systematic Reviews and Meta-Analyses) statement. This methodology was chosen to ensure maximum analytical transparency, reproducibility, and a robust synthesis of existing empirical studies linking human behaviour to management standard performance.

3.1. Search Strategy and Database Selection.

Primary literature searches were conducted systematically using Google Scholar and ScienceDirect, with the scope restricted to peer-reviewed journal articles and official international conference proceedings published between 2014 and 2025. This ten-year window was deliberately selected to capture the global transition towards the High-Level Structure (HLS) framework and the growing integration of human performance factors within ISO 45001. Search strings were constructed using Boolean operators to ensure precision and relevance, combining key terms related to SHEQ and integrated management systems, human factors and safety leadership, and performance outcomes such as operational efficiency and resilience.

3.2. Inclusion and criteria

Specific, objective parameters were employed to filter the retrieved literature. These are deliberated hereunder:

Inclusion criteria

This encompasses first, peer-reviewed empirical studies, either qualitative, quantitative or mixed methods or conceptual frameworks evaluating integrated SHEQ environments. Second, studies explicitly examining leadership behaviour, training, or worker participation as independent variables; and third, research situated within heavy manufacturing, mining, aviation, oil and gas, construction, health care, or public administration.

Exclusion criteria

The exclusion criteria were formulated around, first, dissertations, blog posts, trade magazines articles or editorials, second, studies focusing exclusively on narrow technical engineering designs without human-system integration and leadership mechanisms and third, papers published before 2014.

3.3. PRISMA data collection process

The systematic selection process was carried out over four discrete phases. This enabled the researcher to reduce the initial pool of 456 identical records down to a final sample of 35 papers. The following PRISMA flow diagram shows the entire selection process (Figure 1).

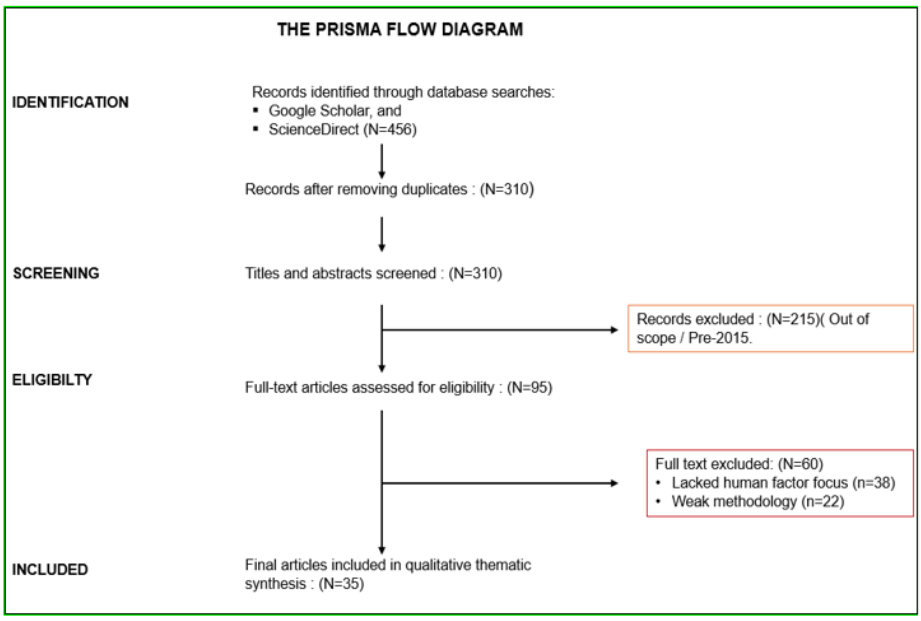

Figure 1: The PRISMA Flow Diagram
Source: Author's Illustration

3.4. Data analysis

35 papers were selected using qualitative thematic analysis. Each of the 35 articles was systematically coded within a matrix. The matrix captured the author, year, geographical context, industrial sector, methodology, theoretical framework, and primary human-factor outcomes. This open coding helped in identifying concurrent patterns, which were, in the end, accumulated and aggregated into four core empirical themes deliberated below:

4. Findings and Discussion

The systematic analysis conducted confirms that transitioning away from mechanistic compliance and appreciating a socio-technical approach dramatically enhances the maturity of organisational systems. The following empirical themes emerged from the synthesised literature matrix:

4.1. Theme 1: Structured leadership accountability and rhetorical commitment

Scholarly consensus identifies leadership as the most critical determinant of system success. Sadiq (2019) and Saraf (2019) establish that senior management accountability and visible commitment are the primary levers for improving performance in ISO-certified organisations. In high-risk environments, Al Hashimi (2014) highlights that board oversight and risk tolerance directly shape EHS performance, with leadership commitment accounting for over 50% of safety outcomes.

In the South African context, Mtikitiki, Madonsela, and Maphanga (2025) find that while policy alignment is high in public institutions, leadership deficiencies remain a major barrier to compliance. Conversely, Strzakowski, Sitarska, and Pactwa (2025) demonstrate that in the mining sector, the use of executive-level accountability mechanisms, such as safety-linked performance bonuses, creates a strong positive correlation between leadership and regulatory compliance. This reinforces the argument by Al Hashimi (2014) that governance must move beyond rhetoric to formalised accountability to drive efficiency.

4.2. Theme 2: Administrative consolidation and resource optimisation through HLS integration

The transition of ISO standards to the High-Level Structure (HLS) framework provides a major mechanism to optimise operational workflows. Darabont, Grigorescu, and Oancea (2019) argue that consolidating multiple standards into a unified core significantly reduces resource duplication, unifies safety policies and eliminates conflicting procedures. Lutete (2025) further contends that for African organisations, successful transition between ISO versions depends on leadership-driven change management to ensure integration enhances resilience rather than just increasing administrative load.

Empirical evidence from the healthcare sector, as reported by Simion Luduşanu, Grigore, and Ionescu (2025), demonstrates that integrating ISO 9001 and ISO 14001 yields quantifiable gains, including a 20-28% increase in energy efficiency and improved stakeholder trust. Similarly, the Industry Consortium (Swissport, dnata, and Menzies Aviation) (2025) reports that the maturation of Safety Management

Systems (SMS) in aviation logistics significantly reduces service delays and enhances reliability.

However, Trierweiller, Peixe, Tezza, Bornia, and Savatski (2016) caution that these efficiency gains are frequently hampered if an organisation fails to deliver integrated training. In the absence of cross-functional training on unified procedures, employees tend to face role confusion, continue duplicating tasks, and experience an unnecessarily heavy administrative load.

4.3. Theme 3: Culture, communication and employee participation as a mediator of system quality

A core insight across global and local literature is that formal, highly technical management structures falter in the absence of a participative safety culture and true employee inclusion. The standard structures, such as ISO 45001, clearly advocate inclusive workforce participation as a key proactive tool for early hazard identification (Sadiq, 2019).

Existing empirical models in manufacturing show that an open safety culture acts as a powerful mediator. Thus, building a supportive environment enhances frontline job satisfaction and morale, which directly culminates in higher manufacturing precision and reduced rework. In developing and emerging markets, nurturing this cultural alignment assists organisations in moving past institutional isomorphisms (Khattak & Ilyas,2018). For instance, according to Oliveira, Nunes, and Ferreira (2024), in heavy construction industries, developing psychological safety and open communication channels minimises on-site accident rates and project rework by approximately 30% through enhanced team learning and error sharing.

4.4. Theme 4: Cross-sector competence, communication protocols and digital innovation

Structured communication and targeted training form the critical link between human behaviour and technical engineering controls, with evidence from manufacturing showing that targeted training strengthens internal compliance culture while collaborative communication frameworks in multi-employer environments reduce redundant audits and operational costs. At the same time, modern SHEQ frameworks increasingly leverage digital technologies, where human-centred ergonomic design and automation minimise operator error, and predictive neural networks using real-time behavioural data enhance accuracy and enable a proactive, data-driven approach to operational safety.

5. Proposed Human-Centred SHEQ Framework

From the fragmented findings above, this study proposes a contextualised, actionable human-centred SHEQ framework (Figure 2). The proposed framework transitions the organisation away from the rigid, passive checklist-oriented compliance towards a socio-technical paradigm that incorporates human behavioural levers directly into standard high-level structures (HLS).

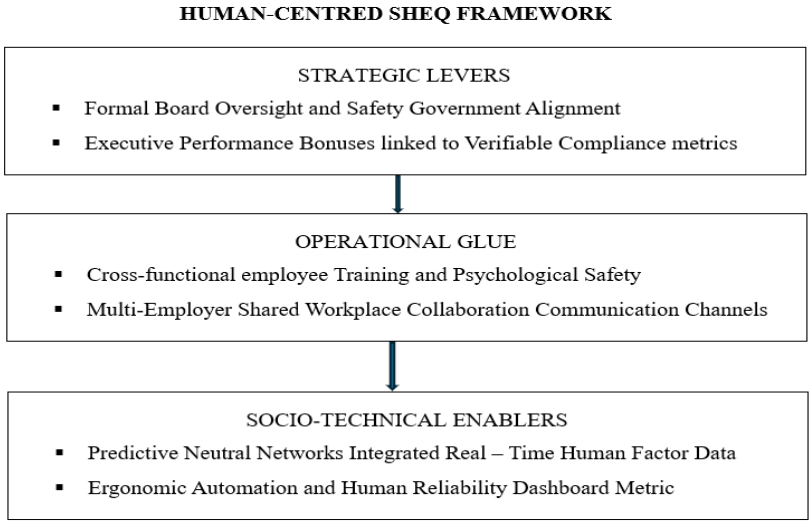

Figure 2: Human-centred SHEQ Framework
Source: Author's Illustrations

The above framework consists of three interdependent, structural dimensions. These structural dimensions are discussed hereunder:

Strategic levers.

This dimension pertains to governance and accountability. It moves past empty policy statements by developing and implementing formalised board oversight and connecting executive-level remuneration

or compensation packages directly to trailing and key safety compliance metrics.

Operational glue.
Operational glue dimension speaks to competence and inclusion. The focus of this dimension is on expanding cross-functional training to break down departmental silos that punctuate organisations, while at the same time building open communication channels that provide an opportunity for frontline workers to actively flag hazards without any reservations or fear of reprimand.

Socio-technical enablers.
This is the last dimension in the framework and addresses technology and ergonomics. It uses digital learning dashboards, ergonomic automation, and predictive data analysis to quickly identify operational errors, enhance decision quality, and build systemic resilience.

6. Conclusion, Recommendation and Future Research

6.1. Academic and practical contributions

The study synthesises fragmented global and local research into a coherent framework, demonstrating how human factor dimensions function as critical mediators between technical standard compliance and overall operational efficiency. In doing so, it offers a substantive academic alternative to rigid, compliance-driven models and extends the application of Safety-II and socio-technical systems theory in developing economies. Practically, the study moves beyond abstract leadership prescriptions by identifying clear operational levers, such as safety-linked incentive structures, multi-employer communication mechanisms, and neutral network data models, that can reduce bureaucratic redundancy and support the achievement of sustainable quality and safety outcomes.

6.2. Actionable recommendations for executive leadership

To operationalise these insights within daily operations, executive leadership should prioritise the formalisation of accountability by restructuring executive and middle-management incentive programmes to allocate at least 20% of performance evaluations to leading human indicators, such as near-miss reporting and cross-functional training completion rates. In parallel, organisations should transition from isolated, standard-specific training approaches to integrated, cross-functional programmes that reduce duplication, strengthen communication, and improve overall operational efficiency, while also establishing shared communication protocols through joint safety and quality review boards across multi-employer and contractor environments to eliminate redundant compliance processes and unlock cost savings. Furthermore, strategic investment in human-centred digital enablers, such as automated tools and real-time performance dashboards, should be prioritised to enhance organisational visibility of operator behaviour, thereby enabling a shift from reactive problem-solving to proactive, data-driven accident prevention.

6.3. Limitations and pathways for future research

While the study provides a comprehensive synthesis of existing research, it relies heavily on a qualitative review of secondary data, which may limit direct empirical validation across different industrial contexts. Future studies should focus on conducting longitudinal, mixed-methods field studies in South Africa and similar African industrial settings to track the organisation's performance before and after adopting this proposed framework.

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Wearable Technology in Construction: A Socio-Technical Pathway to Fatigue Risk Management

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Abstract

Fatigue risks remain underreported yet persistent in construction, impairing worker performance and undermining their health and safety. This study investigates how wearable technology (WT) can be adopted to evolve early fatigue-related interventions in construction health and safety management. The study is underpinned by the socio-technical systems (STS) theory and examines the interplay between human, organisational, and technical dimensions to demonstrate how WT can proactively address fatigue risks while strengthening worker health monitoring. The study adopted a case study strategy to collect qualitative data. The qualitative data were collected through semi-structured interviews with 48 construction personnel across estate development, township development, and road maintenance projects. The thematic analysis method was used to synthesise qualitative findings. The findings confirm that WT is widely regarded as promising for monitoring fatigue indicators and for enabling real-time alerts. However, concerns about comfort, durability, privacy, and surveillance emerged as critical barriers to adoption. Moreover, organisational readiness was identified as a decisive factor for successful adoption. Therefore, future research should advance longitudinal studies to validate the proposed holistic socio-technical framework for fatigue risk management in construction. It should also conduct cross-sectoral comparisons to assess transferability and use participatory design approaches to strengthen workers' trust and acceptance of WT.

Keywords: Construction, fatigue, health and safety, socio-technical systems, wearable technology

1. Introduction

The construction industry is infamous for exposing workers to persistently high rates of accidents, injuries, and fatalities, and thus consistently ranks among the most hazardous sectors worldwide (Heng *et al*., 2024; Jo & Kim, 2024). Fatigue has been flagged as a critical contributing factor, impairing workers' cognitive and physical performance, slowing reaction times, and increasing the likelihood of errors that can lead to accidents (Pandit, 2025; Heng *et al*., 2024). Traditional health and safety measures, while widely adopted, often operate reactively, responding to incidents after they occur rather than anticipating risks before they escalate. This reactive orientation underscores the need for proactive systems that can detect and mitigate fatigue risks in real time (Carayon *et al*., 2015). WT has emerged as a promising innovation in construction health and safety management. For instance, wearable devices such as smart helmets, biometric vests, wristbands, and exoskeletons are increasingly being deployed to monitor physiological signals, including heart rate variability, body temperature, and brain activity (Pandit, 2025; Wong *et al*., 2025; Jo & Kim, 2024). These technologies enable continuous assessment of workers' health parameters, early detection of fatigue, and automated safety interventions (Pandit, 2025; Heng *et al*., 2024).

Fatigue in construction is concerning, given the sector's demanding working conditions. The reality of working long hours, exposure to extreme weather, and performing repetitive manual tasks contributes to both physical and psychological fatigue (Jo & Kim, 2024; Heng *et al*., 2024). These conditions not only compromise worker well-being but also reduce productivity and increase the likelihood of costly errors. Studies have shown that fatigue-related incidents are often underestimated, with workers normalising exhaustion as part of the job (Chong *et al*., 2023; Heng *et al*., 2024). This normalisation creates barriers to effective intervention, highlighting the importance of technologies that can objectively measure fatigue indicators and trigger timely responses. Recent studies have shown that the adoption of WT in construction cannot be understood solely through a technological lens because construction environments involve social imperatives. As a result, this study is underpinned by the socio-technical systems (STS) theory. The STS theory emphasises that safety outcomes emerge from the dynamic interplay between human, organisational, and technical elements (Zarei *et al*., 2024; Knox, 2024). Therefore, effective

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integration of WT requires consideration of worker acceptance, organisational readiness, and ethical governance.

Recent studies have highlighted both the opportunities and challenges of WT adoption in construction. For instance, while biometric monitoring can enhance safety, it also raises concerns about privacy, surveillance, and data ownership (Ogungbe & Ikuabe, 2026; Okonkwo *et al*., 2025). Furthermore, barriers such as high implementation costs, discomfort, and resistance to change remain significant (Ogungbe & Ikuabe, 2026; Ibrahim *et al*., 2023). Therefore, addressing these socio-technical dimensions is essential to ensure that WT adoption strengthens safety performance rather than undermining trust. As such, this study investigates how WT can be used to evolve early fatigue interventions for construction operatives, framed within a socio-technical systems perspective. The study seeks to demonstrate that successful adoption depends not only on technological innovation but also on the alignment of WT with worker-centred design, organisational readiness, and ethical governance. In doing so, this study advances proactive health and safety management in construction.

2. Literature Review

2.1. Wearable Technology in Construction Health and Safety

WT has emerged as one of the most significant innovations in construction health and safety management. Devices such as smart helmets, biometric vests, and exoskeletons are increasingly deployed to monitor physiological signals and environmental conditions, enabling real-time detection of fatigue and stress (Pandit, 2025; Jo & Kim, 2024). These technologies provide continuous visibility into worker health and safety management, signalling a shift from reactive to proactive approaches (Wong *et al*., 2025). The transformative potential of WT lies in its ability to provide predictive analytics. These include AI-enabled devices that can forecast fatigue trends by analysing biometric data, allowing supervisors to intervene before accidents occur (Chen *et al*., 2020; Heng *et al*., 2024). This predictive compliance represents a paradigm shift in construction safety, in which interventions are no longer dependent on worker self-reporting but are instead triggered by objective, real-time data. Such systems enhance both safety and productivity, as workers can be reassigned or rested before performance deteriorates (Aghimien *et al*., 2025).

Nonetheless, various limitations hinder WT adoption. These include WT's high implementation costs, implementation-related discomfort, and technical reliability issues (Ibrahim *et al*., 2023). This challenge is a reality in smaller construction companies, which struggle to justify investment in advanced devices, especially when traditional health and safety measures remain entrenched. Another concern is the durability of devices in harsh construction conditions, with sensors vulnerable to dust, heat, and mechanical damage (Jo & Kim, 2024). While WT offers unprecedented visibility into health and safety metrics, its effectiveness depends on the integration of broader organisational systems. This is because technology alone cannot guarantee improvements in health and safety; socio-technical alignment is essential (Carayon *et al*., 2015; Zarei *et al*., 2024). Therefore, without supportive policies, training, and cultural acceptance, WT risks being perceived as surveillance rather than empowerment (Chong *et al*., 2023; Knox, 2024).

2.2. Fatigue Detection and Intervention

Fatigue is a pervasive risk in construction, linked to long working hours, extreme weather, and repetitive manual tasks. Studies consistently show that fatigue impairs cognitive performance, slows reaction times, and increases the likelihood of accidents (Jo & Kim, 2024; Heng *et al*., 2024). Workers often normalise exhaustion as part of the job, creating barriers to effective intervention (Chong *et al*., 2023). The literature suggests that WT could be an objective means of detecting fatigue, reducing reliance on self-reporting, and enabling early interventions. Therefore, by integrating AI algorithms into these devices, WT can predict fatigue trajectories, recommend rest breaks, and facilitate task reassignment before risks escalate (Chen *et al*., 2020; Heng *et al*., 2024). This proactive approach aligns with global calls for predictive compliance in construction safety (Carayon *et al*., 2015). Recent studies also highlight the productivity-safety synergy of fatigue monitoring, emphasising WT's contribution to both safety and efficiency (Chen *et al*., 2020; Aghimien *et al*., 2025). As such, fatigue alerts can be synchronised with project schedules, ensuring that interventions do not disrupt workflow but enhance long-term productivity (Jo & Kim, 2024). This dual benefit strengthens the business case for WT adoption. Therefore, ethical governance remains critical to ensuring transparent data protocols that build trust (Knox, 2024; Zarei *et al*., 2024).

2.3. Socio-Technical Systems Perspective

The STS theory emphasises that safety outcomes emerge from the dynamic interplay between human, organisational, and technical elements (Zarei *et al*., 2024; Knox, 2024). In construction, this means that WT effectiveness depends not only on device functionality but also on worker acceptance, organisational readiness, and regulatory frameworks. Recent studies on STS highlight the importance of cultural integration, noting that safety is not merely a technical attribute but a collective property of the system, shaped by how workers, managers, and technologies interact (Carayon *et al*., 2015; Gumede & Tladi, 2023). Therefore, for WT to succeed, organisations must embed devices into health and safety plans, ensuring that workers perceive

them as supportive rather than punitive. Moreover, training and participatory design are essential to foster acceptance (Chong *et al*., 2023).

The literature shows that organisational readiness plays a critical role in the successful adoption of WT. Recent studies support the notion that firms with strong health and safety practices and robust data governance frameworks are more likely to adopt WT successfully (Chong *et al*., 2023; Aghimien *et al*., 2025). Conversely, organisations with weak health and safety practices may struggle to integrate WT, as devices cannot compensate for systemic deficiencies (Ibrahim *et al*., 2023). This underscores the need for holistic strategies that align technology with organisational structures to improve health and safety management. Thus, STS theory reinforces the view that WT adoption is as much a social challenge as a technical one, compelling alignment across human, organisational, and technological dimensions (Knox, 2024; Gumede & Tladi, 2023).

2.4. Research Gaps and Emerging Themes

Although WT has been widely studied for its technical capabilities in fatigue monitoring and health and safety improvement, significant gaps remain in the socio-technical dimensions of adoption. The literature emphasises device functionality such as biometric monitoring and predictive analytics while overlooking worker acceptance, ethical governance, and organisational readiness (Chen *et al*., 2020; Ibrahim *et al*., 2023). This narrow focus risks reducing WT to a purely technological solution, neglecting the social and organisational factors that determine its success. Furthermore, most studies are conducted in controlled environments (Chong *et al*., 2023; Heng *et al*., 2024), thereby limiting insights into how WT is perceived across diverse project contexts, including residential, township development, as well as routine road maintenance projects. This reality underscores a need to address these gaps holistically, integrating technical, organisational, and human perspectives.

3. Research Methodology

This study adopted a qualitative case study design to investigate how WT can be adopted to evolve early fatigue interventions in construction health and safety management. This research design aided comparative analysis across residential development, township development, and routine road maintenance projects within the Free State province of South Africa, ensuring contextual diversity. A purposive sampling technique was employed to select participants directly involved in construction site operations. This ensured that insights were grounded in practical realities of fatigue management and WT usability. The qualitative sample comprised 48 interviewees across three case projects, including artisans, plant operators, general workers, supervisors, managers, and registered professionals. This sampling strategy captured both leadership perspectives and hands-on site operative experiences, ensuring maximum variation across roles and contexts.

A multiple-case study design was used to collect qualitative data. The qualitative data were collected through open-ended semi-structured interviews. The interviews were anonymised, transcribed verbatim, and analysed using ATLAS.ti. The thematic codes were developed iteratively around fatigue indicators, WT usability, ergonomic redesign, and organisational compliance. This ensured systematic analysis while remaining grounded in participants' narratives. The interview questions explored construction workers' experiences of fatigue, workers' perceptions of WT usability, comfort, and durability, barriers to adoption, and strategies for embedding WT into organisational safety cultures. The case studies in this research were divided by the type of construction work conducted, as shown below:

Case Project 1 (Estate Development): A large-scale residential project with diverse trades (artisans, operators, and managers). The research sample included members of the construction team, including the health and safety officer, roof carpenter, 2 TLB operators, bobcat operator, quantity surveyors, estate manager, cleaner, 2 forepersons, welder, carpenter, 2 general workers, storeroom helper, 3 plumbers, 2 painters, tipper truck operator, tiler, 2 supervisors, and 3 bricklayers. A total of twenty-seven (27) project participants were interviewed, as illustrated in Figure 1.

Case Project 2 (Township Development): Focused on affordable housing infrastructure. The research sample for this case project included members of the engineering team, including the construction manager, quantity surveyor, TLB operator, grader operator, broom operator, diesel truck operator, shuttering specialist, steel fixing specialist, and smooth drum roller operator. A total of nine (9) interviews were conducted, as shown in Figure 1.

Case Project 3 (Routine Road Maintenance): Involved long hours of roadwork under variable weather conditions. The research sample for this case study included members of the engineering team, contractors, and subcontractors, including the director and foreperson of the grass-cutting subcontractor, 2 forepersons, a driver, 3 brush-cutter operators, 2 supervisors, 2 general workers, and a drum-roller operator. A total of twelve (12) project participants were interviewed, as indicated in Figure 1 in Appendix 1.

4. Findings and Discussion

This section presents the research findings derived from both qualitative case study interviews and quantitative

survey data. The results are organised into significant themes that align with the research objectives: fatigue as a pervasive risk; workers' perceptions of WT; privacy and ethical concerns; organisational readiness and safety culture; productivity-safety synergy; and WT for evolving early fatigue interventions. These findings provide a comprehensive understanding of how WT can be used to detect early fatigue, communicate risks effectively, and evolve proactive interventions to safeguard construction personnel.

4.1. Interview Results from Construction Operatives

4.1.1. Theme 1: Fatigue as a Pervasive Risk

In the estate development project, artisans such as bricklayers and plumbers reported that fatigue was most pronounced in the afternoons, when concentration waned, and errors increased. A bricklayer explained, *"By the end of the day, my hands shake, and I sometimes make many mistakes."* The TLB and Bobcat plant operators described how prolonged machinery operation dulled their responsiveness, with one operator admitting, *"After six hours, I start missing signals from the foreman."* Supervisors acknowledged fatigue but noted that workers rarely reported it due to fear of stigma. In the township development project, plant operators, including the grader, broomer, and diesel truck operators, highlighted the strain from repetitive heavy-machinery tasks. A grader operator also shared that, *"The vibration and noise wear you down; after a few hours, your focus slips."* Managers observed that fatigue slowed task completion and increased risks, but workers normalised exhaustion as part of the job. In the routine road maintenance project, brush cutter operators described fatigue as part of the job, with one worker stating, *"After hours in the sun, your body feels drained, but you keep going because the work must be done."* Forepersons admitted that fatigue often led to minor accidents, such as slips or equipment mishandling.

4.1.2. Theme 2: Workers' Perceptions of Wearable Technology

In the estate development project, artisans such as carpenters and tilers expressed cautious optimism about WT. A carpenter remarked, *"If the helmet can tell me when I'm too tired to continue, it could save lives."* Plant operators were sceptical about the devices' durability in withstanding dust and vibration during construction activities. In the township development project, plant operators favoured smart helmets and biometric vests to detect heat stress and drowsiness. A steel fixer explained, *"If the vest can show when I'm dehydrated, it could prevent accidents."* Managers saw WT as a compliance tool but stressed that adoption would require training and clear policies. In the routine road maintenance project, brush cutter operators favoured wristbands that could monitor hydration and heart rate. However, general workers worried about comfort, with one stating, *"If it's heavy or hot, we won't be able to wear it."* Supervisors emphasised that WT adoption would only succeed if accompanied by training and worker involvement. These findings highlight a divide between leadership optimism and worker scepticism. Managers see WT as a strategic tool for compliance and productivity, while workers remain cautious, focusing on practical concerns such as comfort and durability. It is therefore clear that WT adoption would succeed only if construction wearable devices are designed with workers in mind to ensure comfort and durability. Subsequently, organisational training and participatory approaches are essential for building trust and acceptance, as per the supervisors' advice.

4.1.3. Theme 3: Privacy and Ethical Concerns

In the estate development project, artisans feared that biometric monitoring could be used to penalise rather than protect them. A plumber explained, *"If management uses the data to discipline us instead of helping, no one will wear these devices."* In the township development project, a steel fixer echoed the same concern about WT monitoring purposes, saying, *"If they use these devices to watch us instead of helping us, no one will wear them."* Managers acknowledged these concerns, emphasising the need for transparent data governance. In the road maintenance project, general workers described WT as site policing and expressed concern about constant tracking. One worker said, *"I don't want my health data used against me."* Supervisors emphasised that WT adoption would only succeed if accompanied by clear policies and assurances of privacy. These findings reflect holistic privacy concerns and broader ethical challenges in the adoption of WT for construction fatigue monitoring. Across all three case projects, site operatives feared that their biometric data could be misused for disciplinary purposes, undermining trust. Management, on the other hand, recognised the importance of governance and translating WT adoption into clear policies and practices.

4.1.4. Theme 4: Organisational Readiness and Safety Culture

In the estate development project, forepersons emphasised that WT adoption would only succeed in firms with strong health and safety cultures. One foreperson explained, *"If workers are part of the process, they will trust the technology."* In the township development project, managers stressed that WT must be embedded into existing health and safety frameworks rather than introduced as isolated gadgets. In the road maintenance project, supervisors noted that without organisational support, devices would be perceived as surveillance tools rather than safety aids. Moreso, workers emphasised the need for training and participatory approaches. This shows that organisational readiness is a decisive factor in WT adoption. These results echo that WT adoption requires more than technological innovation. It demands

organisational commitment, training, and participatory approaches that embed devices into health and safety culture. Without this, WT risks rejection or misuse.

4.1.5. Theme 5: Productivity-Safety Synergy

In the estate development project, artisans noted that fatigue alerts could help optimise task allocation, reduce downtime, and prevent costly errors. For instance, one tiler explained, *"If the device tells me to rest before I make a mistake, it saves time and materials."* In the township development project, managers emphasised that predictive compliance could improve efficiency by ensuring workers are rested and focused. In the road maintenance project, brush cutter operators acknowledged that WT could reduce accidents, but stressed that interventions must be aligned with workflow to avoid disruption. One worker explained, *"If the device tells me to rest at the wrong time, it could delay the project."* This underscores WT's dual potential to enhance safety and productivity. By preventing accidents and optimising performance, WT contributes to both worker well-being and organisational efficiency. Therefore, positioning WT as both a safety and productivity tool can strengthen its value proposition, particularly in resource-constrained environments. This dual benefit may encourage adoption by demonstrating that WT supports both worker health and organisational goals.

4.1.6. Theme 6: Wearable Technology to Evolve Early Fatigue Interventions

Across the estate development, township development, and routine road maintenance projects, participants consistently perceived WT as an effective tool for monitoring and managing worker fatigue through real-time tracking of physiological, mental, and environmental indicators. The research participants highlighted that WT could monitor vital signs such as heart rate, blood pressure, and blood sugar levels, as well as stress, exhaustion, microsleeps, and other fatigue-related symptoms, enabling early detection of health risks before they lead to injuries, fatalities, or reduced productivity. The research participants further indicated that WT could assess energy expenditure, work duration, working conditions, hydration needs, hunger, dizziness, and sleep-related deficiencies while providing timely alerts that inform workers when to rest, hydrate, or continue working safely. In addition, WT was viewed as a means of improving communication between employers and workers regarding fatigue levels, supporting proactive interventions, promoting worker health, safety, and wellbeing, and enhancing overall productivity. These findings suggest that WT can facilitate early fatigue detection, real-time risk management, and informed decision-making, thereby creating safer and more sustainable construction work environments.

4.2. Wearable Technology Adoption Holistic Socio-Technical Framework for Fatigue Management

The framework integrates socio-technical systems (STS) theory with the empirical findings of this study to provide a holistic approach for evolving fatigue interventions in construction. It emphasises that successful adoption of WT requires alignment across human, organisational, technical, ethical, and productivity-safety dimensions. Figure 2 demonstrates a holistic socio-technical framework for managing fatigue risks in construction. The framework begins with the human dimension, which emphasises worker-centred design and wellbeing. Empirical evidence from estate development, township development, and road maintenance projects revealed that artisans and plant

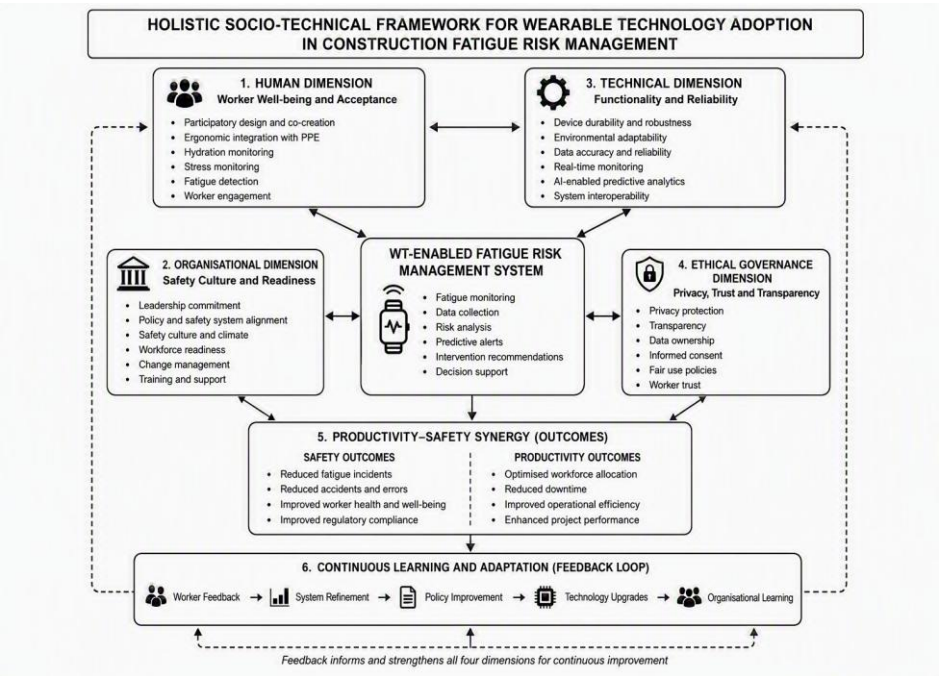

Figure 2: Wearable Technology Adoption Holistic Socio-Technical Framework for Fatigue Management
Source: Author

operators experienced fatigue as a daily reality, often normalised as "part of the job." While workers expressed cautious optimism about WT, they raised concerns about comfort and usability. Socio-technical systems (STS) theory underscores that worker acceptance and participatory design are critical for adoption. Thus, WT must be ergonomically designed, seamlessly integrated into personal protective equipment (PPE), and co-developed with workers to enhance their well-being through hydration alerts, stress monitoring, and fatigue detection.

The organisational dimension highlights the importance of health and safety culture and readiness. Managers across the case projects viewed WT as a compliance and productivity tool, but emphasised that adoption would succeed only in firms with strong health and safety cultures. The STS theory reinforces that technology cannot compensate for weak organisational practices. Therefore, embedding WT into existing health and safety frameworks and aligning it with workflows would ensure that devices are perceived as supportive rather than punitive, thereby bridging individual well-being with organisational health and safety culture. The technical dimension, on the other hand, focuses on device functionality and reliability. The findings highlight workers' concerns about durability in dusty, vibration, and heat-exposed environments. For this reason, the STS theory emphasises that technical systems must be reliable and adaptable to harsh environments.

The ethical governance dimension addresses privacy and trust, which emerged as significant barriers to WT adoption. The findings echoed these concerns, with workers worried about disciplinary consequences. The STS theory underscores the importance of ethical safeguards and transparent policies. The theory supports the involvement of workers in governance decisions, fostering trust and making WT adoption a supportive rather than intrusive measure. Finally, the productivity-safety synergy dimension integrates the dual benefits of WT. The findings highlighted WT's potential to enhance safety and productivity. Workers noted that fatigue alerts could optimise task allocation and reduce downtime, while managers emphasised predictive compliance to improve efficiency. As such, the STS theory reinforces that safety and productivity are interdependent and should be treated as such. Therefore, WT should be embedded into workflows to enhance efficiency without disrupting construction operations.

4.3. Discussion

Fatigue emerged as a critical yet underreported risk across estate, township development, and road maintenance projects, with workers normalising exhaustion as an inevitable part of the job. This cultural acceptance, coupled with long hours, repetitive tasks, and harsh weather, contributes to slower reaction times, errors, and near-miss incidents, consistent with existing literature (Chong *et al*., 2023; Heng *et al*., 2024). WT was cautiously welcomed by construction operatives for their potential to detect fatigue risks, but concerns about usability, durability, and privacy limited trust. Managers viewed WT as a compliance tool, stressing the need for training and clear policies, while workers feared surveillance. The literature confirms that ethical governance and worker-centred design are essential to adoption (Okonkwo *et al*., 2025; Ogungbe & Ikuabe, 2026). These findings align with STS theory, which emphasises that fatigue management requires integration of technical tools with organisational culture, ethical safeguards, and participatory governance (Carayon *et al*., 2015; Zarei *et al*., 2024).

Organisational readiness was identified as decisive for WT success, with strong safety cultures and governance frameworks enabling adoption, while weak practices risked devices being perceived as policing rather than protection. The construction workers and managers recognised that fatigue alerts could optimise task allocation, reduce downtime, and prevent costly errors, reinforcing the productivity-safety synergy highlighted in the literature (Pandit, 2025; Chen *et al*., 2020; Aghimien *et al*., 2025). The STS theory proposes that WT integration should align human, organisational, and technical dimensions to ensure interventions enhance efficiency without disrupting workflows (Knox, 2024; Gumede & Tladi, 2023). Thus, the proposed framework suggests that fatigue in construction could be managed through socio-technical interventions because technical devices alone are insufficient unless embedded within ethical, worker-centred, and organisationally robust frameworks that balance safety and productivity.

5. Conclusion and Further Research

This study described fatigue as a pervasive and underreported risk in construction, significantly affecting health, safety, and productivity in projects. Likewise, site operatives described exhaustion as part of their daily reality, while managers emphasised its impact on efficiency. As a result, WT emerged as a promising solution for monitoring physiological and biomechanical indicators to trigger proactive interventions. However, the results suggested that the adoption is contingent on worker-centred design, organisational readiness, technical reliability, and ethical governance. Although WT has been widely studied for its technical capabilities in fatigue monitoring and health and safety improvement, significant gaps remain in the socio-technical dimensions of adoption. Hence, the framework developed in this study integrated these dimensions to offer a comprehensive approach to fatigue risk management. The study argued that WT adoption represents not only a technological innovation but a socio-technical transformation, with the potential to

enhance health, safety, productivity, and trust among construction operatives. Therefore, future research should advance longitudinal studies to validate the proposed holistic socio-technical framework for fatigue risk management in construction. It should also conduct cross-sectoral comparisons to assess transferability and use participatory design approaches to strengthen workers' trust and acceptance of WT.

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Appendix 1

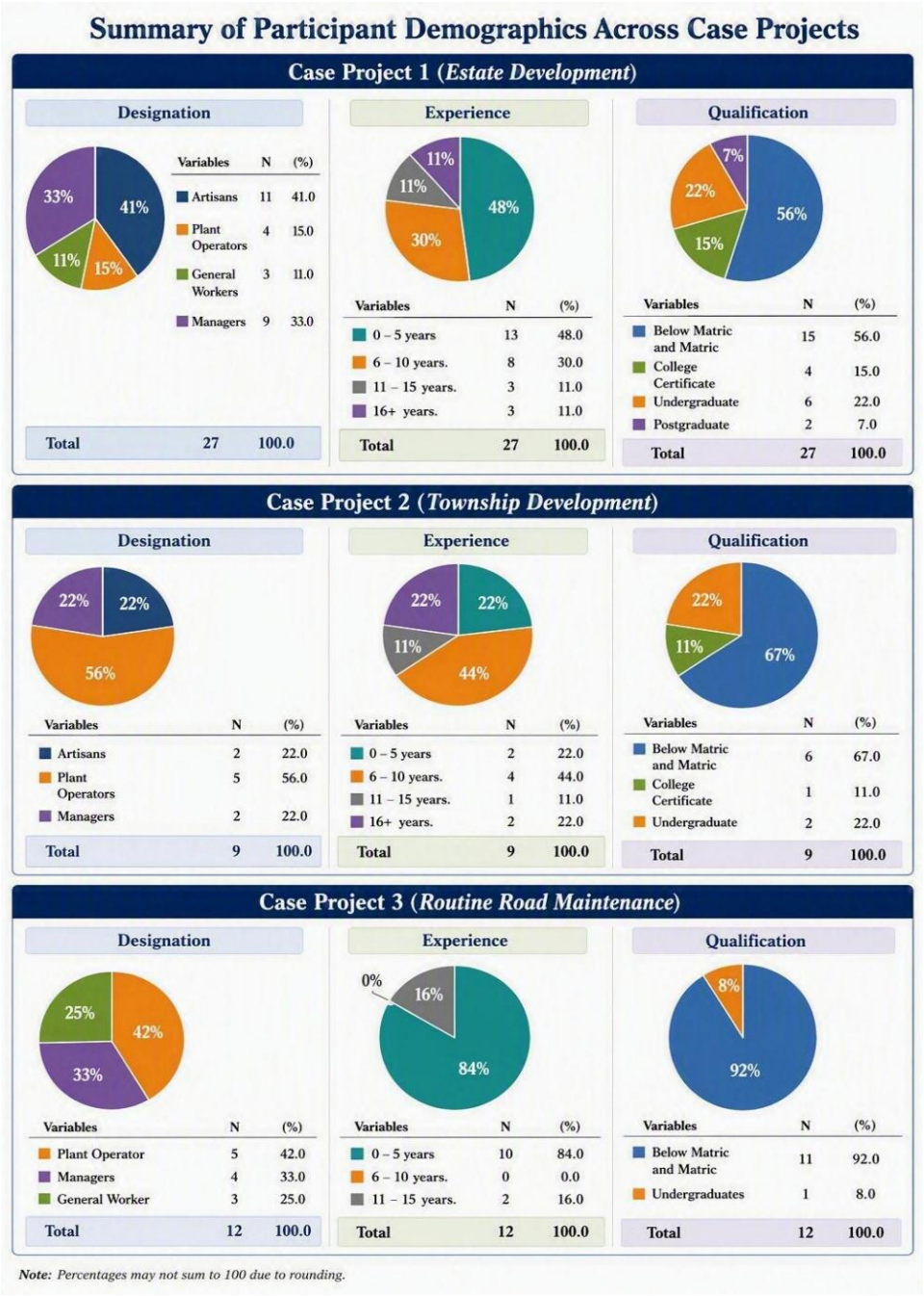

Figure 1: Summary of research participants' demographics across case projects
Source: Author

Assessing the Impact of Work-Life Balance on Performance of Women in Nigeria's Built Environment: The Enabling Role of Digital Technologies

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Abstract

Maintaining a healthy work-life balance (WLB) is a critical factor influencing employee performance. However, women professionals in the built environment persistently experience WLB challenges, which affects performance and retention. While digital technologies have the potential to improve work practices, their influence on WLB for women remains underexplored. This study fills the gap by assessing the impact of WLB on performance of women in Nigeria's built environment, with emphasis on technology as an enabler of gender-inclusive industry transformation. The study adopted a quantitative research approach. Data were collected through structured questionnaire from women professionals in the built environment in Abuja. Mean Item Score (MIS) was employed in analysis of the data. Findings revealed that current balance between work and personal life is unsatisfactory (MIS = 4.01), poor policy provision on maternity leave and return to work exist (MIS = 3.99) and lack of mental health support. Also, lack of digital technologies in enabling flexible and remote work options exist. WLB impedes career growth, develops heightened stress and anxiety. The study concluded that existing WLB impacts negatively on performance of women in the built environment. It was recommended that construction firms should focus on implementation of automated tools and digital training for improved job performance.

Keywords: Built environment; Digital technology; Women; Work-life balance; Performance

1. Introduction

The construction industry provides valuable professional advancement prospects for women However, their persistent underrepresentation within this industry remains a significant issue of concern (Adah *et al.,* 2024). The substantial workload placed on construction industry employees especially the females compromise their family engagements, recreational time, and work effectiveness (Hasan *et al.,* 2021; Wang *et al.,* 2021, Galea *et al.,* 2020). Despite their proven competence, women in the construction industry are expected to meet high-performance standards while managing personal and family responsibilities, which can be overwhelming (Monika & Amit, 2025). While developed countries such as Sweden, Norway and Finland have adopted strong family policies and digital-driven flexible work systems that support better WLB for women, similar structures are largely absent in Nigeria (Joecks *et al.,* 2021; Yerkes *et al.,* 2022). Women in Nigeria often endure long hours, heavy workloads, and male-centric management structures, making balance difficult.

Modern workplaces increasingly rely on digital technologies enabling greater productivity, flexibility and job satisfaction (Pamidimukkala and Kermanshachi, 2022). For women, such technologies can enhance work-life balance by improving autonomy and reducing rigid work-time constraints. Yet the Nigerian construction sector has been slow to adopt these digital technologies leaving women without the flexibility needed to manage both professional and family roles which can limit their job performance, mental health, long-term career growth and retention (Tiwari et al., 2024). Previous literature has predominantly focused on workplace discrimination for women, workload, WLB challenges, organisational culture (Newman & Brittan, 2022). However, there are limited studies on how digital technologies can support WLB and enhance performance. This gap highlights the urgent need for this study to examine the current WLB of women in the built environment, assess the impact of WLB on their performance, examine the prospects of enabled digital technologies on WLB, address the problems and offer practical recommendations for improving women's retention and performance in the construction industry.

2. Literature Review

2.1. Concept of Work Life Balance

According to Adah et al. (2024), Work Life Balance is meant to combine professional duties with other domains of life, like family responsibilities or leisure activities and social engagements. According to Irfan *et al*. (2021), the principal focus of Work Life Balance is to create an environment that allows an individual to

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draw the line between work and life without one overpowering the other all the time. However, construction works, having long working hours, fixed schedules, and sometimes high physical demand, make it increasingly difficult for workers, especially women, to go for a good work-life balance (Wang, 2024). Work Life Balance depends on factors that are an offshoot of the unique requirements or peculiar circumstances of the individual concerned which include, individual, organizational, and societal factors.

2.2. Gender Representations and Work-Life Balance Conditions in the Built Environment

The proportion of females in the global construction workforce is equal to no more than 10 to 15 percent (Pamidimukkala and Kermanshachi, 2022; Adah *et al.,* 2024). Women who undertake the construction sector in developing nations such as Bangladesh, Thailand, South Africa, and Nigeria, are mainly taking non-technical jobs like manual labour work, office work, food services, and general duty work and not in technical or professional job posts (Shibani et al., 2024). Such concerns contribute to the perceived poor female recruitment and retention levels, contributing to gender inequalities in the construction industry (Adah *et al.,* 2024).

Wang *et al.* (2021) underline that women are particularly impacted by long hours, which leads to the impossibility of balancing work and family. Also, as Galea *et a*l. (2020) note, both genders experience inefficiency, fatigue, and even stress due to workloads that are beyond the normal working hours. The problematic nature of the industry is also an unfriendly aspect: a dominating culture by its male counterparts, absence of protective equipment designed specifically for women, and unsatisfactory sanitation structures (Hasan *et al.,* 2021). According to Adah et al. (2024) the lack of flexible work options affects women's WLB and prevents career advancement. There is a need to identify the systematic obstacles that need to be targeted to create a truly inclusive workplace.

2.3. Work Life Balance Challenges for Women in the Built Environment

Women in construction face extended, inflexible, and unpredictable work schedules that clash with childcare, domestic responsibilities, and personal time commitments. The physical demands and mandatory on-site presence limit their ability to manage home-work boundaries, creating chronic fatigue and reduced work-life balance (Shola & Agboola, 2020; Shibani *et al.,* 2021). Women continue to bear the majority of domestic and caregiving responsibilities, making it difficult to reconcile demanding professional duties with family obligations. This dual burden increases stress and worsens work-family conflict, often more intensely than experienced by male counterparts (Augustina and Grace, 2024). Persistent gender stereotypes, male-dominated work cultures, and discriminatory hiring practices limit women's opportunities and undermine their sense of belonging.

Limited exposure to and adoption of digital tools such as remote collaboration platforms, digital project management systems, and flexible monitoring technologies, reduces opportunities for hybrid or remote work (Krajcik, 2023). This digital gap further prevents women from accessing alternative work arrangements that could alleviate WLB pressures and enhance their participation and performance in the built environment (Tiwari et al., 2024). Many construction firms do not provide paid leave, flexible hours, or maternity-related support. Weak institutional structures around parental leave and return-to-work processes force women to choose between career continuity and caregiving, affecting their performance and long-term participation in the industry. Women encounter limited access to mentorship, exclusion from professional networks, and biased assessments of competence. These constraints slow career progression and may discourage long-term participation, particularly when balancing career growth with family responsibilities becomes overwhelming.

2.4. Strategies and Best Practices for Achieving Work Life Balance

Due to the various challenges unique to women in the construction industry, they require customized strategies that address their personal and professional development (Monika & Amit 2025). Introducing paid parental leave, on-site childcare, and flexible return-to-work programs improves ability of women to balance work and family demands and strengthens retention. Access to mentors and professional networks enhances women's career progression, confidence, and ability to navigate workplace challenges, supporting better work life integration. Augustina & Grace (2024) confirmed that policies favouring maternity leave, stress management initiatives, can boost the careers of women in the construction.

Digital tools, cloud systems, and remote-working options provide flexibility that allows women to manage caregiving duties while maintaining professional productivity. Remote work software and project management software are just some of the tools that enable this flexibility (Krajcik, 2023). For instance, Jacobs Engineering, as the global giant in infrastructure and construction, uses cloud-based solutions to oversee projects remotely. This has enabled women in management positions to combine professional expectations with primary responsibilities of care giving to improve diversity and productivity in the workforce.

2.5. Theoretical and Conceptual Framework

This study is anchored on an integrated WLB – Performance – Technology nexus, underpinned by the

Work-Family Conflict Theory and the Job Demands-Resources (JD-R) Model. The Work-Family Conflict Theory explains that conflict arises when demands from work and family roles are incompatible, leading to stress, reduced well-being, and diminished job outcomes (Wang, 2024). Job Demands-Resources (JD-R) Model posits that all work environments consist of job demands and job resources. High job demands lead to stress and exhaustion, while adequate resources enhance motivation, engagement, and performance (Taris & Schaufeli, 2016). Within this relationship, digital technology is conceptualized as a mediating/enabling tool. Tools such as remote work platforms, cloud-based systems, and digital project management applications provide flexibility and reduce work-family conflict, thereby improving performance outcomes (Tiwari et al. 2024). The conceptual model provides a structured concept of the WLB performance relationship in the construction industry and extends existing literature by explicitly incorporating digital technology as a critical enabler (Figure 1).

3. Research Methodology

This study employed a quantitative research approach, utilizing a survey research design. The survey method was considered appropriate because it enabled the collection of standardized data from a relatively large number of respondents, thereby facilitating the assessment of work-life balance factors affecting female construction professionals. Data was gathered primarily through a structured questionnaire while content validity was employed to ensure that the questionnaire contents adequately covered all aspects of WLB and female performance in the construction industry. Simple random technique was employed to select the respondents while a descriptive statistical method using mean item score (MIS) and charts were used to analyse the data. MIS provides a simple, clear, and interpretable measure of central tendency, allowing for easy comparison and ranking of variables based on respondents' perceptions without overcomplicating the analysis. The outcome of the analysed data was ranked according to their level of significance and impact using a rule of thumb. The population comprised of female construction professionals (Architects, Quantity Surveyors, Builders, Civil Engineers) working in Public Organizations and Private Construction firms in Abuja registered with their relevant professional bodies. A total of 238 female professionals were sampled for this study. Table 1 shows the total population of female construction professionals registered with their professional bodies. The Yamane formula for finite populations was employed to determine the sample size: $n = N / (1 + N(e^2))$. Using the formula: $n = 591 / (1 + 591(0.05^2)) = 238$. The questionnaires were distributed electronically through construction organizations within Abuja. Only questionnaires completed by female construction professionals working in Abuja were included in the analysis. A total of 187 responses were gotten which indicates a 79% response rate which was adequate for questionnaire-based research.

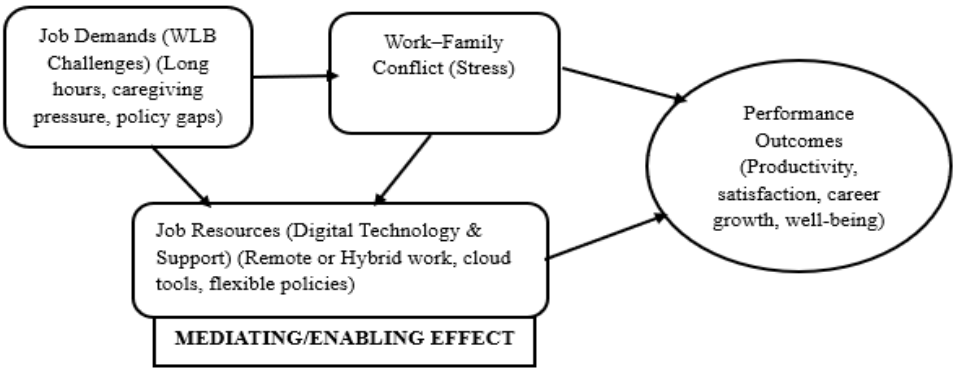

Figure 1: Conceptual Framework
Source: (Researcher, 2026)

Table 1: Analysis of Population size

S/N	Profession	Number of Registered Female Professionals in Abuja	Source
1.	Architects	160	NIA
2.	Quantity Surveyors	220	WAQSN
3.	Builders	106	CORBON
4.	Civil Engineers	105	COREN
TOTAL		**591**	

4. Findings and Discussion

As indicated in Figure 2, the study found out that the current work life balance amongst female professionals in Abuja is unsatisfactory with a mean value of 4.04. This is consistent with the work-family conflict theory, where competing role demands lead to stress and reduced well-being. This supports existing studies that link long working hours and rigid schedules in construction to poor balance among women (Hasan et al., 2021). This was followed by maternity leave policies which are poorly supported with a mean of 4.01. This indicates weak institutional frameworks, reinforcing institutional theory, which emphasizes how organizational policies influence career continuity. As noted by Adah et al. (2024), such gaps contribute to reduced retention and progression of women in the industry. Digital tools for enabling work life balance and availability of remote work options or hybrid were also seen to have higher means of 3.99 and 3.81 respectively. These results highlight significant structural and organizational challenges affecting female professionals in Abuja's construction sector. Female professionals lack critical support systems that could mitigate work pressure and enhance flexibility. This finding supports Tiwari et al. (2024), who emphasized that inadequate digital adoption in construction constrains opportunities for remote collaboration and flexible work, thereby limiting women's participation and performance. From a practical perspective, these findings suggest that construction firms need to prioritise flexible work systems, strengthen maternity policies, and invest in digital technologies.

The results in Table 2 shows that the most critical challenges affecting WLB are pregnancy and motherhood impacts on job roles (MIS = 4.01), limited

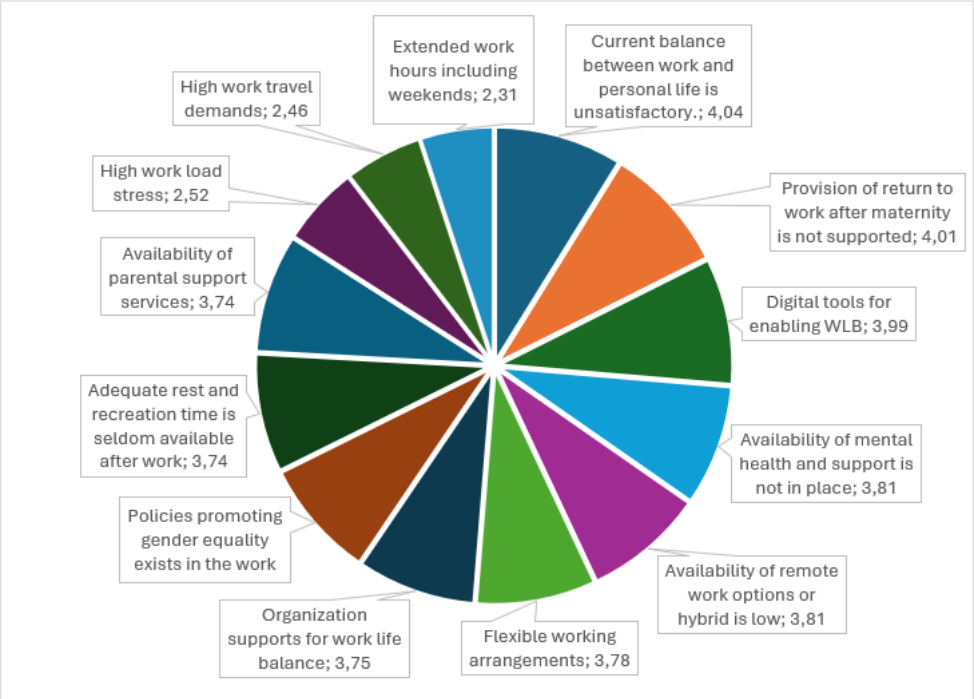

Figure 2: Current Work-Life Balance Conditions of women in the Construction Industry

Table 2: Challenges of work life balance

Challenges to Work Life Balance for Female Professionals	MIS	Rank	Decision
Pregnancy and motherhood negatively affect job roles.	4.01	1st	High Impact
Limited mentorship and networking	3.98	2nd	High Impact
Organizational policies are not gender sensitive	3.92	3rd	High Impact
Lack of remote work options and digital tools affects productivity	3.9	4th	High Impact
Mental health is not prioritised by organizations	3.89	5th	High Impact
Returning to work after maternity is challenging	3.87	6th	High Impact
Male Dominated work culture	3.84	7th	High Impact
Inadequate maternity support in organizations	3.81	8th	High Impact
Long and irregular working hours	3.76	9th	High Impact
Gender bias exists within the organization	3.68	10th	High Impact
Pressure exists between family and career	3.42	11th	High Impact
Workload Prevents time for personal care	2.89	12th	Moderate Impact
Cultural expectations reduce career progression	2.78	13th	Moderate Impact
Lack of female friendly facilities	2.76	14th	Moderate Impact
Average MIS	**3.61**		**High Impact**

mentorship and networking (MIS = 3.98), and non-gender-sensitive organizational policies (MIS = 3.92). This challenge confirms that motherhood significantly disrupts female career continuity, reinforcing earlier findings that inadequate maternity support and rigid work structures force women to choose between career and caregiving (Ghanbaripour, 2023). This aligns with work-family conflict theory, which explains how competing role demands negatively affect job performance and well-being. Similarly, the high ranking of limited mentorship and networking reflects structural barriers to career growth, supporting Augustina and Grace (2024), who noted that lack of professional support systems limits women advancement and increases work-related stress. The study further highlights persistent institutional bias within the industry, consistent with Kermanshachi (2023), who identified male-dominated cultures and rigid policies as barriers to inclusion. The implication of these findings is that WLB challenges are not only individual but deeply embedded in organizational and institutional structures, contributing to low retention, reduced productivity, and slow career progression for women. Construction firms should strengthen maternity and return-to-work policies, provide remote work options, establish structured mentorship programmes, and implement gender-sensitive policies to create a more inclusive and supportive work environment

The radar diagram analysis in Figure 3 shows the comparison of the multiple variables and their relative magnitudes. The values closer to the outer edge (around 4.0 – 4.23) indicate stronger negative effects of poor work life balance on performance of women in construction industry, while values closer to the centre indicate weaker effects. The overall shape of the chart shows that most variables cluster around high values (3.9 – 4.2), suggesting that work life imbalance has a consistently high adverse impact across different dimensions of performance. The most prominent result shown is that work life imbalance impedes career growth (4.23), which is the highest value on the chart. This indicates that imbalance significantly limits professional progression for women. This finding aligns with existing literature, which shows that women in construction often face slowed career advancement due to competing family and work demands (Hasan et al., 2021).

Closely following this is heightened stress and anxiety (4.02), demonstrating that poor work-life balance contributes substantially to psychological strain. This supports prior research linking long working hours and rigid construction schedules to increased stress levels and reduced well-being (Galea et al., 2020). Other notable effects include decline in promotion opportunities (3.98), reduced motivation (3.97), and lower job satisfaction (3.94-3.95). These results collectively show that work-life imbalance does not only affect personal well-being but also undermines workplace performance outcomes such as commitment, productivity, and creativity. The findings imply that poor work-life balance is a critical barrier to both individual performance and career sustainability among women in the construction industry.

The top ranked strategy highlights the importance of maternity and parental support, confirming that caregiving policies are essential for improving

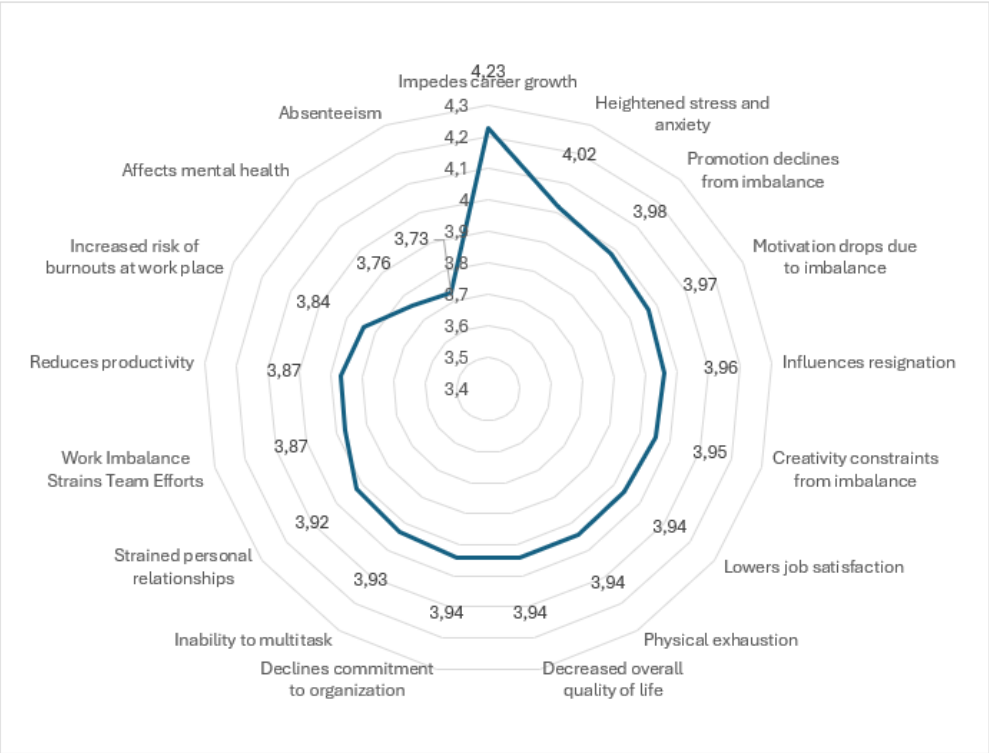

Figure 3: Effect of work life balance on performance

women's retention and WLB, as noted by Ghanbaripour (2023) in Table 3. Similarly, the high ranking of onsite childcare further reinforces the need for structured caregiving support systems to reduce work family conflict. The inclusion of digital technology also reflects the growing importance of flexible and remote working options, supporting Tiwari et al. (2024), who emphasized that digital tools enhance flexibility and productivity for women. The implication of these findings is that work–life balance improvement requires institutional, technological, and caregiving support systems rather than individual coping strategies.

The results in Table 4 reveal a significant gap between the perceived importance of digital technologies and their actual utilization in the construction industry. For instance, remote work platforms (MIS = 4.35, ranked 1st) and cloud-based document sharing (MIS = 4.20, ranked 3rd) are considered highly important but are largely not utilized. This suggests that although organizations recognise the role of digital tools in enabling flexibility and improving WLB, their adoption remains low. This finding supports Tiwari et al. (2024), who noted that limited digital adoption restricts flexible work opportunities for women in construction. Similarly, digital project management tools (MIS = 4.28) are only sometimes utilized. In contrast, mobile communication tools (MIS = 4.18) are fully utilized, indicating that firms tend to adopt simpler technologies while neglecting more advanced systems that could support flexible work arrangements. This aligns with previous studies suggesting that the construction industry is generally slow in adopting advanced digital innovations despite their known benefits. Firms need to move from awareness to actual implementation of digital tools to improve productivity, flexibility, and female retention.

5. Conclusion and Further Research

The study concluded that there exists a significant relationship between work life balance and performance of female professionals in the built

Table 3: Perceived Strategies for Improving Work Life Balance

Strategies for Improving Work Life Balance	MIS	Rank	Decision
Support for maternity and parental leave	4.52	1st	Extremely Important
Onsite childcare support	4.16	2nd	Very Important
Inclusion of digital technology	4.15	3rd	Very Important
Effective communication	4.14	4th	Very Important
Introduction of work life balance policies and initiatives	4.12	5th	Very Important
Emotional and mental health support programs	4.09	6th	Very Important
Creating a safe space and inclusive work space	4.05	7th	Very Important
Fostering supportive leadership to better work life balance	4.04	8th	Very Important
Work flexibility	4.01	9th	Very Important
Mentorship and professional networks	4.00	10th	Very Important
Clear boundaries between work and personal time	3.98	11th	Very Important
Introduction of remote or hybrid work options	3.97	12th	Very Important
Encouragement to seek help when needed	3.95	13th	Very Important
Regular review of employee workload by organization	3.93	14th	Very Important
Prioritization of breaks	3.91	15th	Very Important
Average MIS	***4.00***		***Very Important***

Table 4: Digital technological tools and their level of utilization

Digital Technology	MIS	Rank	Level of Utilization	Level of Importance
Remote work platforms (MS Teams, Zoom)	4.35	1st	Not Utilized	Extremely Important
Digital project management tools	4.28	2nd	Sometimes Utilized	Very Important
Cloud-based document sharing (OneDrive, google drive)	4.2	3rd	Not Utilized	Very Important
Mobile communication (Watsapp, telegram, emails, phone calls)	4.18	4th	Utilized	Very Important
Virtual Site Monitoring (drones, remote CCTV feeds)	4.1	5th	Not Utilized	Very Important
Time-Tracking & Scheduling software	4.05	6th	Not Utilized	Very Important
Digital Wellbeing &mental health apps	3.98	7th	Not Utilized	Very Important
BIM & collaborative digital modelling tools	0.92	8th	Sometimes Utilized	Very Important
E-learning & professional development platforms	3.85	9th	Not Utilized	Very Important

environment. It can be observed that the current work life balance condition of females in the built environment is poor. This results in reduced performance and job satisfaction. There is also under-utilization of digital technology to enhance work life balance which calls for urgent attention. The study recommended that construction firms should adopt technological tools to enhance performance of women in their workplace. Construction firms should promote positive work-life balance for female employees by reducing extended work hours and supporting their smooth transition back to work after maternity leave. Supportive policies should be put in place to enhance women balancing motherhood and professional life. Further studies can be carried out on influence of mentorship programme on work-life balance of women and career progression in the built environment.

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An Exploratory Quantitative Survey of Gender-Sensitive Compliance with Construction Health and Safety Regulations in Pakistan

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Abstract

Pakistan's construction industry is widely recognised as one of the country's most hazardous sectors, characterised by weak and inconsistent enforcement of occupational health and safety (H&S) regulations. Although prior research has examined general safety deficiencies, limited empirical evidence exists on how gender shapes compliance with health and safety regulations, by implication, associated practices. This paper presents a exploratory study that investigates the extent to which compliance with construction H&S regulations in Pakistan incorporates gender-sensitive measures. A quantitative, cross-sectional survey was conducted among 23 construction professionals in Pakistan using convenience and snowball sampling and a structured online questionnaire. Data were analysed using descriptive statistics, chi-square tests, and Fisher's exact tests. The findings indicate that safety regulations are implemented inconsistently, enforcement is often perceived as unequal, and women are frequently excluded from training. Gender-specific personal protective equipment (PPE) and adequate sanitation facilities are largely absent, while cultural norms, weak enforcement, lack of training, and cost constraints remain key barriers. Inferential statistical analysis shows significant associations between the provision of gender-specific PPE and sanitation facilities and between the observation of gender-specific safety issues and support for gender-sensitive policies. The study concludes that Pakistan's construction safety system inadequately addresses gender considerations and that regulatory reform, inclusive enforcement, and organisational change are required to promote equitable protection for all workers.

Keywords: enforcement gaps, gender-responsive policies, women in construction, worker protection, workplace inclusion

1. Introduction

The construction industry plays a significant role in Pakistan's economic development, contributing approximately 2.5–3% of the national gross domestic product (GDP) and providing employment across infrastructure, housing, and industrial projects (Pakistan Bureau of Statistics, 2023). Despite its economic importance, construction remains one of the most hazardous industries in the country, characterised by persistent safety management failures and high accident rates (Adekunle et al., 2024). Although several laws and policies exist to regulate occupational safety, such as the Factories Act 1934, Labour Protection Policy 2006, and Labour Policy 2010, their implementation has consistently fallen short of international standards (Government of Pakistan, 1934; Government of Pakistan, 2010).

Construction safety challenges are further complicated by the gendered nature of the workforce. While the industry is male dominated, women participate primarily in low paid, informal roles such as material handling and finishing work (Pakistan Bureau of Statistics, 2022). These workers often face specific risks, including exclusion from training, ill-fitting personal protective equipment (PPE), inadequate sanitation facilities, and discomfort in reporting safety concerns (ILO, 2021; GIZ, 2022). Despite these challenges, empirical studies examining the relationship between gender and health and safety (H&S) compliance in Pakistan remain scarce (Kabeer, 2008). This study (the Lead author's MSc dissertation otherwise research project), therefore, aims to investigate the extent to which compliance with construction H&S regulations in Pakistan incorporates gender sensitive measures.

2. Literature Review

2.1. Regulatory Frameworks and Safety Compliance

Like many developing countries, such as Nigeria, Pakistan's health and safety regulatory system is complex and comprises an array of federal and provincial laws focused on protecting workers (Umar and Umeokafor, 2024). While the Factories Act 1934 forms the foundation of industrial safety regulation and

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governs worker welfare, PPE provision, training, and inspections in the country (Government of Pakistan, 1934), it primarily focuses on factory settings. Umar and Umeokafor (2024) reviewed the Act and found that the term "construction" appears only six times. In fact, Raheem and Hinze (2013) conclude that construction is not governed by any specific legislation in the country. Of the eleven pieces of legislation enacted by national and provincial assemblies that address occupational safety and health more generally, Umar and Umeokafor (2024) demonstrate that only six are applicable to the construction sector. One example is the Sindh Environmental Protection Act, 2014 (Act No. VIII of 2014), which focuses on environmental management and protection within the province of Sindh. Consequently, the authors argue for the introduction of construction-specific legislation. These underline the fragmented and limited nature of the regulatory framework governing construction health and safety in Pakistan.

Following the 18th Constitutional Amendment in 2010, occupational safety and health became the responsibility of provincial governments in Pakistan. These governments are now tasked with legislating, enforcing, and inspecting workplaces, including those in the construction sector (International Labour Organisation (ILO), 2017). The federal government, however, retains a coordinating and standard-setting role (ibid.). Such governance arrangement introduces several limitations, including a lack of uniformity in standards and enforcement, increased costs for organisations, and administrative confusion (Umeokafor, 2017a). Nevertheless, in April 2026, the National Code of Practice on Occupational Safety and Health for the Construction Sector was approved and issued through a Statutory Regulatory Order (Devdiscourse, 2026). As a result, the Code is now legally binding across Pakistan (ibid.).

The complexity of the regulatory regime may explain why research consistently reports weak enforcement, insufficient inspections, and limited safety systems, particularly among small and informal contractors (Ahmed et al., 2018; Josh and Mak International, 2024; Umar and Umeokafor, 2024). Regulatory authorities also face challenges such as staffing shortages, outdated inspection methods, and limited sanctioning powers. These challenges result in enforcement practices that are largely reactive rather than preventive (Umar and Umeokafor, 2024). It is anticipated that the recently approved National Code of Practice on Occupational Safety and Health for the Construction Sector will help address these longstanding regulatory challenges.

2.2. Gender and cultural barriers in construction safety

Beyond regulatory and organisational factors, gender- and culture-related barriers are observed among women in the construction sector. These barriers are reflected in the low participation of women in Pakistan's construction workforce, which remains at approximately 2 to 5 percent of the total workforce, largely due to cultural norms and occupational segregation (Pakistan Bureau of Statistics, 2022). This under-representation is also evident in leadership positions. Moreover, women in the construction sector encounter discrimination, which results in psychosocial risks (Curtis et al., 2018). Tang (2025) found that in the United States of America, women are more susceptible to musculoskeletal disorders because tools are primarily designed for men. Similar patterns have been observed in South Asia, where, despite the small number of women employed in the industry, women are often exposed to greater risks than their male counterparts. Research further indicates that where women are present, safety systems are rarely designed to address gender-specific needs. Studies from South Asia and other regions show that standardised personal protective equipment (PPE) is frequently designed around male body dimensions, reducing its effectiveness for women (Husam et al., 2024; Tang, 2025). Notably, GIZ (2022) reports that in Pakistan, women have limited access to adequate safety gear and are therefore more exposed to dust, heat, and noise. In addition, exclusion from safety training and inadequate sanitation facilities pose significant health and dignity concerns for women (Jayakaviya et al., 2025; ILO, 2021).

More research papers have highlighted that women are less likely to report safety concerns and incidents. The ILO (2021) reports that fear of harassment, loss of employment, and social stigma discourage women from reporting safety incidents, contributing to the under-reporting of accidents. Jayakaviya et al. (2025) found that in India and Nepal, women often lack access to separate latrine facilities, exposing them to the risk of dehydration, as they may deliberately restrict fluid intake to avoid using unsafe or unavailable toilets. This practice results in fatigue and lower productivity (Jayakaviya et al., 2025).

Overall, these barriers are not isolated but interconnected, as cultural norms, gender stereotypes, and structural limitations within the industry collectively restrict women's participation and expose them to higher occupational risks. The persistence of male-oriented safety systems further reinforces these inequalities, resulting in continued exclusion and inadequate protection for women in construction work (Curtis et al., 2018; Umeokafor, 2017a).

2.3. Compliance Gaps and Organisational Factors

Another key factor is poor compliance, where organisational practices and structural conditions negatively affect construction workers' health and well-being. Poor enforcement, limited awareness,

informal labour arrangements, and cost pressures undermine health and safety compliance across construction sites (Umar and Umeokafor, 2024). Cultural beliefs, including fatalistic attitudes toward accidents, further reduce motivation to follow safety procedures (Bajracharya et al., 2023). For example, a study by Shah et al. (2020) indicates that there is a prevailing perception that women are not exposed in high-risk activities in construction and are therefore excluded from safety meetings. This exclusion means that women represent an untapped and potentially important source of learning and information for improving safety practice. Importantly, existing compliance research rarely considers gender differences, thereby treating the workforce as homogeneous and overlooking women's specific vulnerabilities (Kabeer, 2008).

2.4. Conceptual Framework

Drawing on regulatory structures, gender-related safety challenges, and organisational compliance factors, this study adopts a framework linking regulatory environments, organisational practices, gender norms, compliance behaviours, and safety outcomes (Hinze, 2017). Weak enforcement, informal labour, and cost-driven management practices interact with gender norms to influence access to training, PPE, welfare facilities, and hazard reporting, thereby shaping safety compliance and outcomes (Sarvari et al., 2024). The conceptual framework is illustrated in Figure 1.

3. Research Methodology

A positivist philosophy and a deductive approach were adopted (Saunders et al., 2019). A quantitative, cross-sectional survey design was used to capture perceptions of health and safety compliance and gender-specific challenges at a single point in time (Bryman, 2016). Data were collected using an online questionnaire distributed in 2024 to construction professionals in Pakistan, including engineers, supervisors, and safety officers.

The questionnaire comprised sections on respondent demographics, general health and safety practices, and gender-related safety issues. It assessed participants' familiarity with Pakistan's occupational health and safety regulations to establish baseline awareness. The subsequent sections focused on key study constructs, including perceptions of equal enforcement of safety protocols for male and female workers, participation in health and safety training programmes, availability of gender-specific personal protective equipment (PPE), adequacy of sanitation facilities for female workers, willingness of women to report safety issues, and the perceived need for gender-sensitive health and safety policies. All questions were mandatory to ensure complete responses across all variables. Likert-scale items were used to measure perceptions of implementation, enforcement, training, and reporting. Due to access limitations and the exploratory nature of the study, convenience and snowball sampling were employed, resulting in 23 valid responses. Data analysis involved descriptive statistics and non-parametric tests using SPSS and Excel (Field, 2018). Cross-tabulations, chi-square tests, and Fisher's exact tests were conducted, with results interpreted cautiously because of the small sample size. Although exploratory, these analyses provide useful indications of how perceptions and experiences are related within the dataset. Ethical approval for the study was obtained from the University of Greenwich Faculty of

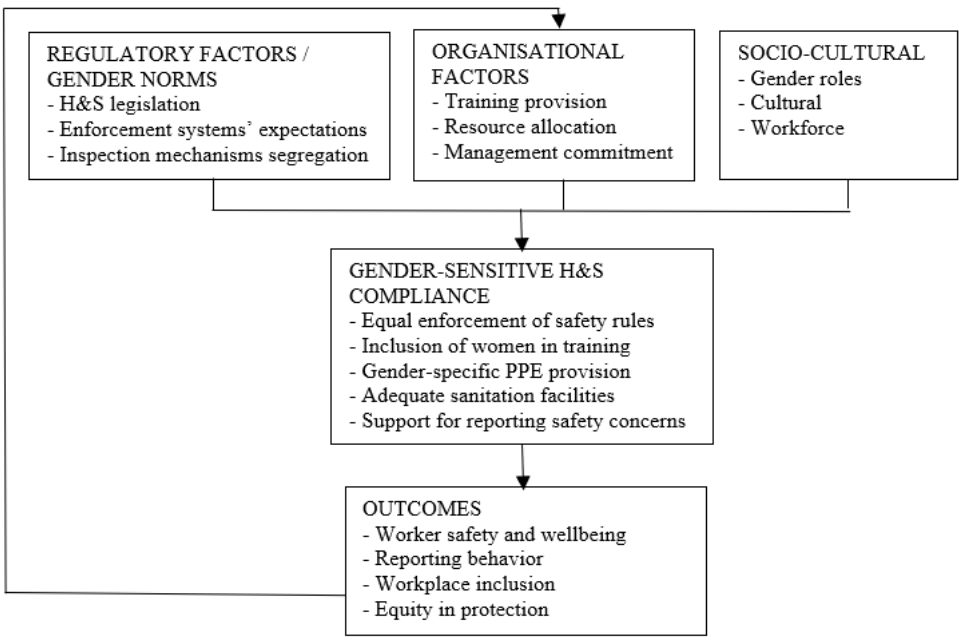

Figure 1: Conceptual framework of the study

Engineering Ethics Committee (reference number: FES-FREC-ENG-25.01.02).

4. Findings and Discussion

A total of 23 participants completed the survey, comprising 19 engineers, one supervisor, one safety officer, and two support or administrative staff. While this distribution is not representative of the full diversity of Pakistan's construction labour force, as an exploratory study it provides insight at that level. Exploring construction health and safety issues using a small sample to generate preliminary insight is consistent with previous studies including Nnedinma (2016) and Umeokafor (2017a). To ensure that respondents possessed an appropriate level of knowledge for the study, they were asked to indicate their familiarity with Pakistan's Occupational Health and Safety Regulations. The results of this assessment are presented in Table 1.

Table 1 shows that respondents demonstrated a relatively high level of awareness of occupational health and safety regulations, as 22 of the 23 participants reported being either "Very familiar" or "Somewhat familiar" with health and safety regulatory requirements in Pakistan. Only one respondent indicated that they were "Not familiar." This does not necessarily imply a complete lack of knowledge or an inability to provide valuable insight. Overall, the responses from 22 informed participants suggest that the dataset largely reflects informed professional opinions rather than views from untrained or inexperienced workers. This adds credibility to the interpretation of findings relating to compliance, enforcement, and gendered health and safety challenges.

4.1. Assessment of gender-sensitive health and safety compliance practices

Table 2 presents a summary of respondents' views across various indicators of gender-sensitive health and safety compliance practices. Although a majority of respondents reported that health and safety enforcement is applied equally to men and women, a substantial proportion perceived inequality in enforcement. This finding highlights persistent gender disparities within a male-dominated industry and is therefore concerning.

While a little over half of the respondents reported having participated in health and safety training, many also indicated the absence of women from the training environment. This suggests structural exclusion of women rather than a lack of training provision itself and is consistent with findings from previous studies in South Asia (ILO, 2021). The extent to which training content is gender-sensitive also remains unclear. The study further identified limited availability of gender-specific personal protective equipment and a high prevalence of inadequate sanitation facilities for women. Although this is not unexpected given the male-dominated nature of the industry, it represents a significant barrier to improving women's participation in construction. Similar patterns have been reported in both regional and international studies, which show that

Table 1: Familiarity with Pakistan's Occupational Health and Safety Regulations

Familiarity Level	n
Not familiar	1
Somewhat familiar	9
Very familiar	13

Table 2: Summary of respondents' views on gender-sensitive H&S compliance

Indicators	Response Category	n
Equal enforcement of safety protocols for male and female workers	No	8
	Not sure	1
	Yes	14
Participation in H&S training	No	13
	Yes	10
Availability of gender-specific PPE	No	13
	Not applicable	3
	Yes	7
Sanitation facilities for female workers	Adequate	9
	Inadequate	10
	Not applicable	4
Women's comfort in reporting safety issues	Don't know	11
	No	5
	Yes	7
Necessity of gender-sensitive H&S policies	Agree	9
	Disagree	2
	Strongly agree	12

the absence of gender-appropriate PPE and welfare facilities contributes to exclusion and increased safety risks for women (Husam et al., 2024; Jayakaviya et al., 2025). Nevertheless, the finding that a majority of respondents recognise the necessity of gender-sensitive health and safety policies is encouraging. This aligns with global calls for more inclusive and equitable safety management practices within the construction sector (GIZ, 2022).

4.2. Relationships Between Key Variables

Table 3 in Appendix 1 is a combined descriptive cross-tabulation of key gender sensitive health and safety indicators. In the table, each block represents a distinct pair of variables assessed in the inferential analysis and therefore must be interpreted independently. The first column identifies the variables being cross-tabulated, while the subsequent columns report the frequencies (n) for each response category of the associated variable. Furthermore, the response category labels differ across blocks because each pairing examines a different aspect of health and safety practice, such as implementation, training, welfare provision, reporting, and policy support. Blank cells indicate that a response category is not applicable for a specific variable pairing. While the table offers descriptive insight into the issues examined, its content underpins the inferential analysis presented in Table 4. The findings suggest differences in the implementation of H&S regulations across roles. Engineers mainly report that regulations are implemented only 'sometimes'. This indicates an inconsistency in translating compliance into practice. This is consistent with the findings of Umeokafor (2017b), who found that compliance with health and safety regulations in Nigeria is formal but not operational, as it is symbolic and supported by documents such as policies and induction records. However, this hardly translates into practice in day-to-day operations on construction site, weak and uneven site implementation (Ibid). Regarding training, the findings in Table 3 indicate mixed experiences with the presence of women on construction sites. In particular, both the trained and untrained respondents note instances in which women were absent from H&S training. However, some reported women's participation or uncertainty about their presence. This is consistent with ILO (2021), which reports that women are excluded from formal health and safety training, overlooked in toolbox talks, and are assumed to pose limited risks in construction.

Table 3 indicates that the level of safety regulation implementation may have no bearing on the extent to which safety issues were observed. This is because observed safety issues were reported across all levels of H&S implementation. This is consistent with the findings of Umeokafor (2017b), who found that disproportionate safety incidents were still occurring on site despite the claimed implementation health and safety regulations in Nigeria. This can be explained by many factors, including the fact that safety measures or compliance actions are not contextualised to address the country's social, economic, political and cultural environments. In the context of the current study, the lack of gender-sensitive measures in compliance with H&S regulations explains why the level of safety regulation implementation does not address safety issues, especially gender-related. The presence or implementation of gender specific safety provisions across the site also differed. Many respondents claimed that gender specific PPE and adequate sanitation facilities for female workers were absent. In fact, on occasion when they were present, the adequacy of the sanitation facilities was more varied. Finally,

Table 4: Summary of inferential analyses of Gender-Sensitive H&S variable

Variables	Test(s)	χ^2 (df)	Fisher p	Sig.	Key Interpretation
Role × H&S implementation	Chi-square; Fisher's exact	2.67 (6)	1.000	No	Perceptions are similar across roles, indicating a systemic issue.
Training × Women inclusion	Chi-square; Fisher's exact	1.56 (3)	0.915	No	Women's exclusion from training is widely reported, regardless of respondents' training status.
Gender PPE × Sanitation facilities	Chi-square; Fisher's exact	10.8 (4)	**0.010**	**Yes**	Gender-specific PPE is associated with better sanitation facilities
Gender issues × Policy support	Chi-square; Fisher's exact	5.75 (2)	**0.029**	**Yes**	Gender-specific safety issues is associated with stronger support for gender-sensitive policies.
Equal enforcement × Reporting comfort	Chi-square; Fisher's exact	3.64 (4)	0.426	No	Equal enforcement alone does not ensure women feel comfortable reporting safety concerns.
H&S implementation frequency × Observed issues	Chi-square; Fisher's exact	5.25 (2)	0.099	No	No significant association.

respondents who reported witnessing gender specific safety issues more frequently expressed strong agreement with the relevance of gender sensitive safety policies. However, those that did not observe such issues showed more mixed views.

Table 4 summaries the inferential statistical analysis of the variables. The table shows that although most associations were not statistically significant, two were. There was a significant association between gender-specific PPE provision and Sanitation facilities that are gender specific. This indicates that construction sites that provide PPE are likely to offer adequate sanitation. This suggests a holistic approach to gender-sensitive safety policies and practices. Conversely, sites that ignore PPE for women also appear to neglect basic sanitation, reinforcing the notion that gender-sensitive safety management is either taken seriously as a whole or largely disregarded. Also, observing gender-specific issues and providing stronger support for gender-sensitive safety policies. This shows that workers who have personally seen or experienced safety issues that impact on women on construction site are more likely to believe that gender specific policies are relevant (Tang, 2025).

5. Conclusion and Further Research

The study has investigated the extent to which compliance with construction H&S regulations in Pakistan incorporates gender-sensitive measures. Drawing on an exploratory study of construction professionals in Pakistan, the findings demonstrate that compliance with construction H&S regulations in Pakistan is inconsistent and insufficiently gender-inclusive. The findings indicate that safety regulations are implemented inconsistently, enforcement is often perceived as unequal, and women are frequently excluded from training. The analysis reveals that gender-specific PPE and adequate sanitation facilities are largely absent, reflecting the construction industry's male-dominated nature. Inferential statistical analysis shows significant associations between the provision of gender-specific PPE and sanitation facilities and between the observation of gender-specific safety issues and support for gender-sensitive policies. The study contributes preliminary empirical evidence on the intersection of gender and safety compliance in Pakistan's construction industry. Given the small sample size, findings should be interpreted as exploratory rather than generalisable. Future research should employ larger, more diverse samples, integrate qualitative methods, and examine sector-specific dynamics to inform inclusive regulatory and organisational reforms.

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Appendix 1

Table 3: Descriptive Cross-tabulated distributions of gender-sensitive H&S variables

Analysis Pair / Indicator	Row Category	Category 1		Category 2		Category 3		Category 4	
		label	n	label	n	label	n	label	n
Role × H&S implementation		Implementation of H&S Regulations							
	Engineer	Always	4	Rarely	6	Sometimes	9	—	—
	Other	Always	0	Rarely	1	Sometimes	1	—	—
	Safety Officer	Always	0	Rarely	0	Sometimes	1	—	—
	Supervisor	Always	0	Rarely	0	Sometimes	1	—	—
Training × Women inclusion				Women on site					
	No training		6	No	5	Not sure	1	Yes	1
	Yes training		5	No	3	Not sure	0	Yes	2

Analysis Pair / Indicator	**Row Category**	**Category 1**		**Category 2**		**Category 3**		**Category 4**	
		label	**n**	**label**	**n**	**label**	**n**	**label**	**n**
H&S implementation frequency × Observed issues		Any observed Issues							
	Always	No	3	Yes	1	—	—	—	—
	Rarely	No	5	Yes	2	—	—	—	—
	Sometimes	No	3	Yes	9	—	—	—	—
Equal enforcement × Reporting comfort		Extent of Women's comfort in reporting safety issues							
	No enforcement	Unsure	2	No	3	Yes	3	—	—
	Not sure	Unsure	1	No	0	Yes	0	—	—
	equal enforcement	Unsure	8	No	2	Yes	4	—	—
Gender PPE × Sanitation facilities		Sanitation Facilities for female workers							
	No PPE	Adequate	4	Inadequate	9	N/A	0	—	—
	PPE N/A	Adequate	2	Inadequate	0	N/A	1	—	—
	Yes PPE	Adequate	3	Inadequate	1	N/A	3	—	—
Gender issues × Policy support		Relevance of gender-sensitive safety polices							
	No gender issues	Agree	7	Disagree	1	S. agree	3	—	—
	Gender issues	Agree	2	Disagree	1	S. agree	9	—	—

Digital Skills and Women's Career Advancement in the South African Construction Industry

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Abstract

The South African construction industry remains male-dominated, with women facing barriers to education, entry, retention, progression and leadership. At the same time, the industry is becoming more digital through tools such as Building Information Modelling, project management software, quantity take-off systems, digital collaboration platforms, sustainability tools, surveying technologies and construction site management applications. This paper examines how digital skills influence women's professional growth in the construction industry. The study adopted a quantitative research approach, using a questionnaire to collect data from 113 randomly selected construction professionals in the South African construction industry. The data collected was analyzed using descriptive statistics. The findings show that mastery of digital tools is perceived to support professional growth through improved work efficiency, access to new responsibilities, recognition, promotion opportunities, and wider participation in technical construction services. Digital tools were also perceived as useful for improving inclusivity, diversity, equality and accessibility in areas such as project management, design, quantity surveying, construction management, data-driven decision-making and sustainability. However, the findings also show that digital skills alone cannot address women's under-representation. Supportive education systems, mentoring, anti-discrimination measures, childcare support, flexible work arrangements, equal pay, gender-sensitive hiring and safer work environments are also required. The paper concludes that digital skills can enhance women's career pathways, but only when supported by wider institutional and workplace reforms.

Keywords: Construction industry, digital skills, gender equality, professional growth, women

1. Introduction

The construction industry is central to economic development, infrastructure delivery and sustainable cities (Sesele, 2022). It provides buildings, roads, water systems, energy infrastructure and other facilities needed for social and economic life (Department of Public Works and Infrastructure, 2022). However, the industry is one of the least gender-balanced sectors globally. Women are under-represented in construction employment, technical roles, site-based work and leadership positions (Hickey and Cui, 2020; Stride et al., 2021).

In South Africa, this challenge is linked to wider social and economic inequalities (StatsSA,2024). Women's participation in construction is affected by educational access, gender stereotypes, limited role models, workplace culture, safety concerns, caring responsibilities, unequal career opportunities and limited access to professional networks (UNESCO, 2024). These barriers are not only social problems; they also affect the industry's ability to attract skilled people, innovate and respond to future labor needs (CETA, 2025).

At the same time, construction work is changing. The fourth industrial revolution has increased the use of digital technologies in planning, design, construction and operation. These tools include Building Information Modelling (BIM), structural analysis software, project management and scheduling tools, construction site management systems, design and drafting tools, quantity take-off and estimating software, cloud collaboration platforms, sustainability and energy analysis tools, and digital surveying systems (Windapo, 2021). These tools can reduce some traditional barriers to participation by enabling remote work, improving collaboration, reducing reliance on physical strength, increasing transparency and creating new technical career paths (Al Salaheen et al., 2024).

Digitalization, therefore, raises an important question: can digital skills support women's professional growth

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in the construction industry? This question is important because digital transformation may either reduce inequality or reproduce existing exclusion. If women do not have equal access to digital training, tools and work opportunities, digitalization may deepen the gender gap (Bailey and Nyabola, 2021). However, if digital skills are made accessible, they can help women enter, remain and progress in construction careers. Therefore, this paper examines how digital skills influence women's professional growth in the South African construction industry.

2. Literature Review

2.1. Gender inequality in the construction industry

The construction industry is widely recognized as male dominated. Women are under-represented in site roles, technical occupations, ownership positions and senior leadership. Stride et al. (2021) note that women constitute a small proportion of the construction workforce and that the COVID-19 period exacerbated existing inequalities. Nieto et al. (2024) further argue that although larger companies may have formal diversity and inclusion policies, their effects are often less visible in small- and medium-sized construction firms.

Women's under-representation is not caused by one factor. It is linked to education, social expectations, workplace culture, hiring practices, lack of role models, poor retention strategies, limited flexibility and weak implementation of equality policies (United Nations, 2016; UNESCO, 2024; Nieto et al., 2024). In construction, these challenges may be more pronounced because the industry is often associated with physical labor, long hours, site-based work, mobility demands, and masculine work cultures (Windapo, 2021). The lack of women in leadership is also a major barrier. Hickey and Cui (2020) report that women occupy fewer than 4% of executive leadership roles in engineering and construction companies in developed countries. This limits the visibility of women role models and can reduce younger women's confidence in pursuing careers in construction.

2.2. Education, STEM and women's career pathways

Women's participation in construction is linked to access to Science, Technology, Engineering, and Mathematics (STEM) education. UNESCO (2024) notes that women are under-represented in STEM education, research, innovation and leadership. Barriers include stereotypes, gender bias, lack of mentoring, limited flexible work structures, poor career management, and inadequate parental or caregiving support policies. The United Nations (2016) proposes action areas for improving women's participation in STEM. These include changing social stereotypes, engaging girls in STEM education, attracting women into higher education, promoting equal career progression, preventing harassment, supporting work-life balance, ensuring gender-sensitive policy design and promoting women's access to technology and innovation.

These ideas are relevant to construction because many construction professions depend on STEM knowledge. Architecture, engineering, quantity surveying, construction management, project management, facilities management and sustainability consulting all require technical knowledge. Therefore, improving girls' and women's pathways into construction must begin with education and continue into employment.

2.3. Digital transformation in the construction industry

The construction industry is being reshaped by digital technologies. Artificial intelligence, BIM, cloud computing, robotics, big data, internet of things, digital surveying, 3D modelling, virtual reality and sustainability analysis tools are increasingly used across the project lifecycle (Wang et al., 2023; Regona et al., 2024; Omrany et al., 2024). These technologies improve design quality, project coordination, cost estimating, scheduling, safety monitoring, resource optimisation, lifecycle management and sustainability assessment.

However, digital adoption is not automatic. Barriers include a lack of knowledge, resistance to change, the cost of training, technical complexity, poor communication of benefits, weak organisational support, and limited technical expertise (Windapo, 2021; Mazurchenko and Zelenka, 2022). These barriers affect all construction professionals, but they may have a stronger impact on women, who already face unequal access to training, networks, tools, and professional opportunities.

2.4. Digital equity inclusion and women's professional growth

Digital equity means that people have fair access to digital tools, digital infrastructure, training and opportunities to benefit from technology. Bailey and Nyabola (2021) highlight global digital access gaps, especially in Africa. If digital access is unequal, digital transformation may increase existing inequalities rather than reduce them. Digital tools can also create new opportunities for women in construction. Windapo (2021) and Al Salaheen et al. (2024) argue that technologies such as BIM, augmented reality, virtual reality, autonomous construction, 3D printing, and drones can reduce barriers associated with site work, including physical strain, safety risks, fear of heights, and work-life balance challenges. These tools may also

challenge traditional views that women belong mainly in administrative roles rather than technical construction work.

3. Research Methodology

The study adopted a quantitative research approach. A questionnaire was used to collect data from 112 randomly selected registered with the Construction Industry Development Board (Cidb)-registered in the South African construction industry. The survey was appropriate because the study aimed to gather perceptions from a range of professionals on digital tool mastery, career growth and women's inclusion in the industry. The questionnaire was administered electronically via Survey Monkey. The survey captured 112 recorded responses. However, the number of valid responses varied across questions because some respondents did not complete all sections. Therefore, the findings are interpreted descriptively and with scientific rigor.

The data were analyzed using descriptive analysis. Responses were examined to identify patterns in digital mastery, perceived career influence, perceived support for women's growth and factors affecting women's education and employment pathways. Inferential statistical claims were not made but the conclusions are drawn from observed patterns in the survey data.

The survey used categorical questions and Likert-type response scales. Digital mastery was measured using categories such as very low, low, moderate, high and very high. Perceptions of inclusivity and career influence were measured using categories such as not at all, some extent, moderate extent, large extent and very large extent. The digital tools investigated are shown in Table 1.

The study has two main limitations. First, the sample is not claimed to represent all construction professionals in South Africa and second, the study is based on perceptions and does not directly measure actual career outcomes such as promotions, salaries or job changes. Future research should use a larger dataset and may apply inferential analyses to test relationships among digital mastery, gender, and career outcomes.

4. Findings and Discussion

4.1. Profile of respondents

The dataset includes respondents from different construction-related roles. These include construction managers (40%), engineers (15%), quantity surveyors (3%), architects (2%), and other built environment participants, including project managers and facilities management practitioners (39%). Several respondents work as contractors (49%), subcontractors (13%), consultants (11%), government (4%), educational institutions (5%), and other organisations (18%).

The dataset also includes both male and female respondents, although male respondents are more visibly represented (74%). This reflects the wider male dominance of the construction industry. Respondents also came from different age groups, education levels and experience categories. Many had more than 6 years of construction experience, with several reporting over 21 years (26%). Many respondents were directors or business owners (78%), which suggests that many responses came from people with decision-making experience in construction organizations. Respondents worked for companies ranging in size from microenterprises (51%) to large enterprises (8%). This is important because small firms may face stronger barriers to adopting digital technologies due to costs, limited training budgets, and limited digital infrastructure.

4.2. Perceived mastery of digital tools

The data show different levels of mastery across digital tool categories. Some respondents reported high or very high mastery of tools for project management 3.3 weighted average on a scale of 5), design and drafting (2.63), construction site management (2.88), quantity take-off (3.03), and cloud collaboration (2.68). Other respondents reported low or very low mastery, especially in more specialized areas such as

Table 1: Construction-related digital tool categories investigated

Digital tool category	Examples
3D modelling and BIM	Revit, ArchiCAD, Tekla Structures, Civil 3D
Structural analysis and design	ETABS, SAP2000, STAAD.Pro, SAFE
Project management and scheduling	Primavera P6, MS Project, Procore
Construction site management	PlanGrid, Fieldwire, Bluebeam Revu, BIM 360
Design and drafting	AutoCAD, SketchUp, Rhino 3D, BricsCAD
Quantity take-off and estimating	CostX, WinQS, Planswift, Candy CCS
Accounting and financial management	Sage, QuickBooks, CMiC
Surveying, mapping and GIS	Trimble, Leica Geo Office, DroneDeploy, ArcGIS
Facility and asset management	Archibus, Planon, IBM Maximo
Cloud collaboration and document management	Autodesk Construction Cloud, Trimble Connect, Aconex
Sustainability and energy analysis	IES VE, DesignBuilder, One Click LCA, Tally

sustainability and energy analysis (2.14), facility and asset management (2.71), structural modelling (2.3), and some advanced BIM functions (2.39).

This pattern suggests uneven digital readiness in the construction industry. Some professionals are already using digital tools effectively, while others remain at low levels of mastery.

The data also shows that respondents acquired digital skills through several routes. These include formal education (21.25%), on-the-job learning (42.62%), self-teaching (25.66%) and informal learning (10.48%). On-the-job learning and self-teaching appear frequently in the dataset. This suggests that digital skills are often developed through practice rather than only through formal education. This is useful because it shows that digital skill development can happen at different career stages. However, it also means that people without access to digital work tasks, mentors or supportive employers may be disadvantaged.

4.3. Digital tools and inclusivity, diversity, equality and accessibility

Respondents were asked the extent to which digital tools facilitate inclusivity, diversity, equality and accessibility in the South African construction industry. The responses indicate that many participants see digital tools as supportive of inclusion, particularly when they improve collaboration, communication, accuracy, planning, and access to information. Digital tools such as BIM, cloud collaboration platforms, project management systems and digital document management were found to improve access to project information. This may reduce the exclusion of people who are not physically present on site or who work from different locations. It can also support flexible work, remote coordination and better communication among project teams.

Design and drafting tools, quantity take-off software and project management tools were also perceived as relevant to career growth. These tools can help professionals demonstrate technical competence, manage tasks more efficiently and participate in higher-value work. For women, this may be important because digital competence can help challenge stereotypes that women are less suited to technical construction roles. However, digital tools do not automatically produce equality. If women are not given access to software, licenses, training, digital devices, project experience or supportive mentors, they cannot benefit equally. Digital inclusion, therefore, requires both technology access and organizational support.

4.4. Digital skills and women's professional career growth

The study sought to know whether mastery of digital tools influences professional career growth. Responses show that digital mastery is perceived to influence career growth through the ability to take on new responsibilities, positive feedback and recognition, promotion opportunities, new job offers, important professional recognition, and major career advancement. Several respondents rated digital mastery as having a large or very large influence on career growth (32%). This supports the view that digital skills are no longer optional in construction. They are becoming part of professional competence.

For women, digital skills can support growth in at least four ways. First, they can improve employability by making women more competitive for technical and managerial roles. Second, they can increase visibility, as professionals who can use digital tools may be recognized as capable and innovative. Third, they can open access to less physically demanding but highly technical roles such as BIM coordination, planning, cost management, sustainability analysis and digital project controls. Fourth, they can support entrepreneurship, especially for women-owned firms that use digital tools to improve tendering, estimating, design, coordination and reporting as shown in Table 2.

Table 2: Main ways digital skills can support women's professional growth

Career growth pathway	How digital skills may support women
Employability	Improves technical competence and job readiness
Promotion	Supports performance, recognition and responsibility
Entrepreneurship	Helps women-owned firms improve estimating, planning and reporting
Technical participation	Opens roles in BIM, design, scheduling, cost control and data analysis
Flexible work	Supports remote coordination, cloud collaboration and digital communication
Professional confidence	Enables independent and effective task completion

The findings support the literature suggesting that digitalization can create new pathways into construction, but only when women have access to training and practical experience.

4.5. Construction services where digital skills can influence women's growth

Respondents identified numerous construction service areas in which digital mastery can support women's career growth. These include architecture, engineering, construction management, project management, interdisciplinary collaboration, precision and error detection, data analysis, virtual reality, construction site layout, construction automation, facilities management, quantity surveying, sustainability, energy efficiency, resource optimization, data-driven decision-

making, lifecycle management and enhanced indoor environments. These areas demonstrate that digital skills can support women's growth throughout the entire construction lifecycle. They are not limited to design offices. They extend to site management, sustainability, asset management and project delivery.

Particularly important areas include:

1. Project management and scheduling: Digital planning tools can support women's participation in management and leadership roles.
2. Quantity surveying and estimating: Digital estimating tools can improve cost accuracy and support commercial career pathways.
3. BIM and digital design: BIM can support coordination, modelling and interdisciplinary collaboration.
4. Sustainability and energy analysis: These tools link women's participation to green construction and sustainable development.
5. Cloud collaboration: These tools can support flexible work and wider access to project information.
6. Construction site management tools: These tools can help women participate more fully in site coordination, inspection and reporting.

This is important because women's inclusion should not be restricted to administrative work. Digital tools can help widen women's participation in technical and leadership roles.

4.6. Gender and digital skills acquisition

The study sought to know whether gender was a determining factor in learning and mastering digital tools. The responses were mixed. Some respondents indicated that gender was not a determining factor (64.35%), while others answered "yes" to one or more digital tools (35.65%). This suggests that gender may not affect all respondents equally, but it remains a relevant issue for some. The open-ended comments also show different views. Some respondents suggested that gender is not an issue, while others pointed to the need for women's empowerment, better support structures, proper uniforms, training programmes and formal or informal education. These comments show that gender inclusion is experienced differently across the industry.

The finding suggests that digital skills policy should avoid two extremes. It should not assume that all women experience the same barriers. It should also not assume that gender does not matter. A balanced approach is needed; digital skills programmes should be open to all, but they should also recognise the specific barriers women may face.

4.7. Segregation and access to the construction field

Respondents rated the level of segregation of girls and women in accessing the construction field on a 1-5 scale, with categories such as not acceptable, acceptable, average/fair, good/satisfactory, and very good. The responses vary, but many respondents rated the situation as average/fair (44.21%), acceptable (20%) or not acceptable (15.79%). This indicates that women's access to construction is still seen as a concern to people. This finding agrees with the literature that women's under-representation begins before employment. It is linked to education, subject choice, social expectations, career guidance, admission systems, financial aid, mentoring and safety. Therefore, improving women's digital skills in construction must begin before entry into the labour market. Schools, colleges, universities, and training institutions need to expose girls and women to digital construction technologies early on.

4.8. Education factors supporting women's access and retention

The survey asked respondents to rate factors that attract, promote access to and retain women in education. The factors included preventing gender bias in student admissions and financial aid, gender-sensitive mentoring, workshops, and networks, preventing discrimination and sexual harassment, promoting gender equality in international mobility, and providing childcare facilities for students. The responses show support for many of these factors. Mentoring, workshops, networks, anti-discrimination measures, anti-harassment measures and childcare support were commonly rated as important to some extent, a large extent or a very large extent.

These findings support UNESCO (2024) and the United Nations (2016), which emphasise that gender equality in STEM requires more than access. Retention is equally important. Women need safe, supportive and enabling learning environments. Digital construction education should therefore include mentoring, peer networks, practical tool training, role models and clear anti-harassment systems.

4.9. Education factors strengthening women's career pathways

The study also examined factors that strengthen women's pathways into employment. These included industry exposure; gender roles and work culture; glass ceiling; job satisfaction; maternity leave; caregiving support policies; equal pay legislation; gender equality policies; legislation and policies; mass and social media; gender balance requirements; manager and peer interactions; women managers; mentorship; hiring strategies; flexible strategies; caregiver leave and reintegration; childcare support; assessment procedures and metrics; infrastructure and materials suited to women's bodies; mechanisms against gender-based

violence; workforce policy; management trust in recruiting women; flexible working hours; and programmes for women's health.

The responses show that respondents perceive women's employment pathways to be shaped by many workplace and policy factors. This supports the argument that digital skills alone are not enough. A woman may master digital tools but still face barriers if recruitment is biased, site culture is hostile, childcare support is absent, pay is unequal, or promotion systems are unclear.

Digital skills must therefore be integrated into a wider inclusion strategy. This strategy should combine training, fair hiring, mentoring, workplace safety, flexible work, gender-sensitive performance evaluation, and leadership development.

5. Discussion of Findings

The findings show that digital skills can support women's professional growth in construction. They can increase employability, improve technical participation, support promotion and enable access to new roles (Al Salaheen et al., 2024). They can also support inclusion by improving collaboration, flexibility and access to project information (Windapo, 2021). However, the findings also show that digital skills are not a complete solution. Digital transformation can only support equality if women have fair access to tools, training, work experience and supportive workplaces (Bailey and Nyabola, 2021). Without these, digitalisation may benefit those already privileged in the industry. This finding is consistent with the view that digital transformation does not automatically produce equity. Where digital skills development is informal, self-directed or dependent on unpaid personal time, it can reproduce existing gender inequalities because women may have less access to time, networks and organisational support for advanced technology learning (Gardner, 2019). Therefore, digital skills development should be formally embedded in workplace training, mentoring and career-development systems rather than treated as an individual responsibility.

The key contribution of this paper is that it frames digital skills as a pathway within a wider system of inclusion. Digital skills can strengthen women's professional growth, but they must be supported by inclusive education, affordable and accessible training, mentoring and role models, safe learning and work environments, fair recruitment and promotion, flexible work arrangements, childcare and caregiving support, equal pay and anti-discrimination policies, and management trust in recruiting and promoting women (UNESCO, 2024). The findings also suggest that inclusion must be addressed at organisational and site level. Recent work on gender inclusion in construction shows that workplace safety, career progression, top-management commitment and inclusion at leadership level are essential attributes for improving gender inclusion in construction environments (Husam et al., 2024). This supports the argument that digital skills must be accompanied by institutional measures that make construction workplaces safer, fairer and more supportive for women.

Digital equity enabling platform for inclusivity, diversity, equality and accessibility should not only provide access to software (Bailey and Nyabola, 2021). The platform should also avoid symbolic or superficial forms of inclusion (Hickey and Cui, 2020). Evidence from the AEC sector shows that increased numerical representation does not always translate into genuine participation, influence or equity, particularly where women are placed in limited roles or do not have equal power to shape organisational decisions (Hong, 2024). Therefore, this study proposes a solution that include measurable indicators of access, participation, promotion, leadership and retention. It should connect digital skills training with education, employment, professional registration, career support, entrepreneurship and policy reform.

6. Conclusion and Further Research

This paper examined how digital skills influence women's professional growth in the South African construction industry. Using questionnaire data from construction industry professionals, the paper found that digital tool mastery is perceived to support career growth through improved technical competence, new responsibilities, recognition, promotion opportunities and wider participation in professional services. The findings show that digital tools can support women's growth in architecture, engineering, construction management, project management, quantity surveying, facilities management, sustainability, energy data analysis, site management and digital collaboration. However, the study also shows that digital skills alone cannot resolve gender inequality. Women's professional growth also depends on access to education, mentoring, anti-discrimination measures, safe workplaces, flexible work, childcare support, fair hiring, equal pay, leadership opportunities, and a supportive organizational culture.

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ACADEMIC PAPERS: THEME 5 -
Construction Education, Skills, Capacity Development and Professional Competence

Authentic Teaching and Learning in Undergraduate Construction Programmes: Academic Perspectives on Competence Development

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Abstract

Competence development, rather than a predominant focus on disciplinary content knowledge, is increasingly shaping curriculum reform agendas in construction education. In construction and engineering programmes, graduates are expected to apply knowledge effectively within complex, practice-based project environments that demand collaboration, professional judgement, and adaptability. Authentic teaching, learning, and assessment have therefore gained prominence as pedagogical approaches for strengthening workplace readiness and developing industry-relevant and 21st-century skills. In this context, this paper reports on a qualitative case study of undergraduate built environment programmes at a large research-intensive university in KwaZulu-Natal, South Africa. The study sought to identify the extent to which professional and transferable competences are embedded within units of learning, and how these competences are intentionally developed through teaching, learning, and assessment practices. The study explored academics' perspectives on how authentic teaching, learning, and assessment practices contribute to competence development in construction education. Data were generated through seven semi-structured interviews with academics involved in teaching undergraduate-built environment modules and analysed using thematic analysis. Four themes emerged from the data: (1) competence mapping and professional relevance, (2) authentic learning design through industry-simulated tasks, (3) assessment alignment and constructive coherence, and (4) reflective integration and pedagogical tensions. The findings revealed strong support for authentic pedagogies as a means of developing workplace-relevant competencies; however, academics reported challenges in implementing fully authentic learning experiences due to curriculum coverage requirements, large class sizes, limited access to industry projects, and institutional assessment constraints. Consequently, many academics adopted what may be described as "bounded authenticity," whereby elements of professional practice were incorporated through case studies, simulations, and project-based tasks rather than full industry immersion. The paper contributes to discussions on curriculum reform in the construction business and project management education by highlighting practical strategies for strengthening competence development while balancing institutional realities.

Keywords: Authentic learning, Construction education, Competence development, Curriculum reform

1. Introduction

The construction industry is increasingly characterised by complexity, technological disruption, sustainability imperatives, and multidisciplinary collaboration. These shifts require graduates entering the fields of construction and engineering to possess not only strong disciplinary knowledge but also the capacity to apply that knowledge in dynamic workplace contexts (du Plessis & Holtzhausen, 2025). Employers now expect graduates to demonstrate competencies such as problem-solving, communication, critical thinking, teamwork, and professional judgement in real-world project environments (Geng et al., 2025). Consequently, higher education institutions are undergoing pressure to ensure that undergraduate programmes develop graduates who are workplace-ready and capable of navigating the realities of contemporary construction practice (du Plessis & Holtzhausen, 2025).

Within this context, competence-based curriculum reform has gained significant attention in higher education. Rather than focusing predominantly on subject content knowledge, universities are increasingly prioritising the development of transferable graduate attributes and professional competencies that can support successful workplace transition (Biggs & Tang, 2011; Sokhanvar et al., 2021). In construction education, this shift is particularly important because professional practice requires students to integrate technical knowledge with managerial, contractual, financial, and interpersonal skills. The construction sector demands graduates who can operate effectively in complex project settings where decision-making is often influenced by uncertainty, competing stakeholder interests, and time and cost constraints.

Authentic teaching and learning have emerged as a key pedagogical response to this challenge (Tahirsylaj & Sundberg, 2026). Authentic learning is grounded in

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situated learning theory and seeks to place students in contexts that resemble the professional environments in which knowledge will ultimately be applied (Herrington & Oliver, 2000; Tahirsylaj & Sundberg, 2026). Rather than relying solely on abstract classroom-based instruction, authentic learning emphasises real-world tasks, collaborative problem-solving, multiple perspectives, reflection, and assessment activities that mirror professional practice (Herrington & Oliver, 2000). These principles are particularly well-suited to construction education, where students must learn to interpret drawings, manage contractual issues, respond to project risks, and make decisions that reflect industry realities.

Authentic assessment approaches move beyond traditional examinations and instead require students to demonstrate competence through tasks that simulate professional activities and workplace expectations (Tahirsylaj & Sundberg, 2026). These may include project reports, case analyses, tender documentation, contract administration exercises, presentations, and reflective portfolios. Research suggests that authentic assessment enhances the transferability of learning by enabling students to connect theoretical concepts with their practical application in future employment contexts (Boud & Falchikov, 2006; Sokhanvar et al., 2021). For construction programmes, this alignment between curriculum, teaching, and assessment is critical to ensuring that students are prepared for the demands of project-based professional practice.

Despite the growing recognition of authentic pedagogies, their implementation within construction-related undergraduate programmes remains inconsistent. Academics may interpret competence and authenticity differently, and curriculum structures often continue to privilege content coverage over applied learning. Furthermore, professional accreditation requirements and institutional assessment systems can constrain innovation in teaching practice. It is therefore important to explore how academics conceptualise and embed authentic teaching and learning within their modules. This paper is located within this discourse and reports on a case study conducted within undergraduate construction-related programmes at a South African institution.

2. Literature Review

The increasing complexity of the construction industry has intensified calls for curriculum reform in higher education, particularly within construction and project management programmes (Harinarain Haupt, 2016). Graduates entering the sector are expected to demonstrate not only technical knowledge, but also the ability to apply this knowledge in real-world project contexts that demand problem-solving, communication, teamwork, and professional judgement (Geng et al., 2025; Haupt Harinarain, 2016). As a result, higher education institutions are increasingly shifting from content-driven curricula towards competence-based teaching and learning approaches that emphasise employability and workplace readiness (Biggs & Tang, 2011).

Competence-based education is underpinned by the notion that learning should move beyond knowledge acquisition to include the development of transferable skills and professional capabilities (Zhan et al., 2025). In construction education, this is particularly important because graduates must operate in environments characterised by uncertainty, risk, complex stakeholder relationships, contractual obligations, and project delivery pressures (Harinarain & Haupt, 2015). These demands align with the broader higher education discourse on graduate attributes and 21st-century skills, including critical thinking, collaboration, adaptability, and ethical decision-making (Oliver, 2013).

2.1. Authentic Teaching and Learning

Authentic teaching and learning have emerged as a critical approach in higher education, particularly in discussions about preparing graduates for the complexities of contemporary professional environments. Authentic learning is grounded in situated learning theory, which posits that knowledge is most effectively acquired when learning occurs in contexts that closely resemble the environments in which it will be applied (Tahirsylaj & Sundberg, 2025). Herrington and Oliver (2000) argue that authentic learning environments should incorporate real-world relevance, ill-defined problems, multiple perspectives, collaboration, and opportunities for reflection. These characteristics are highly relevant to construction education, where professional practice involves solving complex, context-dependent problems rather than merely recalling theoretical concepts (du Plessis & Holtzhausen, 2025).

In recent years, global debates have emphasised the role of authentic teaching in bridging the persistent gap between academic knowledge and workplace practice (Boud & Falchikov, 2006). Scholars contend that by embedding authentic teaching approaches, universities can create learning experiences that allow students to transfer their skills across disciplinary and professional contexts (Ashford-Rowe, Herrington, & Brown, 2014). This has made authentic learning an integral part of curriculum reform agendas aimed at enhancing the relevance and applicability of higher education.

Within construction and engineering programmes, authentic learning may take the form of case-based learning, live industry projects, simulated contract administration exercises, risk management scenarios, and project-based teamwork (Harinarain & Haupt, 2015). Such approaches allow students to engage with the ambiguity and multidisciplinary nature of construction practice. By mirroring workplace realities,

authentic learning creates opportunities for students to develop professional identity and gain confidence in applying disciplinary knowledge. Recent systematic reviews confirm that authentic learning and assessment enhance engagement, critical thinking, collaboration, and employability skills across higher education disciplines (Sokhanvar et al., 2021).

2.2. Authentic Assessment

Closely aligned with authentic teaching is the concept of authentic assessment. Authentic assessment focuses on evaluating not only what students know but also how they can apply their knowledge to real-world or professional contexts (Zhan et al., 2025). According to Sokhanvar et al. (2021), authentic assessment requires students to perform tasks that replicate the complexity of work or societal contexts, demanding the integration of knowledge, skills, and attitudes. This approach challenges traditional assessment practices, such as examinations, that often emphasise rote memorisation and recall of content knowledge.

The value of authentic assessment lies in its potential to strengthen the transferability of competences. For example, case studies, portfolios, simulations, and project-based tasks are increasingly used in higher education to assess students' ability to demonstrate professional judgement, problem-solving, and collaboration (Ashford-Rowe et al., 2014). These assessment approaches align with the global trend toward competency-based education, which seeks to ensure that graduates leave university with demonstrable capabilities that meet workplace expectations.

Closely linked to authentic learning is authentic assessment, which has become increasingly prominent in higher education reform. Zhan et al. (2025) define authentic assessment as an assessment that requires students to apply the same competencies, attitudes, and knowledge that they would need in professional practice. This differs significantly from traditional assessments, such as examinations, which primarily test recall and conceptual understanding. Instead, authentic assessment requires students to perform tasks that resemble those undertaken by practitioners in the field, such as preparing project reports, analysing claims, producing tender documentation, or presenting solutions to real construction management problems (Tahirsylaj & Sundberg, 2025).

The literature consistently highlights the pedagogical value of authentic assessment in supporting deeper learning and employability. For example, recent reviews found that authentic assessment strengthens workplace readiness by developing critical professional skills such as problem-solving, communication, and self-reflection (Sokhanvar et al., 2021). In the context of construction education, this is particularly important because many professional tasks require integration of technical knowledge with interpersonal and managerial competence. Project managers, quantity surveyors, and construction professionals must routinely interpret information, negotiate with stakeholders, manage risk, and make time-sensitive decisions (du Plessis & Holtzhausen, 2025).

2.3. Challenges in Implementing Authentic Pedagogy

Despite the recognised benefits, the literature also identifies several challenges in implementing authentic teaching and assessment. One key challenge is the tension between curriculum coverage and competence development (Zhan et al., 2025). Academics often face pressure to cover extensive disciplinary content while simultaneously embedding practical, applied learning experiences. Large class sizes, limited time, institutional assessment regulations, and accreditation requirements may further constrain innovation in teaching practice. This tension is especially evident in construction programmes, where professional accreditation standards may require coverage of broad technical content areas.

Another important issue emerging from the literature is the varying interpretation of what constitutes "authenticity." McArthur (2023) argues that authentic assessment should not become a superficial educational buzzword, but rather should meaningfully connect academic learning with work, society, and student well-being (Zhan et al., 2025). This perspective is particularly relevant in construction education, where authentic learning should not merely simulate workplace tasks, but should also foster ethical responsibility, sustainability awareness, and professional judgement.

Although the broader higher education literature on authentic learning is well established, there remains a relative scarcity of studies focusing specifically on authentic pedagogy in undergraduate construction education within the South African context. This study seeks to contribute to this gap by exploring how academics conceptualise and embed authentic teaching, learning, and assessment practices within construction-related modules.

While the broader higher education literature on authentic learning and assessment is well established, there remains limited research specifically focused on undergraduate built environment programmes in the South African context. There is a need to understand how academics within these disciplines conceptualise competence, authenticity, and professional readiness. This study addresses this gap by exploring academic perspectives on authentic teaching and learning within undergraduate built environment programmes.

3. Research Methodology

This study adopted a qualitative case study design to explore academics' perspectives on authentic teaching, learning, and assessment in undergraduate programmes. A qualitative approach was chosen because it enables the collection of in-depth insights into academics' lived experiences, pedagogical practices, and interpretations of competence within their teaching contexts (Creswell & Poth, 2018). The case study design allowed for a detailed investigation of authentic teaching practices at the University of KwaZulu-Natal (UKZN).

The participants comprised seven academics drawn from the Engineering and Land Surveying Disciplines in the School of Engineering. The academics had an average of 8 years of teaching experience in higher education, ranging from early-career lecturers to more senior staff. Purposive sampling was employed to select participants who had direct teaching responsibilities in undergraduate programmes and were therefore well-positioned to reflect on how competences were taught, learned, and assessed in their modules.

Data were generated through semi-structured interviews, which provided a flexible yet focused means of exploring academics' perspectives on authentic teaching and learning. Each interview lasted approximately 30 minutes and was conducted in person or via Zoom, depending on the participants' availability. The interview schedule included open-ended questions focusing on three main areas: (1) participants' understanding of authentic teaching, learning, and assessment; (2) strategies used to embed competences in undergraduate modules; and (3) perceived challenges and opportunities in implementing competence-oriented teaching. All interviews were analysed thematically. During the seventh interview, no substantially new themes or concepts emerged, indicating that thematic saturation had been reached. This approach is consistent with qualitative research guidance suggesting that saturation may occur within relatively small samples when participants share expertise related to a focused research question (Creswell & Poth, 2018).

Ethical principles relating to informed consent, confidentiality, and voluntary participation were observed throughout the study. Participants were informed of the purpose of the research and their right to withdraw at any stage without consequence. Institutional ethical clearance was obtained prior to data collection.

4. Findings and Discussion

The thematic analysis of the interviews yielded four interrelated themes that illuminate how academics in undergraduate construction programmes conceptualise and enact authentic teaching and learning. These themes are: (1) competence mapping and professional relevance, (2) authentic learning constraints, (3) assessment alignment and constructive coherence, and (4) reflective integration and pedagogical tensions (Figure 1).

The participant profile depicted in Table 1 demonstrates representation across multiple built environment disciplines and academic ranks.

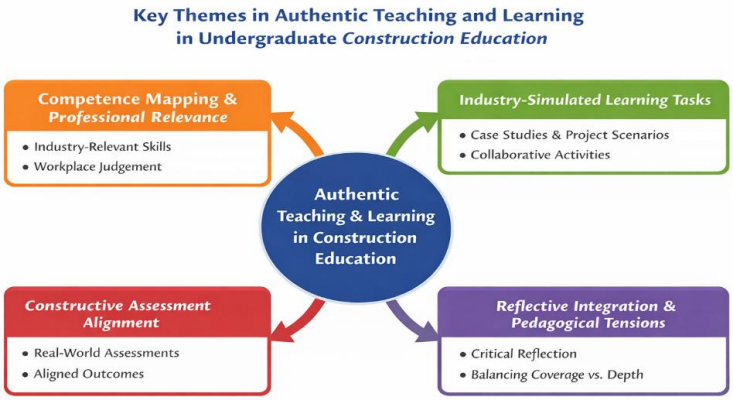

Figure 1: Key themes in authentic teaching and learning (Author's creation)

Table 1: Participant Profile

Participant	Discipline	Academic Rank	Years of Teaching Experience
P1	Civil Engineering	Associate Professor	15
P2	Agricultural Engineering	Lecturer	3
P3	Land Surveying	Associate Professor	12
P4	Chemical Engineering	Associate Professor	11
P5	Civil Engineering	Senior Lecturer	8
P6	Land Surveying	Lecturer	3
P7	Civil Engineering	Senior Lecturer	5

Theme 1: Competence Mapping and Professional Relevance

A dominant theme across the interviews was the recognition that undergraduate construction education must move beyond content transmission to deliberate competence development. Participants consistently emphasised that modules should prepare students for the practical realities of the construction industry, including decision-making, communication, and problem-solving.

Participant 2 explained, "*It is no longer enough for students to know the theory of project planning; they need to be able to use it in a way that mirrors what happens on site and in project meetings.*"

This perspective closely aligns with the findings from Villarroel et al. (2021), which posits that learning is most effective when embedded in contexts that resemble professional practice. Participants described competence not merely as technical mastery, but as the integration of disciplinary knowledge with workplace judgement.

Another academic noted: "*Our graduates must be able to read a situation, manage conflict between stakeholders, and still make decisions that keep the project moving*" (Participant 5).

This finding aligns with Geng, et al. (2025) framing of graduate attributes as capabilities that transcend disciplinary boundaries and with Oliver's (2013) emphasis on employability-oriented curriculum renewal. In the context of construction and project management education, these competencies reflect the sector's demand for graduates who can navigate risk, stakeholder interests, and project constraints.

The findings therefore suggest that academics increasingly view competence development as central to curriculum reform, consistent with broader higher education trends towards outcome-based and workplace-responsive education (Biggs & Tang, 2011).

Theme 2: Authentic Learning Constraints

While participants strongly endorsed the value of industry-simulated learning tasks, a consistent finding across the interviews was that the implementation of authentic learning is often constrained in practice. Academics expressed a clear understanding of what constitutes ideal authentic learning in construction education, yet highlighted structural, institutional, and contextual barriers that limit its full realisation.

Participants described the ideal authentic learning environment as one in which students engage directly with live or highly realistic construction scenarios over sustained periods. This would include working with real project documentation, interacting with industry stakeholders, and responding to evolving project conditions.

Participant 1 articulated this ideal: "*In a perfect situation, students would work on a live project from start to finish, engaging with real drawings, real contracts, and even real clients. That is where the real learning happens*."

Similarly, another noted, "*Ideally, we would simulate the full lifecycle of a construction project, where students must deal with procurement, delays, claims, and stakeholder pressures as they arise*" (Participant 4).

These descriptions align closely with the principles of authentic context (Herrington & Oliver, 2000), which emphasise learning through participation in real-world practices. However, participants consistently indicated that such approaches are not always feasible within the constraints of undergraduate programmes.

Time and Curriculum Constraints

A major limitation identified was the restricted time available within modules, which often necessitates prioritising content coverage over extended, complex tasks. "*We only have a 12-week semester. You simply cannot run a full project simulation and still cover all the required theory*" (Participant 3).

"*There is pressure to get through the syllabus, especially in technically heavy modules. That limits how 'authentic' you can really be*" (Participant 5). This reflects the well-documented tension between breadth and depth in curriculum design (Biggs & Tang, 2011), where the need to cover prescribed content constrains opportunities for immersive learning.

Class Size and Resource Limitations

Participants also highlighted large class sizes and limited resources as barriers to implementing authentic, interactive learning tasks. "*It is very difficult to manage detailed simulations when you have over a hundred students. You just don't have the capacity to give meaningful feedback*" (Participant 7).

"*Authentic tasks require time, engagement, and feedback. With large classes, it becomes more about managing logistics than facilitating learning*" (Participant 2). These findings align with the broader literature, which identifies workload and scalability as key constraints in the implementation of authentic assessment (Vlachopoulos & Makri, 2024).

Limited Industry Engagement

Another challenge is access to industry and real-world project data, which is essential for creating truly authentic learning experiences. "*We would love to use real project data, but companies are often reluctant to share due to confidentiality issues*" (Participant 6).

"*Without strong industry partnerships, it becomes difficult to create truly authentic scenarios; we end up relying on simplified case studies*" (Participant 1). This limitation restricts the extent to which students can engage with the complexity and unpredictability of real construction environments.

Student Preparedness and Cognitive Load

Participants further noted that students may not always be ready for highly complex, ill-defined tasks, particularly at lower levels of study. "*First- and second-year students often struggle with open-ended tasks. They want clear answers, not ambiguity*" (Participant 4).

"*You have to scaffold authenticity. If you throw students into a fully complex scenario too early, they become overwhelmed*" (Participant 3). This highlights the importance of scaffolding within authentic learning design, ensuring that complexity is introduced progressively (Herrington & Oliver, 2000).

The findings suggest that while academics value authentic learning, they are often engaged in a process of negotiation between the ideal and the practical. Rather than fully immersive simulations, many adopt "bounded authenticity", where elements of real-world practice are incorporated within manageable constraints.

Importantly, the findings reinforce that authentic learning in construction education should not be viewed as an all-or-nothing approach. Instead, it exists along a continuum, where even partial integration of real-world tasks can contribute meaningfully to competence development.

Theme 3: Assessment Alignment and Constructive Coherence

The third theme focused on how assessment practices either support or hinder competence development. Participants consistently argued that traditional assessment approaches were inadequate for evaluating workplace competence. While all seven participants supported authentic assessment in principle, there was disagreement about how deeply authenticity should be embedded in the assessment design.

Several participants expressed concern that examinations continue to dominate assessment structures, despite industry demand for applied competencies. Participant 1 explained: "A student can achieve 80% in an examination and still struggle to apply that knowledge when faced with a real project problem." Similarly, Participant 4 noted: "The issue is that examinations measure what students remember, but they do not necessarily measure how they think as future construction professionals."

Participants described attempting to incorporate authentic assessment tasks such as project reports, tender evaluations, dispute analyses, and stakeholder presentations. However, many indicated that institutional moderation requirements and large student numbers often constrained the complexity of these assessments.

Interestingly, participants reported an ongoing tension between assessing technical knowledge and assessing professional judgement. While technical competence was viewed as relatively straightforward to evaluate, professional judgement was perceived as subjective and therefore more difficult to assess reliably.

This suggests that authentic assessment in construction education involves balancing reliability and standardisation against the need to evaluate complex workplace competencies.

This theme emphasises coherence between outcomes, teaching activities, and assessment (Biggs & Tang, 2011). However, participants also highlighted institutional barriers. Participant 7 noted: "*Sometimes the university system still pushes us towards traditional exams because they are easier to administer at scale*." This tension reflects a recurring issue in the literature. Vlachopoulos and Makri (2024) note that while authentic assessment is widely advocated, implementation is often constrained by workload, standardisation requirements, and class size. The findings therefore suggest that while academics recognise the value of authentic assessment, systemic constraints may limit full alignment.

Theme 4: Reflective Integration and Pedagogical Tensions

The final theme concerns the reflective dimension of authentic teaching and the tensions academics face in balancing professional relevance with curriculum coverage. Participants frequently described themselves as operating between two worlds: the university and the construction industry.

Participant 7 observed: "Industry wants graduates who can hit the ground running, but universities are expected to produce thinkers, not just practitioners." Participants repeatedly referred to the challenge of "covering content" while also developing applied competence. Participant 5 explained, "*There is always this tension between teaching what the syllabus requires and creating space for deeper applied learning.*"

This reflects a well-documented challenge in higher education pedagogy (Biggs & Tang, 2011). In construction education, where programmes often need to satisfy professional accreditation requirements, this tension may be particularly acute.

Reflection was also viewed as an important learning mechanism. "*We encourage students to justify why they made a project decision, not just what decision they made*" (Participant 2). This aligns with authentic learning principles of reflection and articulation (Herrington & Oliver, 2000). Reflective activities help students develop professional judgement, which is critical in construction management.

Several participants argued that reflective activities help students develop professional judgement, ethical awareness, and decision-making capabilities that are difficult to cultivate through traditional teaching methods. However, participants acknowledged that students frequently resist reflective tasks because they perceive them as less important than technical content.

McArthur (2023) further argues that authentic assessment should support students' well-being, identity, and societal relevance rather than merely serve as a workplace simulation. This broader view is relevant in construction education, particularly in relation to sustainability, ethics, and social responsibility.

Collectively, the findings suggest that authentic teaching and learning in undergraduate construction programmes are increasingly framed around competence development, workplace simulation, and aligned assessment.

5. Contribution to Knowledge

This study contributes to the growing body of scholarship on authentic teaching and learning in construction education in three ways. First, the study extends existing authentic learning literature by demonstrating that authenticity in construction education exists on a continuum rather than as a binary condition. While the literature often presents authentic learning as the replication of workplace environments (Herrington & Oliver, 2000), the findings reveal that academics operate within significant institutional constraints that prevent full immersion in industry. Consequently, academics selectively embed workplace-relevant experiences through simulations, case studies, project-based learning, and authentic assessments. This paper conceptualises this phenomenon as bounded authenticity, whereby authentic learning is intentionally adapted to fit institutional realities while maintaining professional relevance.

Second, the study contributes empirical evidence from the South African construction education context, an area that remains underrepresented in the international authentic learning literature. While much of the existing scholarship originates in North America, Europe, and Australia, this study provides insights into how authentic pedagogies are interpreted and implemented in a developing economy characterised by resource constraints, large student cohorts, and significant challenges in graduate employability.

Third, the study advances understanding of the relationship between competence development and curriculum design within undergraduate construction programmes. The findings demonstrate that authentic teaching, learning, and assessment are most effective when deliberately aligned with professional competencies rather than treated as isolated pedagogical interventions. This reinforces the importance of constructive alignment in preparing graduates for increasingly complex construction environments.

6. Conclusion and Further Research

This paper explores how authentic teaching and learning are conceptualised and implemented within undergraduate construction-related programmes, with a particular focus on competence development and workplace readiness. Located within the broader discourse of curriculum reform in higher education, the study responded to the growing need for construction graduates who can transfer disciplinary knowledge into complex professional settings characterised by uncertainty, collaboration, and real-time decision-making.

The findings demonstrate that academics increasingly recognise the importance of moving beyond content transmission towards deliberate competence development. Authentic learning activities such as live case studies, project simulations, collaborative tasks, and workplace-oriented assessments were viewed as effective mechanisms for preparing students for the realities of construction and project management practice. These approaches were found to support not only technical competence, but also professional judgement, teamwork, communication, and decision-making skills that are essential for workplace transition.

At the same time, the study identified significant structural and pedagogical challenges. Tensions between syllabus coverage and deep applied learning, institutional reliance on traditional assessment formats, and varying academic interpretations of authenticity may limit the full implementation of authentic pedagogies. These findings reinforce the need for deliberate curriculum alignment and academic development initiatives that support lecturers in designing learning experiences that closely mirror professional practice.

Based on the findings of this study, it is recommended that construction-related programmes adopt a more explicit competence-mapping approach, in which professional capabilities such as project planning, risk management, and contractual reasoning are

intentionally embedded across modules and levels of study. Learning outcomes should clearly articulate both disciplinary knowledge and workplace-oriented competencies.

Academics should be encouraged to integrate more industry-simulated and problem-based learning tasks into undergraduate modules. These may include live case studies from construction projects, project scheduling exercises, risk management workshops, tender and procurement documentation tasks and stakeholder negotiation scenarios.

Assessment strategies should move beyond predominantly traditional examinations towards authentic assessment methods that better evaluate workplace readiness, such as construction claims analysis, reflective learning portfolios and group-based project simulations.

Further research should extend this study by incorporating student perspectives on authentic learning experiences within construction programmes. Understanding how students experience and interpret authentic tasks will provide a more holistic view of curriculum effectiveness.

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Inclusive assessment practices for supporting diverse student needs in Universities: A Scoping review and synergistic framework for future-ready Built Environment graduates

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Abstract

In the context of climate change, rapid urbanisation, and technological disruption, universities are increasingly expected to produce future-ready Built Environment graduates capable of responding to complex professional demands. This paper examines how inclusive assessment practices support diverse student needs within Built Environment programmes while maintaining professional competency standards. A structured literature synthesis was conducted using peer-reviewed literature published between 2015 and 2025. Searches across Scopus, Web of Science, and Google Scholar yielded 613 publications, of which 57 met the inclusion criteria. The selected studies were analysed using thematic synthesis, guided by inclusive assessment principles, Universal Design for Learning, and assessment for learning. The synthesis identified four dominant themes: flexible assessment design, multiple and authentic assessment formats, feedback and transparency, and institutional and accreditation-related challenges. The originality of the study lies in positioning inclusive assessment within the professional and competency-based demands of Built Environment education, particularly where equity must be balanced with accreditation expectations. Drawing on the synthesis of the literature, the study develops a synergistic framework that integrates flexibility, authenticity, transparency, and institutional support as interconnected dimensions of inclusive assessment. Overall, the findings suggest that inclusive assessment can promote equitable learning while maintaining the standards required for professional practice in the Built Environment. The proposed framework offers a structured approach for universities seeking to strengthen inclusive assessment practices and develop future-ready Built Environment graduates.

Keywords: Built Environment education, Flexible assessment design, Higher education, Inclusive assessment, Synergistic framework.

1. Introduction

The Built Environment sector is under increasing pressure from climate change, rapid urbanisation, and technological change, all of which require professionals capable of delivering resilient and sustainable infrastructure (United Nations, 2019; World Economic Forum, 2020). Universities are expected to respond by preparing graduates who are not only technically competent but also adaptable and responsive to evolving societal and industry demands (OECD, 2021). However, assessment practices in higher education often assume that students learn in similar ways, which can marginalise those with diverse learning needs and limit equitable participation (Boud and Falchikov, 2007; Wanner and Palmer, 2018). In South Africa, where transformation and access remain central to higher education policy, this raises concerns about whether current assessment approaches adequately support inclusive learning (Council on Higher Education, 2020). When assessment does not accommodate diversity, students may be unable to fully demonstrate their capabilities, which ultimately affects the preparedness of graduates entering professional practice (Male et al., 2021). This highlights a critical need to reconsider how assessment is designed within Built Environment education.

Research in higher education shows a shift towards inclusive and student-centred assessment practices aimed at improving engagement and learning outcomes. Frameworks such as Universal Design for Learning and Assessment for Learning promote flexible assessment design, multiple modes of engagement, and continuous feedback (CAST, 2018; Carless, 2015). Within Built Environment education, approaches such as authentic assessment, problem-based learning, and reflective practice are increasingly used to support both learning and professional development (Oviawe, 2020; Male et al., 2021). While these developments indicate progress, the literature remains fragmented and often lacks discipline-specific focus. In particular, there is limited synthesis of how inclusive assessment is implemented within Built Environment programmes and how such practices align with professional accreditation requirements (Boud, 2020). More importantly, there is no clear, consolidated understanding of how inclusive assessment can be

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systematically applied while maintaining professional competency standards. This gap necessitates a structured investigation.

To address this gap, this study asks: *How do inclusive assessment practices support diverse student needs in Built Environment programmes while maintaining professional competency standards?* This question focuses on a central tension in higher education, where inclusivity must be balanced with the need to meet professional and regulatory expectations. By examining this intersection, the study seeks to clarify how assessment can support both equitable learning and discipline-specific competence. This provides a focused direction for analysing existing literature and identifying practical strategies relevant to Built Environment education. This study adopts a review-informed framework development approach to examine how inclusive assessment is understood and implemented across existing research.. Scoping reviews are appropriate for mapping key concepts, identifying knowledge gaps, and synthesising evidence from diverse sources, particularly in emerging and interdisciplinary fields (Arksey and O'Malley, 2005; Munn et al., 2018; Tricco et al., 2018; Peters et al., 2020).

This study contributes to both theory and practice by consolidating fragmented literature on inclusive assessment and situating it within the context of Built Environment education, thereby strengthening the link between educational theory and professional competency development. Beyond synthesising existing knowledge, the study develops a synergistic framework that integrates flexibility, authenticity, transparency, and institutional support as interconnected dimensions of inclusive assessment. The framework provides a structured lens for understanding how assessment practices can simultaneously promote equity, inclusion, and professional competence in Built Environment programmes.

From a practical perspective, the study offers guidance for academics, curriculum designers, institutional leaders, and policymakers seeking to design assessment strategies that accommodate diverse student needs while maintaining accreditation and professional standards. By supporting more inclusive and competency-aligned assessment practices, the framework contributes to the development of future-ready graduates equipped to respond to the complex environmental, technological, and societal challenges facing the Built Environment sector. More broadly, the study advances ongoing efforts to promote equity, accessibility, and student success within higher education. The remainder of the paper is structured as follows: Section 2 reviews the literature on inclusive assessment and Built Environment education, Section 3 explains the review-informed framework development approach, Section 4 presents and discusses the findings and proposed framework, and Section 5 concludes the paper and outlines future research directions.

2. Literature Review

2.1 Theoretical foundations of Inclusive Assessment

Inclusive assessment is grounded in educational theories that emphasise equity, accessibility, and student-centred learning (Boud and Falchikov, 2007). According to CAST (2018) Universal Design for Learning (UDL) is one of the most widely recognised frameworks, advocating for the design of learning environments that accommodate learner variability through multiple means of engagement, representation, and expression. This approach shifts the focus from adapting students to fixed assessment methods towards designing assessments that are inherently inclusive (CAST ,2018). Assessment for Learning (AfL) complements this perspective by positioning assessment as an ongoing process that supports learning through feedback, self-reflection, and active student involvement (Carless, 2015). These frameworks challenge traditional assessment models that prioritise standardisation over flexibility.

In practice, however, applying these frameworks is not always straightforward. Boud (2020) notes that institutional structures and resource limitations can restrict the implementation of flexible assessment practices. Similarly, Carless (2018) highlights that AfL requires sustained feedback and engagement, which may increase workload for both lecturers and students. Wanner and Palmer (2018) further suggest that the success of these approaches depends on contextual factors such as institutional support and academic capacity. This information indicate that theoretical foundations alone are not sufficient without practical strategies for implementation (Boud, 2020).

The literature therefore shows that inclusive assessment is shaped by complementary theoretical approaches that address both access and learning processes (Carless, 2018). What remains less clear is how these frameworks are applied in specific disciplines. The need for closer examination then arises on how inclusive assessment can be implemented in fields such as Built Environment education.

2.2 Inclusive Assessment in Higher Education

Inclusive assessment has gained increasing attention in higher education as institutions respond to diverse student populations and the need for equitable learning environments. It is generally understood as the design of assessment practices that reduce barriers and enable all students to demonstrate their learning effectively (Boud and Falchikov, 2007; Wanner and Palmer, 2018; Boud, 2020; Ajjawi et al., 2020). In response, there has been a shift towards flexible assessment methods,

including varied assessment formats, clear criteria, and continuous feedback, all of which aim to improve student engagement and learning outcomes (Wanner and Palmer, 2018). These developments reflect a move away from traditional, uniform assessment approaches (Boud, 2020).

Despite this progress, implementation remains uneven. Some studies report improvements in student participation and engagement, while others highlight ongoing challenges related to institutional constraints and entrenched academic practices (Wanner and Palmer, 2018; Boud, 2020; Carless, 2015). For example, Wanner and Palmer (2018) show that flexible assessment can enhance engagement, yet its use is often inconsistent across programmes. At the same time, assessment systems continue to prioritise grading and accountability, which limits their potential to support inclusive learning (Boud, 2020). These differences suggest that inclusive assessment is not yet fully embedded in higher education practice.

Overall, the literature indicates that while inclusive assessment is widely supported in principle, it is not consistently applied in practice (Boud, 2020; Wanner and Palmer, 2018). This gap becomes more significant in professionally oriented disciplines, where assessment must also meet industry and accreditation requirements (Male et al., 2021).

2.3 Inclusive Assessment in Built Environment Education

In Built Environment education, assessment is closely linked to professional practice, where students are expected to demonstrate technical competence, problem-solving ability, and collaboration skills (Male et al., 2021). To address this, many programmes have adopted authentic assessment approaches such as project-based tasks and real-world simulations, which aim to reflect industry practices (Oviawe, 2020). These approaches aim to ensure that graduates are equipped with practical skills required in professional environments.

Even so, the extent to which these practices support inclusivity remains limited. Male et al. (2021) emphases on the importance of developing broader competencies such as communication and teamwork, yet assessment often continues to prioritise technical performance over diverse ways of learning. Boud (2020) further notes that rigid assessment structures create a tension between maintaining professional standards and accommodating different student needs. In some cases, rigid assessment structures may disadvantage students who do not align with traditional assessment formats, thereby restricting equitable participation (Wanner and Palmer, 2018). It then becomes clear that while authentic assessment supports professional readiness, it does not automatically lead to inclusive learning (Oviawe, 2020; Male et al., 2021). Current practices appear to strengthen competence but do not fully address diversity (Boud, 2020). This raises important questions about how assessment in Built Environment education can be designed to support both professional expectations and inclusive learning.

In the South African and broader Global South context, inclusive assessment is particularly important because higher education continues to reflect unequal schooling backgrounds, uneven access to learning resources, and diverse student preparedness. In Built Environment programmes, these inequalities may affect how students engage with technical drawings, project-based tasks, digital tools, site-related activities, and professional communication. This means that inclusive assessment cannot be treated only as a general higher education concern. It must also respond to the disciplinary demands of Built Environment education, where students are expected to demonstrate both academic understanding and practice-based competence.

2.4 Challenges and research gap

Challenges continue to limit the effective implementation of inclusive assessment. One of the most frequently cited issues is academic staff capacity, as designing flexible and inclusive assessments requires time, training, and institutional support (Wanner and Palmer, 2018). In addition, the workload associated with multiple assessment formats and ongoing feedback can discourage lecturers from adopting these approaches (Carless, 2018). These factors suggest that inclusive assessment is not only a pedagogical issue but also an institutional one (Boud, 2020).

A further challenge lies in aligning inclusive practices with professional accreditation requirements. Built Environment programmes are often governed by strict regulatory standards that emphasise consistency and measurable outcomes (Boud, 2020). This creates a tension between standardisation and flexibility, making it difficult to implement inclusive assessment without compromising professional expectations. Existing studies provide limited guidance on how these competing demands can be balanced (Boud, 2020; Wanner and Palmer, 2018; Male et al., 2021).

Across the literature, a clear gap emerges. While inclusive assessment is well established in general higher education research, there is limited understanding of how it can be effectively implemented within professionally accredited Built Environment programmes (Male et al., 2021). There is also no clear framework explaining how inclusive assessment can be aligned with professional competency requirements within the context of Built Environment and its accrediting bodies.

3. Methodology

3.1 Research approach

This study adopts a review-informed framework development approach to examine how inclusive assessment is understood and applied within Built Environment education. The structured literature synthesis was used to identify, organise, and interpret existing knowledge on inclusive assessment practices, while the framework development component focused on integrating the synthesised findings into a Synergistic Framework for Competency-Aligned Inclusive Assessment. This approach was appropriate because the topic cuts across education, pedagogy, and professional practice, and therefore required both a structured review of existing literature and the development of a practical framework for Built Environment education. The methodological logic of the study was informed by broader research design guidance, which emphasises alignment between the research question, data sources, selection criteria, and analytical procedures (Creswell and Creswell, 2023; Saunders et al., 2023). Drawing from the research question stated in the introduction, the synthesis focused on inclusive assessment practices, diverse student needs, and professional competency standards in Built Environment programmes. The review-informed process was guided by established evidence-synthesis principles and followed five main stages: identifying the research focus, locating relevant studies, selecting studies, extracting data, and synthesising findings (Arksey and O'Malley, 2005; Levac et al., 2010; Munn et al., 2018; Tricco et al., 2018; Peters et al., 2020).

3.2 Data sources and search strategy

The search for relevant studies was carried out across Scopus, Web of Science, and Google Scholar. These databases were selected because they provide broad coverage of peer-reviewed work in both higher education and Built Environment research. Search terms were developed around the core concepts of the study. These included "inclusive assessment," "flexible assessment design," "higher education," "Built Environment education," "student diversity," and "assessment for learning." The terms were combined using Boolean operators (such as AND and OR) to refine the results. The review focused on peer-reviewed studies published between 2015 and 2025 to capture recent developments, while older foundational sources were retained only where they provided important theoretical grounding. The search process was guided by recent scoping review and reporting literature to improve transparency and methodological rigour (Tricco et al., 2018; Peters et al., 2020; Page et al., 2021).

3.3 Inclusion and exclusion criteria

To keep the review focused, clear inclusion and exclusion criteria were applied. Studies were included if they examined inclusive assessment within higher education, particularly in the Built Environment or closely related disciplines. Research that addressed assessment design, accessibility, student engagement, or learning outcomes was considered relevant. Studies were excluded if they did not deal directly with assessment, focused only on teaching methods without assessment components, or were conducted outside higher education contexts. Non-English publications and studies without accessible full texts were also excluded to ensure consistency in analysis. These criteria helped ensure that the selected studies were both relevant to the research question and comparable in scope.

3.4 Screening and study selection

The selection of studies followed a staged screening process aligned with PRISMA-informed reporting principles. The initial search produced 613 records. After duplicates were removed, titles and abstracts were screened against the inclusion and exclusion criteria. The remaining studies were then subjected to full-text screening to confirm their relevance to inclusive assessment, higher education, and Built Environment education. To improve reliability and reduce selection bias, screening decisions were checked against the predefined criteria, and uncertain cases were discussed among the authors before final inclusion. At the end of the process, 57 studies were retained for analysis. The revised Figure 1 presents the study selection process as a PRISMA-ScR flow diagram (Figure 1).

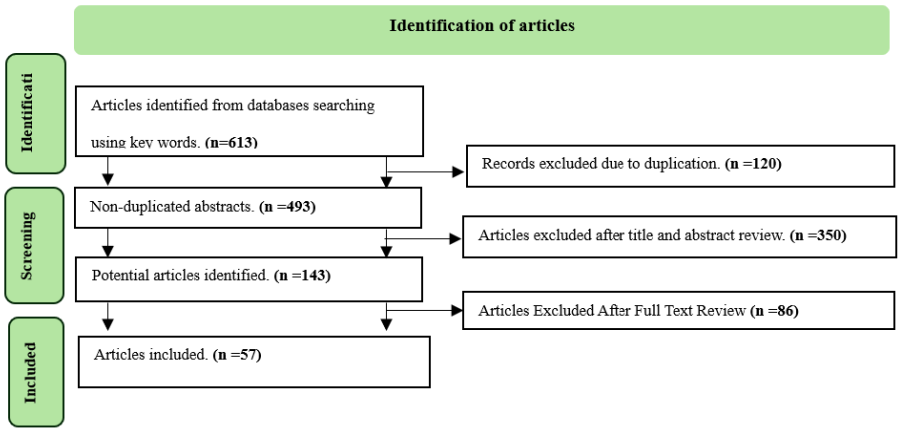

Figure 1: PRISMA flow diagram of study selection.
Source: Author's depiction (2026).

3.5 Data extraction and analysis

Data were extracted using a structured extraction matrix that captured the author, year of publication, study focus, methodology, assessment approach, key findings, and relevance to Built Environment education. The analysis followed thematic synthesis. Initial codes were first generated from recurring ideas in the selected studies, including flexibility, authenticity, feedback, transparency, accessibility, student diversity, staff capacity, and professional competency. Related codes were then grouped into broader categories, which were refined into the final themes presented in the findings. To strengthen the interpretation of the evidence, a CASP-informed appraisal was used to consider the clarity of study aims, methodological appropriateness, relevance of findings, and contribution to the review question. Studies were not excluded solely on the basis of appraisal outcomes, as the purpose of the review-informed synthesis was to map and integrate the available evidence rather than assess effect size or quality only (Table 1).

Table 1: Summary of thematic coding and synthesis

Initial codes	Synthesised theme	Interpretation for Built Environment education
Flexible deadlines, alternative formats, varied submission modes	Flexible assessment design	Flexibility can reduce barriers while still requiring alignment with learning outcomes.
Projects, simulations, real-world tasks, practice-based learning	Multiple and authentic assessment formats	Authentic assessment supports professional readiness but must be scaffolded to remain inclusive.
Rubrics, formative feedback, clear criteria, feedback timing	Feedback and transparency	Transparent expectations and timely feedback support fair student participation.
Staff workload, large classes, digital access, accreditation expectations	Implementation and accreditation challenges	Inclusive assessment requires institutional support and alignment with professional standards.

3.6 Limitations

This review is limited to studies published between 2015 and 2025, although earlier foundational work was included where necessary. The study also relies entirely on published literature and does not incorporate empirical data from students, academics, or industry practitioners. In addition, as a literature-based framework development study, the focus is on mapping and integrating the existing body of knowledge rather than evaluating the quality of individual studies in detail. Despite these limitations, the approach provides a clear overview of the field and identifies areas where further research is needed.

4. Findings and discussion

4.1 Flexible assessment design

Flexibility in assessment design emerges as a central feature of inclusive assessment practices. Across the literature, approaches such as varied submission formats, extended deadlines, and alternative modes of demonstrating learning are consistently linked to improved engagement and participation (Wanner and Palmer, 2018; Boud, 2020; Tai et al., 2022). This suggests that flexibility allows students to demonstrate competence in ways that align with their strengths, thereby reducing structural barriers that often disadvantage certain groups.

At a theoretical level, this aligns with the principles of Universal Design for Learning, which emphasise providing multiple means of engagement and expression (CAST, 2018). From this perspective, flexibility is not simply an adjustment, but a deliberate design strategy that anticipates learner diversity rather than reacting to it. However, the literature also highlights that flexibility must be implemented within clearly defined boundaries. Concerns around fairness and consistency frequently arise, particularly where assessment outcomes must be comparable across students (Boud, 2020).

Within Built Environment education, this tension becomes more pronounced. Assessment is often linked to professional competencies that must be demonstrated in a consistent and measurable way. As a result, unrestricted flexibility may conflict with accreditation requirements and industry expectations. This indicates that flexibility must be structured in a way that preserves both inclusivity and rigour. Ultimately, the literature suggests that flexibility is most effective when it is intentionally designed, clearly communicated, and aligned with learning outcomes. When applied in this way, it becomes a tool for equity rather than a compromise of standards.

4.2 Multiple and authentic assessment formats

The use of multiple and authentic assessment formats represents a significant shift in assessment practices. Increasingly, traditional examination-based approaches are being complemented by project-based tasks, simulations, and real-world problem-solving activities that reflect professional practice (Male et al., 2021; Oviawe, 2020). This shift is particularly relevant in the

Built Environment education, where applied knowledge and decision-making are central to professional competence. Authentic assessment is widely associated with deeper learning, as it situates knowledge within real-world contexts (Carless, 2015; Nicol, 2010). It allows students to engage with complex, practice-based problems, thereby strengthening their readiness for professional environments. In addition, exposure to such tasks supports the development of transferable skills, including collaboration, communication, and critical thinking.

However, the literature also cautions against assuming that authenticity automatically leads to inclusivity. While these approaches may benefit students who are confident and experienced in applied tasks, others may struggle due to differences in prior exposure, learning preferences, or access to resources (Ajjawi et al., 2020). This highlights the importance of scaffolding and guidance in ensuring that authentic assessments remain accessible to all students. Therefore, authenticity should be understood as one component of inclusive assessment rather than a complete solution. Its effectiveness depends on how it is designed, supported, and aligned with student needs.

4.3 Feedback and transparency in assessment

Feedback is a central mechanism through which inclusive assessment is enacted. The literature consistently shows that formative feedback supports learning by helping students understand expectations, identify areas for improvement, and refine their performance over time (Carless, 2015; Wanner and Palmer, 2018). In this sense, feedback plays a developmental role, enabling students to actively engage with their learning process.

Transparency in assessment criteria further strengthens this process. When expectations are clearly communicated, students are better able to interpret tasks and align their work with required standards (Nicol, 2010). This reduces uncertainty and minimises hidden barriers that may disadvantage certain groups of students. Transparency also promotes fairness by ensuring that all students have access to the same information.

Despite these benefits, the literature highlights inconsistencies in feedback practices. Variability in the quality, timing, and depth of feedback can result in unequal learning experiences. In some cases, feedback is provided too late to influence future performance, limiting its effectiveness as a learning tool.

Within Built Environment programmes, where assessment often involves complex and technical tasks, the role of feedback becomes even more critical. Clear, timely, and actionable feedback can support students in developing both conceptual understanding and practical competence. This suggests that feedback should be embedded as a continuous process rather than a one-time event.

4.4 Challenges in implementing inclusive assessment

While the value of inclusive assessment is widely acknowledged, its implementation remains uneven. One of the primary challenges identified in the literature is the capacity of academic staff. Designing inclusive assessments requires time, pedagogical expertise, and institutional support, all of which may be limited (Ajjawi et al., 2020; Carless, 2015). As a result, educators may rely on traditional assessment methods that are easier to manage but less responsive to diverse student needs. Another significant challenge relates to the alignment between inclusive assessment and professional accreditation requirements. Built Environment programmes are often governed by strict standards that require measurable and consistent outcomes (Male et al., 2021). This creates a tension between flexibility and standardisation, as programmes attempt to maintain both inclusivity and professional credibility.

Institutional constraints further complicate the situation. Factors such as large class sizes, limited digital infrastructure, and rigid curricula can restrict innovation in assessment design. In addition, resistance to change among academic staff may slow the adoption of new approaches. These challenges suggest that inclusive assessment cannot be implemented in isolation. Instead, it requires institutional commitment, policy alignment, and ongoing support for academic staff. Without these elements, inclusive practices are likely to remain fragmented and inconsistent.

4.5 Implications for Built Environment Education

The findings of this review point towards the need for a more integrated approach to assessment within Built Environment education. While flexibility, authenticity, and feedback each contribute to inclusivity, their effectiveness depends on how they are combined within a coherent assessment strategy. Importantly, inclusive assessment requires a shift in how assessment is conceptualised. Rather than designing for a hypothetical “average” student, assessment should be designed with diversity in mind from the outset. This aligns with contemporary educational frameworks that emphasise accessibility, equity, and student-centred learning.

At the same time, professional competency standards must be maintained. This requires a careful balance between flexibility and rigour, ensuring that all students meet required outcomes while still being supported in different ways. Achieving this balance is particularly important in the Built Environment programmes, where graduates are expected to perform in complex and

dynamic professional environments. Ultimately, the successful implementation of inclusive assessment depends on the alignment between pedagogy, institutional structures, and professional expectations. When these elements are aligned, inclusive assessment can contribute not only to equity but also to the development of adaptable and future-ready graduates.

The findings also have social and research implications. Socially, inclusive assessment supports equity, student belonging, and fair participation by reducing barriers faced by students with diverse learning needs and backgrounds. In Built Environment education, this is important because assessment influences both student progression and professional readiness. From a research perspective, the review highlights the need for more empirical studies, particularly in South African and Global South contexts, on how inclusive assessment can be balanced with professional competency and accreditation requirements.

4.6 Proposed Synergistic Framework for competency-aligned Inclusive Assessment in Built Environment Education

Based on the review findings, this study proposes a Synergistic Framework for Competency-Aligned Inclusive Assessment in Built Environment Education (Figure 2). The framework synthesises the four dominant themes identified in the literature, namely flexible assessment design, authentic assessment tasks, feedback and transparency, and institutional-accreditation alignment. Rather than functioning as isolated assessment practices, these dimensions interact synergistically to support equitable learning experiences while maintaining professional competency standards (Figure 2).

At the centre of the framework is competency-aligned inclusive assessment, which represents the integration of inclusivity and professional competence within assessment practices. The framework recognises that assessment should accommodate diverse student needs while ensuring that graduates achieve the competencies required for professional practice. The graduate outcomes embedded within the framework include professional competence, equity and inclusion, adaptability, critical thinking, industry readiness, and lifelong learning. These outcomes reflect the attributes required of future-ready Built Environment graduates.

The framework further identifies leadership and institutional commitment, professional standards and accreditation requirements, staff capacity building, resources and infrastructure, and policies and support systems as enabling factors that support the implementation of inclusive assessment practices. These factors create the institutional conditions necessary for sustainable and effective assessment innovation.

The four outer dimensions represent the key components of the framework. Flexible assessment design provides multiple pathways for students to demonstrate learning and competence. Authentic assessment tasks promote the application of knowledge within real-world and professional contexts. Feedback and transparency support learning development by clarifying expectations and facilitating continuous improvement. Institutional and accreditation alignment ensures that assessment practices remain consistent with quality assurance requirements and professional standards.

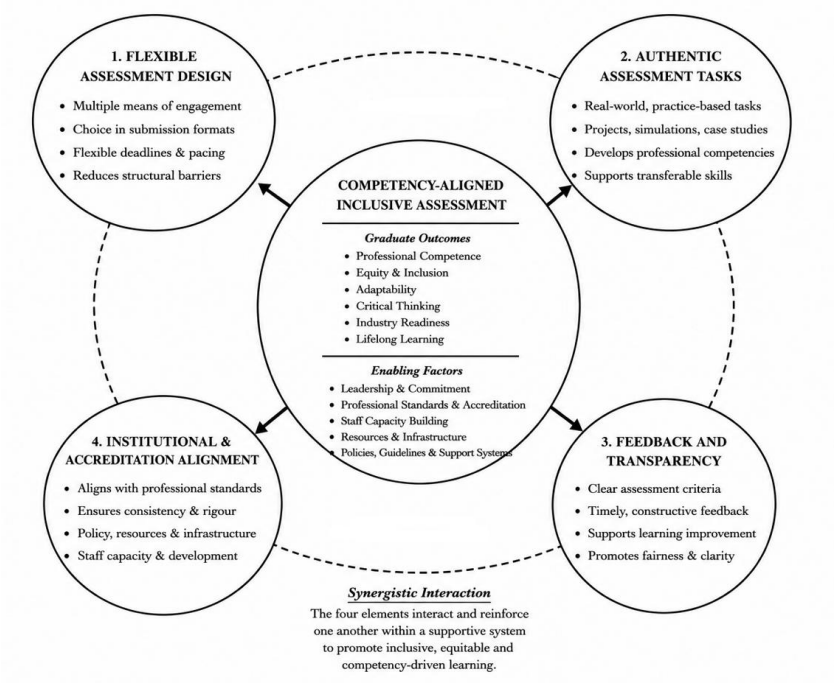

Figure 2: Synergistic Framework for Competency-Aligned Inclusive Assessment in Built Environment Education.
Source: Author's construct (2026).

A key contribution of the framework is its emphasis on synergistic interaction. The framework proposes that inclusive assessment is most effective when these dimensions operate collectively rather than independently. For example, authentic assessment is strengthened through transparent feedback processes, while flexible assessment practices require institutional support and accreditation alignment to maintain fairness and thoroughness. Through these interactions, the framework promotes inclusive, equitable, and competency-driven learning.

The proposed framework contributes both theoretically and practically. Theoretically, it extends inclusive assessment scholarship into the context of competency-based Built Environment education. Practically, it provides a structured guide for academics, curriculum developers, programme coordinators, and policymakers seeking to design assessment systems that support diverse learners while maintaining professional and accreditation standards.

5. Conclusion and future research

This study set out to examine how inclusive assessment practices support diverse student needs within Built Environment education while maintaining professional competency standards. Using a structured literature synthesis, the study mapped existing literature to identify dominant practices, patterns, and gaps. The findings show that inclusive assessment is largely shaped by four interconnected elements: flexibility in assessment design, the use of authentic and varied assessment formats, feedback and transparency, and institutional-accreditation alignment. Together, these elements contribute to improved student engagement and more equitable learning experiences. However, the findings also highlight that inclusivity is not achieved automatically. Instead, it depends on how assessment is designed, communicated, and supported in practice.

At the same time, the review reveals ongoing tensions between inclusive practices and the need to meet professional accreditation requirements. In Built Environment programmes, assessment must demonstrate measurable competencies, which can limit the extent to which flexibility is applied. In addition, institutional constraints such as limited resources, large class sizes, and varying levels of staff capacity continue to affect implementation. Overall, the study shows that inclusive assessment is not simply a pedagogical adjustment but a broader shift in how assessment is conceptualised. When implemented effectively, it has the potential to support both equity in learning and the development of competent, future-ready graduates in the Built Environment.

5.1 Future research directions

While this study provides a broad overview of inclusive assessment practices in Built Environment education, further research is needed to examine how these practices are implemented in specific teaching and learning contexts. Empirical studies would be useful in showing how inclusive assessment works in real classrooms, how students experience different assessment approaches, and how lecturers manage inclusivity while still meeting professional and accreditation requirements. Future studies could also explore the role of institutional policies, resources, leadership, and organisational culture in supporting or limiting the adoption of inclusive assessment practices. In addition, more attention should be given to how inclusive assessment can contribute to the development of future-ready Built Environment graduates, particularly in response to emerging demands linked to digital transformation, sustainability, and changing professional practice.

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A Knowledge-Based Competency Metric for ICT Project Managers in South Africa's Digital Transformation Era

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Abstract

Technology-intensive ICT projects in emerging economies, particularly South Africa, continue to underperform despite the widespread use of global competency frameworks such as PMBOK, IPMA and PRINCE2, indicating a misalignment with local contextual realities. This study aims to examine this gap and identify the competencies most critical for project success in digitally intensive environments. A systematic literature review (SLR) with thematic synthesis was employed to analyse recent theoretical and empirical studies on project manager competencies and digital transformation, including artificial intelligence, data analytics and remote collaboration. The findings indicate that, in addition to foundational technical competencies, adaptive, digital and strategic capabilities such as AI literacy, data-driven decision-making, stakeholder sensemaking and contextual intelligence are key determinants of success yet are insufficiently represented in existing frameworks. To address this gap, the study proposes a knowledge-Based Competency Metric (KBCM) comprising four domains: knowledge, performance, personal and agile/adaptive competencies. The proposed metric provides a context-sensitive tool for competency assessment, targeted capability development and governance, thereby supporting improved project performance and more effective leadership in South Africa's evolving digital transformation landscape.

Keywords: Digital transformation, Emerging economies, ICT projects, Project manager competencies, South Africa

1. Introduction

Persistent project underperformance in technology-intensive environments suggests that widely used competency frameworks do not adequately reflect the dynamic and interdisciplinary nature of modern ICT contexts. In South Africa, this misalignment is intensified by rapid digitalisation, organisational complexity, resource constraints and critical skills gaps, while emerging technologies such as artificial intelligence, data analytics and cybersecurity are reshaping project management expectations. This study aims to examine the alignment of global competency frameworks with the realities of South Africa's ICT sector and to identify competencies critical for project success in digitally intensive environments. The objectives are to (i) evaluate the contextual fit of global competency frameworks, (ii) synthesise competencies associated with project success under digital transformation conditions, and (iii) develop a knowledge-based competency metric (KBCM) tailored to the South African ICT context. The research adopts a systematic literature review to synthesise theoretical and empirical evidence, enabling structured identification of key competency domains and gaps. The study is significant in addressing the lack of a context-specific competency model by providing a practical, evidence-based tool to support competency assessment, development, governance and improved project performance in complex digital environments.

2. Literature Review

2.1. Foundational perspectives on competence

Competency theory defines competencies as integrated combinations of knowledge, skills and behaviours that enable effective performance in role-specific contexts, a view that underpins contemporary project management competence models (Boyatzis,1982; PMI, 2017). In ICT settings, scholarship consistently elevates behavioural and relational capabilities (leadership, communication, emotional intelligence) alongside technical mastery as key predictors of success (Alvarenga et al., 2020; Pacheco et al., 2023). These insights are typically operationalised through structured frameworks that allow assessment across multiple dimensions (knowledge/performance/personal) (PMI, 2017).

2.2. Global project management competence frameworks

Widely adopted frameworks such as PMBOK/PMCD, IPMA ICB and PRINCE2 codify competence domains and provide guidance on role expectations, assessment and development (PMI, 2017; Alvarenga et al., 2020). While these models offer strong structure and portability, evidence increasingly shows that rigid, one-size-fits-all prescriptions underperform in volatile, digitally intensive contexts where agile and hybrid delivery dominate (Dias et al., 2023; Ndou et al., 2024).

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Studies also point to gaps in how traditional frameworks represent data/AI fluency, cybersecurity, and human-centred change skills that are now pivotal in ICT projects (Mishra et al., 2023; Li et al., 2025).

2.3. Digital transformation and dynamic capabilities

Digital transformation reframes competence as a dynamic capability: project leaders must sense technological and stakeholder shifts, seize opportunities through adaptive governance, and transform delivery systems through learning and reconfiguration (Teece, 2007; Anning-Dorson et al., 2025). At the project level, this translates into data-driven decision-making, iterative product/value road-mapping, and psychologically safe experimentation, particularly in AI-centred initiatives (Vial et al., 2023; Mishra et al., 2023). These demands elevate competencies such as stakeholder sensemaking, contextual intelligence, and ethical judgement alongside technical prowess (Alvarenga et al., 2020; Pacheco et al., 2023).

2.4. Technological readiness and adoption barriers

Technology adoption depends on organisational and individual readiness. Readiness constructs (optimism, innovativeness, discomfort, insecurity) explain variance in adoption and usage behaviours that PMs must actively manage (Parasuraman, 2000; Kumar et al., 2022). In digital programmes, algorithm aversion, reluctance to trust AI recommendations, can derail benefits unless competencies in transparent communication, participatory design and change leadership are present (Filiz et al., 2023). In parallel, readiness for AI/cloud/cyber initiatives hinges on governance and maturity practices that PMOs can institutionalise (Lavoie & Daim,2017; Bertránd, 2016).

2.5. Competence and performance relationships

Empirical studies link PM competencies to multi-dimensional project success (goal attainment, stakeholder satisfaction, time, cost, quality). Soft-skill clusters, leadership, communication, and emotional intelligence consistently moderate and amplify the effects of technical expertise on outcomes (Alvarenga et al., 2020; Sposito et al., 2024). Systematic reviews identify competencies across cognitive, personal, social, and sustainability dimensions, with decision-making, ethics, and EI frequently associated with higher success rates (Pacheco et al., 2023; Sampaio et al., 2022). Quantitative studies also show positive associations between PMBOK-aligned capabilities (e.g., risk, cost, HR, procurement) and KPI achievement during implementation phases (Dias et al., 2023).

2.6. South African ICT context and competency implications

South Africa's digitalisation is framed by national strategies and governance guidelines that specify expectations for skills, ethics and accountability in ICT programmes. The National Digital and Future Skills Strategy prioritises foundational and advanced digital capabilities, including data, AI and cybersecurity literacy, with implications for PM role definitions and development pathways (Department of Communications and Digital Technologies,2020). Public-sector CGICT Project Management Guidelines formalise roles (Sponsor, Steering Committee, PM) and lifecycle governance, reinforcing competencies in strategic alignment, business case stewardship and risk management (DPSA,2022). Sector reports highlight infrastructural unevenness (e.g., power reliability; rural connectivity), 5G rollout dynamics, and digital inclusion gaps, demanding resilience planning, regulatory navigation, and equity-oriented stakeholder engagement (ICASA, 2025; SITA, 2024). Empirical local studies further emphasise leadership, communication, and knowledge-sharing competencies, including the role of informal knowledge systems in SMEs (Mbebe & Jowah,2024; Shongwe,2017). Collectively, these drivers require a hybrid competence model that blends global standards with SA-specific constraints and opportunities (Aigbavboa et al., 2023; Lesebo et al., 2023).

2.7. Synthesis and gap

Across the above strands, ICT project managers need balanced portfolios spanning **knowledge** (ICT/AI/cyber/agile), **performance** (planning, risk/quality, stakeholder alignment), **personal** (leadership, EI, ethics) and **agile/adaptive** capabilities (iterative delivery, learning, VUCA navigation) (PMI,2017; Ndou et al.,2024). However, mainstream frameworks under-specify digital-era competencies and offer limited guidance on contextualisation for resource-constrained, institutionally complex settings.

This gap motivates a knowledge-based competency metric tailored for South Africa's ICT sector to support assessment, development and governance that are simultaneously standardised and context-sensitive (Mishra et al.,2023; Mbebe & Jowah,2024).

3. Research Methodology

3.1. Design

This study employed a Systematic Literature Review (SLR) with narrative/thematic synthesis to identify, appraise, and integrate evidence on project manager competencies associated with success in digitally intensive ICT projects, particularly within the South African context. The SLR followed a structured multi-phase process of planning, conducting, and documenting, ensuring methodological rigour, transparency, and replicability in the identification and

synthesis of evidence. An SLR was selected over other review types because the study aims to develop a defensible, context-sensitive competency metric (KBCM), which requires a comprehensive, systematically validated evidence base rather than a descriptive or conceptually driven overview. Unlike narrative, scoping, or integrative reviews, the SLR approach enables explicit inclusion and exclusion criteria, traceable screening decisions, and formal quality appraisal, thereby reducing selection bias and enhancing the credibility of derived competency constructs. This is particularly important in the context of digital transformation, where competencies are fragmented across diverse bodies of literature and must be systematically consolidated into a coherent, operationalisable model suited to the South African ICT environment.

3.2. Protocol, eligibility, search and selection

Table 1 presents an adapted PRISMA-style summary of the systematic literature review process. A written protocol defined information sources, search strings, inclusion/exclusion criteria, quality appraisal, and extraction variables to ensure methodological rigour and traceability (Hassan et al., 2022; Rahman & Rahman, 2023). Keywords: digital transformation, emerging economies, ICT projects, project manager competencies, and South Africa were structured into four concept blocks and combined using Boolean logic across Scopus, Web of Science, IEEE Xplore, and targeted domain journals and South African policy sources (Mangaroo-Pillay & Coetzee,2022; Rahman & Rahman,2023). Database searches and citation chasing identified 85 candidate studies (n=85); following screening and quality appraisal, 33 were retained (n=33). Included sources addressed ICT project-manager competencies, links to project success, and emerging-economy or South African contexts, while exclusions removed duplicates, non-English papers, methodologically weak studies, and those lacking extractable competency constructs.

factors. The extracted data were synthesised by mapping constructs and indicators onto the four meta-domains of the Knowledge-Based Competency Metric (KBCM): Knowledge, Performance, Personal, and Agile/Adaptive, consistent with coding approaches used in related systematic literature reviews (Mangaroo-Pillay & Coetzee,2022).

3.4. Limitations and trustworthiness

Trustworthiness was enhanced by using multiple databases, targeted sectoral and policy sources, and predefined inclusion and exclusion criteria. These measures supported transparency and methodological rigour consistent with systematic review standards (Rahman & Rahman, 2023).

4. Findings and Discussion

The review identifies a balanced portfolio of competencies across four domains, digital/technical, leadership/behavioural, execution/performance, and agile/adaptive, as the most consistent predictor set of ICT project success in South Africa (PMI,2017; Alvarenga et al.,2020; Pacheco et al.,2023). Specifically, the analysis shows growing salience of AI/data literacy, cybersecurity, and systems integration, complemented by communication, emotional intelligence, ethical judgement, robust risk/quality management, and iterative learning practices (Vial et al.,2023; Mishra et al., 2023; Ayyaz et al.,2021; Ndou; Ingrosso & Di Girolamo,2024).

The findings further show that digital and data-centric practices are reshaping ICT project delivery through data-driven decision-making, human–AI teaming and product-oriented road-mapping. These findings align with scholarship advocating a blend of traditional governance and agile experimentation, while emphasising transparent communication, stakeholder education and trust-building to mitigate algorithm aversion and strengthen technology readiness (Vial et al.,2023; Mishra et al.,2023; Parasuraman,2000).

Table 1: Adapted PRISMA Review Summary for the Included Literature

Review Stage	Count	Description
Records identified	**85**	Records captured in the literature review analysis workbook (treated as the master identification set).
Records excluded during screening and appraisal	**52**	Duplicate records were removed during screening. Methodologically weak studies were excluded during appraisal. Studies lacking extractable competency constructs were excluded.
Studies included in the final synthesis	**33**	Inclusion focused on ICT PM competencies, project success links, and emerging economy/South African relevance.
Synthesis output	**4 domains**	The included studies were synthesised into four KBCM domains: Knowledge, Performance, Personal, and Agile/Adaptive.

3.3. Data extraction and analysis

A structured extraction template captured study characteristics, competency constructs, measurement indicators, project success dimensions, and contextual

South African contextual realities. Resilience planning for power and connectivity disruptions, alignment with e-government priorities, and inclusive delivery reflect

South Africa's digital strategy and public-sector ICT governance frameworks (Department of Communications and Digital Technologies, 2020; DPSA, 2022). These priorities are reinforced by infrastructural and access inequalities, while local scholarship highlights leadership, communication, and knowledge-sharing, particularly in SMEs, as competencies that support the inclusion of lightweight knowledge-based practices in the proposed metric (ICASA, 2025; SITA, 2024; Mbebe & Jowah, 2024; Shongwe, 2017).

4.1. Discussion of findings in relation to the literature

(A) Digital/technical competencies are necessary but not sufficient.AI literacy, data governance, cybersecurity, and agile/hybrid delivery are now threshold competencies (PMI, 2017; Li et al., 2025; Mishra et al., 2023). The literature shows that outcomes improve materially when these capabilities are integrated with behavioural strengths that enable sensemaking, explanation, and ethical decision-making in tech-mediated contexts (Vial et al., 2023; Filiz et al., 2023). The finding that PMs must educate stakeholders and cultivate psychological safety for experimentation, therefore, aligns with evidence that human factors determine whether algorithmic insights translate into value (Kumar et al., 2022; Vial et al., 2023).

(B) Leadership/behavioural competencies moderate project outcomes. Evidence indicates that leadership, communication, and emotional intelligence strengthen the contribution of technical expertise to multidimensional project success, including time, cost, quality, and stakeholder satisfaction (Alvarenga et al., 2020; Pacheco et al., 2023; Sampaio et al., 2022). These competencies reduce rework, accelerate delivery cycles and improve stakeholder satisfaction, thereby translating project plans into realised benefits (Sposito et al.,2024; Pacheco et al.,2023). In the South African context, behavioural competence also encompasses ethical stewardship and cultural intelligence, particularly in diverse and public-interest project settings (Mbebe & Jowah,2024).

(C) Execution/performance discipline continues to predict success. Despite the shift towards hybrid delivery models, execution discipline, including planning and re-baselining, risk quantification, quality control, KPI tracking and stakeholder alignment, remains strongly associated with on-time, on-budget and quality outcomes (PMI, 2017; Ayyaz et al., 2021). The use of artefact reviews, dashboarding and sponsor 360° feedback further anchors competence in observable performance and delivery results (Souza et al., 2022; PMI, 2017).

(D) Agile/adaptive capacity is a differentiator in VUCA settings. Where requirements shift and infrastructure is uneven, adaptive governance and team-level agility (Scrum/Kanban, rapid experiments, high-quality retrospectives) correlate with resilience and throughput (Ndou et al., 2024; Moe et al., 2010). These practices instantiate dynamic capabilities, the ability to sense, seize, and transform, which reframes competence as continuous reconfiguration under uncertainty (Teece, 2007).

(E) Contextualisation to South Africa is essential for validity and use. Policy frameworks (CGICT), national skills priorities, and sector conditions (5G rollout patterns, digital inclusion gaps) shape both competency requirements and their assessment (DPSA, 2022; DCDT, 2020; ICASA, 2025). In SME-dominated ecosystems, embedding knowledge-management practices increases maturity without heavy process overheads (Shongwe, 2017).

4.2. Implications for the Knowledge-Based Competency Metric (KBCM)

The proposed four-domain KBCM Knowledge, Performance, Personal, and Agile/Adaptive faithfully operationalises the integrative profile surfaced by the review and provides observable indicators with fit-for-purpose assessment methods (scenario tasks, artifact reviews, KPI dashboards, EI inventories, live simulations) (PMI,2017; Sonstein et al.,2022; Ndou et al.,2024). Two implications follow: Measurement for development. Domain-level heatmaps support targeted upskilling (e.g., AI/data governance clinics; risk/quality masterclasses; agile facilitation coaching), a strategy widely advocated in fast-moving digital contexts (Mishra et al., 2023; PMI, 2017).

Context-specific governance. Annual metric refreshes anchored in SA policy/sector updates maintain relevance and ensure the tool reflects evolving constraints and opportunities (DPSA, 2022; ICASA, 2025; SITA, 2024).

4.3. Knowledge-based competency metric (KBCM)

Table 2 synthesises the literature into four interrelated domains: Knowledge, Performance, Personal, and

Table 2: Knowledge-Based Competency Metric (KBCM)

Domain	Example Indicators	Primary Assessment Methods	Typical Development Actions
Knowledge (ICT/AI/cyber/agile)	Explains model lifecycle and risks; maps systems integrations; applies data governance	Scenario-based items; short practicals; portfolio evidence	AI/cyber labs; integration playbooks; policy clinics
Performance (delivery discipline)	Schedules/re-baselines; quantifies risk; tracks KPIs; aligns stakeholders	Artifact review; KPI dashboards; 360° sponsor feedback	Risk/quality masterclasses; OKR/KPI coaching
Personal (leadership/EI/ethics)	Frames vision; negotiates; demonstrates EI; ethical trade-offs	Behavioural interview; EI inventory; ethics vignettes	Coaching; EI workshops; ethics roundtables
Agile/Adaptive (learning, VUCA)	Runs Scrum/Kanban; enables rapid experiments; learns from retrospectives	Live simulations; retrospective quality; WIP metrics	Agile facilitation training; experimentation funds

Agile/Adaptive, each with indicators, assessment methods, and development actions to address competency gaps. In Knowledge, actions emphasise hands-on upskilling and governance literacy through AI/ML and cybersecurity labs, data-governance practicums, and systems-integration clinics (PMI, 2017; Vial et al.,2023; Mishra et al.,2023). Performance focuses on delivery discipline, including risk and quality masterclasses, schedule re-baselining, KPI/OKR coaching, and stakeholder alignment practices (PMI, 2017; Ayyaz et al., 2021; DPSA, 2022). Personal actions develop leadership, emotional intelligence, and ethical capability through coaching, EI workshops, and ethics-based case discussions (Alvarenga et al., 2020; Sampaio et al., 2022; Mbebe & Jowah, 2024). Agile/Adaptive emphasises learning and experimentation via Scrum/Kanban facilitation, retrospectives, and simulations supporting dynamic capabilities in VUCA contexts (Ndou et al.,2024; Teece,2007; DPSA,2022). Each indicator is scored on a 5-point rubric, producing heat maps to support development planning, role alignment, and PMO governance, with annual updates to ensure continued relevance.

5. Conclusion and Further Research

This study developed a Knowledge-Based Competency Metric (KBCM) to identify and operationalise the competencies most critical to ICT project success in South Africa's digital environment. The findings demonstrate that project performance depends on an integrated portfolio of digital, technical, behavioural and agile/adaptive capabilities, with behavioural and adaptive competencies enhancing the value of technical expertise. By combining established competency frameworks with dynamic capability and technology readiness perspectives, the KBCM provides a practical, context-sensitive tool for assessing and developing project management capability in AI-enabled environments. Aligned with national policy and governance requirements, the metric supports organisations in translating digital transformation priorities into measurable competencies, thereby improving project delivery and strengthening adaptive leadership in complex and evolving ICT contexts.

Recommendations

To enhance project outcomes, organisations should implement the KBCM as a development-driven governance tool by conducting baseline and periodic competency assessments and linking identified gaps to targeted interventions such as AI/data-governance training, risk and quality management workshops, and agile facilitation development (PMI,2017; Mishra et al.,2023; Ndou et al.,2024). PMOs should integrate competency indicators into project assurance and decision-making processes, thereby strengthening alignment with business objectives and performance monitoring (DPSA, 2022; Ayyaz et al., 2021). Given South Africa's infrastructural and digital inclusion challenges, organizations should prioritise resilience planning, stakeholder education, and transparent communication to support the adoption of advanced technologies (Filiz et al., 2023; Vial et al., 2023; DCDT, 2020). Regular updates to competency frameworks, aligned with policy and sector changes, are essential to sustain their relevance and effectiveness (ICASA, 2025; SITA, 2024).

Further Research

Building on these contributions, further research should validate the KBCM using mixed methods across organisations to confirm reliability and links to project KPIs (PMI, 2017; Ayyaz et al., 2021). Studies should also assess the influence of policy, governance, and infrastructure constraints on the effectiveness of competency (DCDT, 2020; DPSA, 2022; ICASA, 2025). Longitudinal research is required to evaluate the impact of KBCM-aligned upskilling on project performance in AI-enabled environments (Mishra et al., 2023; Ndou et al., 2024).

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Exploring Technical Capacity Deficits in South African Public Infrastructure Delivery Systems

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Abstract

Infrastructure in developing and emerging economies continues to experience persistent cost and time overruns despite extensive policy reforms and institutional investments. In the South African public sector, these challenges are intensified by shortages of skilled technical personnel, fragile knowledge systems, and an overreliance on external consultants. This study investigates the nature and extent of technical capacity gaps within government departments and public entities responsible for infrastructure delivery. A systematic literature review (SLR) of peer-reviewed journals, reports, and policy documents was conducted to synthesise evidence on technical capacity, skills development, and capacity-building practices in the built environment. The review also examines how misaligned capacity-building initiatives, characterised by poorly defined objectives and limited responsiveness to actual learning needs, constrain sustainable capability development. The study contributes to theory and practice by clarifying the relationship between capacity development theory, institutional theory,sustainable development theory and systems theory. This is conducted by informing a strategic framework to strengthen internal state capability for more effective, timely, and cost-efficient infrastructure development.

Keywords: Technical capacity, infastructure delivery, capacity building

1. Introduction

In the South African landscape, infrastructure development has emerged as a fundamental catalyst for socio-economic transformation, serving as a primary driver of government expenditure and a cornerstone for inclusive growth (Noah et al., 2025). Central to this developmental agenda are the National Development Plan (NDP) 2030 and the Infrastructure Development Act (2014), which mandate prioritising infrastructure in national planning to achieve goals such as industrialisation and sustainable urbanisation. The construction sector's significance is further underscored by its economic contribution, employing over 1.2 million people and contributing approximately R111 billion to the national GDP (Aiyetan & Das, 2022). However, despite these robust legislative frameworks and the strategic intentions of the Infrastructure Development Plan (IDP), a significant disconnect persists between policy aspirations and implementation outcomes. The public sector continues to grapple with limited technical capacity in the critical domains of project planning, design, engineering, and procurement. Technical capacity is frequently discussed in terms of shortages of specialised skills, including engineering skills, project management, and supply chain management. However, this study takes a broader view. It suggests that technical capacity should be understood as a systemic issue, shaped not only by the presence of skilled individuals but also by how well their competencies are supported by institutional arrangements, organisational systems, and opportunities for ongoing learning. From this perspective, capacity constraints do not arise solely from a lack of skills, but from weak alignment and fragmentation across these interconnected elements.

This capacity crisis is rooted in systemic institutional weaknesses and historical disparities. The legacy of apartheid continues to impact the quality of basic education and professional progression, creating a bottleneck in the supply of technical skills (Thusi & Chauke, 2023). Internally, public institutions and State-Owned Enterprises (SOEs) suffer from weak corporate governance, political interference, and high staff turnover, which depletes institutional memory and fosters a reliance on "accidental project managers" who lack formal qualifications (Moodley & Chetty, 2022; Rwelamila, 2007). Consequently, industry challenges frequently manifest as cost overruns, schedule delays, and substandard workmanship, culminating in structural failures and building collapses (Mwelu et al., 2024). Furthermore, procurement implementation is frequently compromised by a lack of knowledge among Supply Chain Management personnel, leading to non-compliance, tender irregularities, and pervasive corruption (Mamokhere & Thusi, 2024). These failures represent a significant drain on the national fiscus and undermine public trust, as infrastructure investments often fail to deliver enduring public value or transition into "white elephants" (Dithebe et al., 2022; Rasebotsa et al., 2024).

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The justification for this study lies in the urgent need to align public sector operations with modern sustainability mandates, such as Sustainable Development Goal (SDG) 9, which calls for resilient infrastructure and fostering innovation. Current management interventions often fail because they treat implementation hurdles as isolated technical errors rather than symptoms of a deeper, systemic lack of transformative capacity (Borrás et al., 2024). Therefore, this research seeks to assess technical capacity gaps, identify the institutional and educational barriers impeding expertise, and evaluate the effectiveness of existing capacity-building strategies. By exploring how underlying technical and institutional foundations can be systematically reconstructed, the study aims to propose a strategic framework to strengthen technical capacity within the sector. Ultimately, this research contributes to the discourse on building a capable state by highlighting the critical intersection between technical proficiency and institutional governance, ensuring that public investments are transformed into high-performing, long-term assets.

2. Theoretical Framework

2.1. Capacity Development Theory

Capacity Development Theory emphasises the importance of strengthening the capabilities of individuals, organisations, and institutions to perform effectively and achieve developmental objectives, highlighting the need for technical expertise, organisational reform, and systemic support to ensure that infrastructure projects are properly designed, efficiently implemented, and sustainably maintained across their lifecycle. Abraham et al. (2022) argue that understanding variations in economic activity requires robust measurement of human capital and its contributions, cautioning that failure to account for human capital investments may lead to inaccurate assessments of a country's productive capacity. Similarly, Gruzina et al. (2021) contend that economic growth is closely linked to the development of human capital, which enhances innovation and explains disparities in growth between developed and developing countries. Moloto (2024) identifies risks such as inadequate skills, political interference, and poor subcontracting management, which collectively disrupt project coordination and weaken technical oversight, hereby increasing the likelihood of project failure. Complementing this, Msimango et al. (2024) highlight that insufficient capacity in planning, implementation, and monitoring leads to poor project delivery, cost overruns, and the omission of lifecycle costing in budgeting processes, ultimately undermining sustainable infrastructure outcomes.

2.2. Institutional Capacity Theory

Institutional Theory provides a comprehensive lens for understanding how formal structures, such as laws, policies, and regulations, together with informal norms including culture, traditions, and routines, shape organisational behaviour and decision-making in the public sector, particularly in relation to the planning, financing, and management of infrastructure projects. The theory emphasises the need for an enabling institutional environment that supports technical capacity development and sustainable outcomes. Abulatif (2024) argues that the institutional capacity of public administrations directly influences the quality of policy planning and implementation, thereby affecting service delivery outcomes. Building on this, Domorenok et al. (2021) highlight the importance of aligning integrated policy design with sustained political commitment and leadership, noting that effective policy integration extends beyond structural reforms to include long-term coordination, cross-sectoral collaboration, and consistent political support. In a similar vein, Abor et al. (2026) emphasise that strengthening institutional capacity within government agencies is critical for successful infrastructure delivery, with training, knowledge-sharing, and international partnerships enhancing technical and managerial competencies. In developing contexts such as South Africa, however, institutional effectiveness is often constrained by tensions between formal regulatory frameworks and informal practices, as well as systemic resource limitations; accordingly, Rasebotsa et al. (2024) stress that robust institutional frameworks that promote accountability and specialised skills are essential yet frequently undermined by systemic instability. Consequently, this creates inconsistencies in the implementation.

2.3. Sustainable Infrastructure development

Sustainable Development Theory promotes a balanced approach to development that integrates economic growth, social equity, and environmental protection, making it highly relevant to infrastructure development, which has long-term impacts on both communities and ecosystems. It emphasises that infrastructure projects should be assessed not only for their immediate functionality but also for their contribution to long-term resilience, inclusiveness, and environmental stewardship, as reflected in the United Nations Sustainable Development Goal 9. Jinapor et al. (2024) highlight the need for robust implementation frameworks that ensure effective monitoring, enforcement, and compliance, as well as transparent and accountable decision-making and strict adherence to environmental regulations, particularly in the context of foreign direct investment and industrial development. Similarly, Abor et al. (2026) emphasise that integrating environmental and social considerations into infrastructure planning and design can mitigate negative impacts, enhance climate resilience, and promote social equity, while Brixiova et al. (2011) advocate for the adoption of sustainable practices such as green building standards, renewable energy technologies, and nature-based solutions to

improve environmental sustainability and quality of life. Furthermore, Borrás et al. (2024) argue that achieving sustainability requires deep structural transformations in socio-technical systems, necessitating that public sector organisations develop the transformative capacity to move beyond entrenched construction practices and procurement models towards innovative approaches that prioritise long-term ecological integrity and social value. In this context, limitations in technical and institutional capacity constrain the extent to which infrastructure systems can achieve long-term economic, social and environmental sustainability.

2.4. System Theory

Systems Theory offers a holistic perspective on infrastructure development by emphasising the interconnectedness of project variables, viewing infrastructure not as a series of isolated activities but as a complex system of interdependent components. Misnan et al. (2025) argue that the success of sustainable projects is shaped more by the complexity and quality of relationships within multi-stakeholder alliances than by the performance of individual entities alone. In this context, infrastructure systems require the alignment of technical, social, and institutional elements, as failure in any one component can trigger cascading effects throughout the project lifecycle. This perspective is critical for understanding transformative capacity in the public sector, where Borrás et al. (2024) suggest that organisations, when conceptualised as open systems, are defined by their ability to mobilise internal resources and adapt to external pressures in driving sustainability transitions. Similarly, Behravesh et al. (2022) demonstrate that initiatives such as sustainable public procurement represent systemic shifts embedded within broader institutional contexts shaped by organisational capacity, culture, and stakeholder dynamics. In the context of South Africa, Rasebotsa et al. (2024) highlight that infrastructure delivery is governed by interconnected factors such as funding, skills, and governance operating as feedback loops, while Dithebe et al.(2022) show how disruptions, including post-pandemic shocks, can ripple across the system, undermining project performance and public value creation; thus, effective infrastructure governance requires a holistic approach that strengthens multiple institutional capacities simultaneously to ensure resilience and long-term sustainability.

Collectively, these theories provide a multi-dimensional explanation of infrastructure delivery challenges by demonstrating how technical capacity (Capacity Development Theory), institutional constraints (Institutional Theory), sustainability requirements (Sustainable Development Theory), and systemic interdependencies (System Theory) interact to shape infrastructure outcomes. Rather than operating in isolation, these dimensions reinforce one another, such that weaknesses in institutional structures can limit the effectiveness of technical skills, while poor system integration can undermine sustainability objectives In this way, the framework highlights that efficient and sustainable infrastructure delivery requires coordinated, multi-dimensional approaches rather than isolated interventions, particularly in complex contexts such as South Africa.

3. Literature Review

The delivery of sustainable infrastructure in the public sector is fundamentally contingent on technical capacity, which enables public institutions to plan, procure, implement, operate, and maintain infrastructure assets that generate long-term economic, social, environmental, and institutional value. Technical capacity underpins governments' ability to translate policy ambitions and development objectives into functional, resilient, and sustainable infrastructure systems. In developing country contexts, however, the literature consistently documents persistent and systemic capacity deficiencies that undermine this translation process.

3.1. Human Capital Crisis and Technical Skill Absence

The shortage of critical human capacity across all tiers of public service reflects not only a quantitative deficit but a structural inability to align available skills with the technical demands of infrastructure delivery (Ncamphalala et al., 2025). However, a deeper critique of this shortage suggests that the problem is not merely a numerical lack of individuals, but a profound mismatch between existing human capital and the evolving requirements of the Fourth Industrial Revolution. As Kosh (2026) argues, many public entities settle for available rather than competent personnel simply to fill positions—a practice that fundamentally compromises long-term productivity and talent competition.

When examining specific sectors, the synthesis of recent research reveals that skills shortages lead to the deterioration of physical infrastructure. Moloto (2024) and Chege et al. (2019) demonstrate this in the African railway sector, where independence was followed by a deterioration of maintenance expertise. In the South African context, this is the result of four decades of negligence and a loss of highly skilled labour (Maheso et al., 2018). This historical trajectory suggests that technical capacity is a fragile asset; once sustained investment in skills and technology is disrupted, institutional capability deteriorate over time, making recovery increasingly difficult and prolonging infrastructure underperformance.

3.2. Educational Foundations and the Legacy of Skill Deficits

Critically, the roots of this shortage in South Africa are often traced back to the legacy of Bantu education, which created a fractured foundation for technical skill development (Habiyaremye et al., 2022). Current critiques of the education system, particularly Technical and Vocational Education and Training (TVET) institutes, highlight a significant lack of alignment with market needs (Msibi, 2021; Spaull, 2019). This misalignment means that, even where training is provided, the skills developed do not correspond to the technical and managerial demands of modern infrastructure projects, thereby limiting the ability of personnel to effectively plan, executive, and oversee complex developmentsWhile some scholars associate overruns with project size, there is a growing consensus that poor decision-making driven by staff incompetence and lack of expertise is the primary driver (Lovrin et al., 2024; Tarhunia et al., 2024).

3.3. Institutional Barriers and Policy-Implementation Gaps

There is a profound paradox in South African infrastructure governance: although extensive policy frameworks exist, their effectiveness is undermined by weak institutional coordination and fragmented implementation processes, which prevent policies from being translated into consistent project outcome. (Adom et al., 2024). Domorenok (2021) argues that while the global trend has shifted towards an integrated policy approach, in South Africa, this is hampered by structural factors. The literature identifies institutional overlap and fragmented coordination as primary barriers. Madisha (2024) asserts that dependencies among the three spheres of government create administrative bottlenecks that hinder the creation of a credible project pipeline.

Furthermore, Olatunji (2025) and Matikinca et al. (2024) critique the absence of integrated management systems, particularly in the water sector, where many municipalities operate without dedicated climate strategies. This fragmentation is a systemic governance failure that contributes to project delays (Zafarullah, 2025). Recent oversight reports from the Auditor General and COGTA (2021; 2024) provide a damning critique, showing that South African municipalities lack the managerial competence and risk-planning skills needed to respond to environmental shocks, a deficit exacerbated by a lack of political will (Mathonsi et al., 2025).

3.4. Evaluation of Capacity-Building Strategies and Systemic Resilience

There is a disconnect between South Africa's policy landscape and its practical resilience to environmental shocks. Das (2025) emphasizes that climate hazards do not merely cause physical damage; they deepen existing socio-economic disparities. While the government has deployed flagship upskilling programs, Habiyaremye et al. (2022) provide a sobering critique of their effectiveness, noting a profound mismatch in skills composition. This highlights a conceptual failure: providing more training is ineffective if the skills developed do not align with the technical demands of the infrastructure sector.

The literature identifies a complex web of obstacles: fragmented policies, bureaucratic complexities, and corruption that prevent the operationalisation of infrastructure systems (Adom et al., 2024). Gumbo (2024) reinforces this by noting that the National Development Plan (NDP) has made slow progress, primarily due to a failure to implement policies and an absence of broad partnerships.

3.5. Strategic Framework for Integrated Infrastructure Management

Skills development must be embedded within broader capacity-building measures, including public-private partnerships (Habiyaremye et al., 2022). However, these partnerships are frequently hindered by institutional fragmentation. The success of infrastructure delivery is not merely a product of tools but of human dynamics. Ghabo et al. (2022) maintain that alignment must account for the balance of technical, managerial, and interpersonal skills.

4. Research Methodology

This study adopts a qualitative content analysis approach to systematically examine and interpret the existing literature on technical capacity and the delivery of sustainable infrastructure. Content analysis is a rigorous research method for identifying patterns, themes, and relationships in textual data, enabling the extraction of meaningful insights from a body of literature.

A qualitative research design was employed to enable in-depth exploration of conceptual and empirical studies. This approach is particularly suitable for synthesising diverse perspectives and identifying recurring themes related to technical capacity constraints, institutional and systems.

Data for the study were obtained through a systematic review of peer-reviewed journal articles, policy reports, and institutional publications. Relevant sources were identified using academic databases such as Google Scholar, Scopus, and Web of Science, using search terms including “technical capacity”, “infrastructure delivery”, “public sector infrastructure”, “skills development” and “governance”. The references were taken primarily from literature published between 2021 and 2026. This was an intentional decision taken to ensure recent developments and earlier works were considered.

Inclusion criteria focused on studies related to public sector infrastructure delivery and literature addressing technical capacity, skills development, and governance.

A total of 36 studies were selected out of an estimated 150 articles which were analysed based on their titles, abstracts, text relevance, credibility, and contribution to the research objectives.

The content was synthesised into overarching themes that reflect the systemic nature of technical capacity deficits and their implications for sustainable infrastructure delivery.

To ensure the credibility and reliability of the analysis, the study applied consistent coding procedures and relied on high-quality, peer-reviewed sources. Triangulation was achieved by comparing findings across multiple studies to validate emerging themes. Additionally, transparency in the selection and analysis processes enhances the study's replicability.

5. Findings and Discussions

The study further reveals that institutional fragmentation, weak intergovernmental coordination, and absence of integrated management systems undermine effective implementation. A key finding is that the human capital challenge is not only a matter of limited availability but also a mismatch between existing skills and the technical demands of modern infrastructure systems. This has contributed to declining infrastructure performance, particularly through inadequate maintenance and poor project execution.

The study further reveals that institutional fragmentation, weak intergovernmental coordination, and the absence of integrated management systems undermine effective implementation. Despite the existence of well-developed policy frameworks, a persistent gap between policy formulation and execution remains evident.

Additionally, current capacity-building initiatives are found to be largely ineffective due to their limited alignment with sector-specific needs. Governance challenges, including weak accountability and political constraints, further exacerbate these capacity limitations. From a capacity development perspective, this reflects a failure to align human capital formation with institutional and sectoral needs, thereby constraining effective infrastructure delivery.

6. Conclusion and Further Research

This study has demonstrated that limitations in technical capacity is a critical enabler of sustainable infrastructure delivery in the public sector. The findings reveal that infrastructure challenges in the South African context are not merely operational, but systemic, rooted in deficiencies in human capital, institutional arrangements, and governance practices.

The study concludes that the technical capacity constraint extends beyond a shortage of skills to include a structural mismatch between existing competencies and the demands of modern infrastructure systems. This mismatch, compounded by weak alignment between education and labour market needs, undermines the ability of public institutions to deliver and sustain infrastructure effectively.

In addition, institutional fragmentation, poor intergovernmental coordination, and weak implementation mechanisms contribute to a persistent gap between policy formulation and execution. Despite the existence of comprehensive policy frameworks, their effectiveness is limited by governance challenges, including inadequate accountability, insufficient risk management capacity, and constrained political will.

The study further highlights that current capacity-building initiatives are largely ineffective due to their lack of alignment with sector-specific requirements. As a result, efforts to strengthen infrastructure delivery remain fragmented and fail to produce sustainable improvements.

Overall, the study affirms that technical capacity is a multidimensional and systemic issue that requires a holistic and integrated response. Strengthening sustainable infrastructure delivery will depend on coordinated interventions that align skills development, institutional reform, and governance improvements. Without such an approach, the long-term resilience, efficiency, and sustainability of public infrastructure systems will remain at risk.

Future research should focus on empirically assessing the impact of technical capacity on infrastructure performance, particularly regarding project delays, cost overruns, and sustainability outcomes. There is also a need to develop context-specific project and construction management frameworks suited to South African conditions.

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Evaluating Methodological Approaches in Student Housing Quality Research in Africa: A Systematic Review

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Abstract

This paper presents a systematic review of methodological approaches employed in student housing research in Africa. The review uses the PRISMA framework and relies on 345 empirical studies from 42 African countries. The review finds that the methods applied in this research are skewed towards quantitative and cross-sectional designs, often based on non-validated instruments. The methodologies provided essential insights into infrastructural conditions and overall satisfaction with student housing and quality. However, they fail to capture the complexity and contextual specificity of students' lived experiences. Qualitative and mixed-methods research, though less common, offered deeper insights into adaptation behaviours and socio-cultural dimensions of housing, but are rarely grounded in robust theoretical frameworks. Notably, participatory methods are very limited, and ethical considerations are reported inconsistently. The review underscores significant gaps in longitudinal data, representation of marginalised populations, and cross-institutional comparisons. The study calls for a shift towards more inclusive, participatory, and theoretically anchored research methodologies. Furthermore, there is a need to develop validated instruments, implement longitudinal tracking, and establish collaborative governance structures that engage students in research and policy processes. These will enhance the quality, equity, and responsiveness of student housing in African higher education contexts.

Keywords: Adaptive strategies, off-campus hostels, on-campus hostels, student housing quality, student housing satisfaction

1. Introduction

Student housing is a critical component of higher education infrastructure in Africa. While African governments continue to expand access to higher education to meet their human capital and development needs, investment in other higher education infrastructure far outpaces investment in residential facilities. As a result, universities across Africa face a significant mismatch between the demand for and supply of student housing, leading to overcrowding. Unfortunately, most of the few existing facilities have also been allowed to deteriorate, making living conditions a challenge (Chiwaya & Liwago, 2026). Occupants face challenging conditions, including poor ventilation and sanitation and a lack of essential services such as reliable water and electricity (Kasina et al., 2025; Attakora-Amaniampong et al., 2025; Nwankwo & Nwankwo, 2025). These problems affect structural planning, psychological health, and students' academic performance (Maqbool et al., 2025; Maina et al., 2025; Asare-Baafi et al., 2025).

Academics have sought to address the challenges of student housing in higher education through research. For instance, Zaman and Hosain (2024) developed sophisticated methodological approaches, using validated measurement instruments and advanced statistical techniques, such as structural equation modelling, to investigate the impact of student housing conditions on academic performance. Similarly, Umar et al. (2025) used qualitative and participatory research approaches to assess students' lived experiences and satisfaction in student residences.

Similarly, studies on student housing in Africa largely rely on quantitative cross-sectional surveys assessing perceptions of housing conditions, including ventilation, security, maintenance, and access to utilities (Stemn et al., 2024; Amoah et al., 2025). However, these studies often use survey instruments with limited validation and are conducted at single institutions using convenience sampling (e.g., Attakora-Amaniampong et al., 2025), which presents methodological limitations. These limitations can reduce the reliability and comparability of findings. Qualitative studies on shared living arrangements and satisfaction with living spaces remain limited (Nwankwo & Nwankwo, 2025; Kasina et al., 2025). It appears that few studies of student housing quality and

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satisfaction in the African context have used mixed methods – that is, quantitative and qualitative approaches. As a result, these studies often fail to adequately account for the multifaceted nature of students' lived experiences in student housing and the prospects for inclusive knowledge. Therefore, this study seeks to ascertain the extent to which studies of student housing quality in an African context have used mixed methods. The paper addresses the question: What methodological approaches are used in research on student housing quality and satisfaction in Africa? In addressing this question, the paper first identifies the dominant research methodologies used in housing quality and satisfaction research in Africa. Second, it examines the strengths and weaknesses of these methods; third, it identifies gaps in these studies. In this review, the paper contributes to improving the methodological choices in student housing research in Africa and offers guidance for future research on student housing quality and satisfaction.

2. Literature Review

2.1. Methodological Approaches to Student Housing Research

A complex methodological tradition has shaped studies of student housing in the Global North. These studies largely employed quantitative research designs, focusing on student accommodation preferences, quality, and the relationship between student residence preferences and academic outcomes (Altinay et al., 2024; Karimi et al., 2025). According to Altinay et al. (2024), a large number of these studies use cross-sectional surveys, usually through both face-to-face and online surveys, and standardised instruments. Other studies confirmed the use of housing quality indicators (Zhang & Zhao, 2024) and the residential environment satisfaction scale (Karimi et al., 2025). These tools are usually pre-tested to ensure reliability and validity. For instance, Zaman and Hosain (2024) used advanced statistical tools such as Structural Equation Modelling (SEM) and Hierarchical Linear Modelling (HLM) to assess the relationship between a student's residential preference and academic student outcomes, retention, and mental health. Similarly, Karimi et al. (2025) used longitudinal studies to examine students' responses to indoor environmental quality over time, while Wang et al. (2025) used Geographic Information Systems (GIS) to examine the spatial patterns and accessibility to campus facilities, as well as their exposure to pollution and crime. Few scholars used qualitative approaches such as focus group discussions, interviews, and participatory mapping (Zhang & Zhao, 2024). These were used to determine the lived experiences of students whose concerns may not be fully captured through standardized surveys. In recent years, studies have adopted mixed-methods approaches, typically through sequential explanatory designs, to comprehensively examine the complex relationships among housing conditions, satisfaction, and student adaptation (Song & Dincer, 2025).

3. Research Methodology

The study adopted a systematic literature review to examine the methods used in student housing research in Africa. The method involved several steps. First, relevant literature was sought from academic databases such as Scopus, Web of Science, JSTOR, and African Journals Online (AJOL). The search process began with keywords such as 'student housing preferences', 'student housing', 'university dormitory facilities', 'university hostels', 'student housing quality', 'student housing maintenance', and 'student residential preferences'. These terms were used to search for housing studies in Africa between 2000 and 2025, yielding an initial retrieval of 345 papers (Scopus=212, Web of Science=109, JSTOR=16, and African Journals Online (AJOL)=8). Next, duplicate and unrelated studies were removed, leaving 103 articles. These articles were then sorted into themes. Three thematic areas emerged from the articles, namely: 'student housing quality', 'student housing satisfaction', and 'student preferences'.

The second phase involved screening the 103 records for completeness of reporting, methodological clarity, and relevance to the study's objective (see Figure 1 in Appendix 1). This resulted in the retention of 42 records for screening. Excluded records had unclear sampling processes, inconsistent methodology, and limited depth of findings. The retained studies employed robust methods and provided reliable empirical evidence on student housing preferences, conditions, and satisfaction. The analytical approach involved extracting information, including publication year, country of study, research design, sampling technique, sample size, and data collection methods. The extracted data were then coded and grouped into thematic categories. These categories included the study's focus, the methods used, and the methods' strengths and weaknesses/limitations. A thematic synthesis was then employed to identify recurring patterns, methodological trends, and research gaps across the studies.

4. Findings

4.1. Descriptive findings

The descriptive evaluation showed that most studies in Africa are geographically concentrated in Nigeria, Ghana, Cameroon, and South Africa. The analysis revealed that scholarly interest in student housing in Africa increased significantly from 2015 onwards. This scholarly interest has contributed to heightened calls for policy attention to student housing in Africa's higher education institutions.

Methodologically, the review showed that 60% of the studies employed cross-sectional survey designs. These studies largely used a structured survey to assess students' satisfaction with housing conditions and services. Also, qualitative research approaches recorded 20% of the reviewed studies, which often relied on interviews, a few case studies, and focus group discussions. Furthermore, 20% of these studies used mixed-methods designs, such as post-occupancy evaluations, interviews, and surveys (e.g. Sanni-Anibire & Hassanain, 2016; Du Plessis et al., 2021).

4.2. Dominant Methodologies in Student Housing Research

The analysis shows that several student housing studies adopted post-occupancy evaluation (POE) frameworks as a methodological tool to examine the quality of student housing. This framework enables researchers to systematically assess student housing quality from the perspective of the students who reside in it. Furthermore, the framework facilitated the identification of recurring shortcomings in infrastructure and service quality across the reviewed studies. For instance, Sanni-Anibire and Hassanain (2016) used this approach to inform student housing design and management practices. Likewise, Adegoke et al. (2021) used this tool to assess student housing performance and maintenance quality among university residences in Nigeria.

Furthermore, the systematic review found that non-probabilistic sampling, such as convenience or purposive sampling, was common among researchers, largely constrained by limited access to institutional datasets. These studies often relied on selected case samples. Qualitative methods were less common in the studies. Omitting qualitative methods may overlook the social and experiential aspects of student housing that can enrich such studies. The few studies that used qualitative approaches, such as case studies and interviews, focused on student housing shortages and infrastructural constraints (for example, Wanie et al., 2017; Shakantu & Simpeh, 2018). Studies that employed mixed-methods – qualitative and survey methods – provided a deeper understanding of students' residential experiences (e.g., Du Plessis et al., 2021). Generally, there is limited use of qualitative methods to capture students' experiences with housing quality.

4.3. Conceptual and Thematic Findings

The study identified several recurring themes, including the student residence experience, the nature and quality of student housing, and students' overall satisfaction. Regarding housing quality, the study found that persistent infrastructure challenges affect university accommodation systems. These were largely driven by inadequate maintenance, overcrowding, and limited sanitation services. Earlier studies observed that insufficient maintenance practices and limited tenant awareness negatively affect student housing quality (e.g., Oladapo, 2006). In terms of students' experiences, the study found that housing preferences were closely linked to maintenance responsiveness and the availability of building services. For instance, Toyin Sawyerr and Yusof (2013) found that housing quality and service provision were critical factors in students' residential experiences in Africa. Inadequate study spaces and sanitation conditions were also found to influence students' residential preferences (e.g., Aigbavboa et al., 2014; Oke et al., 2017).

There were also themes related to environmental quality and health. Indoor environmental quality issues, such as poor ventilation, thermal comfort, visual, and acoustic challenges, contributed to health risks, including sick building syndrome (e.g. Nduka et al., 2021). The effects of this sick building syndrome included reduced concentration, academic performance, and study habits (e.g., Mbazor, 2021; Mngutyo & Mngutyo, 2016).

The review shows that the conceptual scope of student housing research has expanded to include challenges related to physical accessibility, inclusivity, and market dynamics. For instance, Attakora-Amaniampong et al. (2022) and Appau et al. (2024) focused on housing access for students with disabilities, highlighting a gap in the inclusivity of student housing design and support services. Also, the review has further shown that market forces, such as location and digital platforms, tend to influence student housing choices across higher education institutions in Africa (e.g., Avogo et al., 2022; Aziabah et al., 2022).

4.4. Methodological Gaps

The study identified gaps in research methods used in student housing research in Africa (see Figure 2). First, the study found that research on student housing largely relies on standardised and validated measurement instruments. This pattern was observed in most quantitative studies, which focused on student housing satisfaction and quality. Although most of these studies used questionnaires, many relied on self-developed instruments and did not report on reliability testing (e.g. Oke et al., 2017; Toyin Sawyerr & Yusof, 2013). This undermines the comparability of findings across studies and contexts.

Second, there is the issue of the geographical and institutional concentration of research. The review found that a substantial proportion of the studies focused on single institutions and specific campuses in Ghana and Nigeria. Despite their contributions, these studies are limited in their ability to generalise findings across higher education institutions in Africa. There is a need to broaden the scope to multi-institutional and cross-national contexts, where this form of study is scarce, particularly in Central, North, and East Africa.

Third, the review found a lack of longitudinal research designs in student housing research. Most studies used cross-sectional survey methods, making it impossible to examine the pattern of student housing satisfaction in response to infrastructure and policy interventions. This absence of longitudinal designs may be explained by the limited duration of students' programmes (usually four years for undergraduate programmes). Typically, no study used quasi-experimental approaches to assess housing quality.

Fourth, the review found that very few studies used mixed methods – that is, quantitative and qualitative methods in their research. In particular, there was an absence of participatory approaches in the research. However, participatory approaches are useful because they make respondents partners in knowledge production and exchange rather than passive actors responding to closed-ended questions. This has implications for policy formulation and acceptance.

Fifth, there is limited evidence of the all-inclusiveness of student housing study designs. None of the studies reported involving vulnerable student populations. Given the special needs of vulnerable groups, such as the blind and physically challenged, in housing design, their representation in housing studies is imperative. However, scholarly studies in student housing have only recently begun to recognise this group of students (see, for example, Attakora-Amaniampong et al., 2024; Appau et al., 2024).

5. Discussions

The study reviewed research methods for student housing in Africa. It identified significant methodological gaps that could shape the future of student housing research in Africa. The findings show that student housing quality and satisfaction are critical determinants of academic performance and well-being (Mbazor, 2021; Toyin Sawyerr & Yusof, 2013; Oke et al., 2017; Aigbavboa et al., 2014). Nonetheless, challenges such as overcrowding and inadequate maintenance, which result in health problems, persist in higher-education student housing (Nduka et al., 2021; Nwankwo & Nwankwo, 2025; Oladapo, 2006). Furthermore, the review found that student housing safety and service quality shaped students' preferences and satisfaction (see, for example, Sanni-Anibire & Hassanain, 2016; Simpeh & Shakantu, 2020; Adegoke et al., 2021; Adisa et al., 2019). These findings indicate that building performance is important for holistic academic success. Moreover, the study observed growing concern about student housing market dynamics, and the use of digital platforms in rental decisions was supported by Aziabah et al. (2022) and Avogo et al. (2022). The study noted a few methodological gaps in these studies. While the studies show the deployment of advanced research techniques such as longitudinal design, spatial analysis, and Structural Equation Modelling (SEM) (Zaman & Hosain, 2024; Karimi et al., 2025; Wang et al., 2025), there is less combination of qualitative methods that allow the experiences of student respondents to be shared to enhance knowledge production and sharing.

6. Conclusions

This systematic review highlights relevant methodological gaps in student housing research in Africa. Addressing these gaps through more qualitative and participatory research designs will enhance research output and yield more impactful outcomes through policy and management reforms. Thus, the paper encourages expanding the conceptual understanding and focus of student housing research to include the needs of vulnerable groups. Further, it proposes a more integrated, interdisciplinary, inclusive, and mixed-methods approach to research on student housing in Africa. This will lead to evidence-based, client-centred student housing design and to a more qualitative, participatory research design that captures residents' sentiments and contributes to reforms to improve student housing conditions.

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Appendix 1

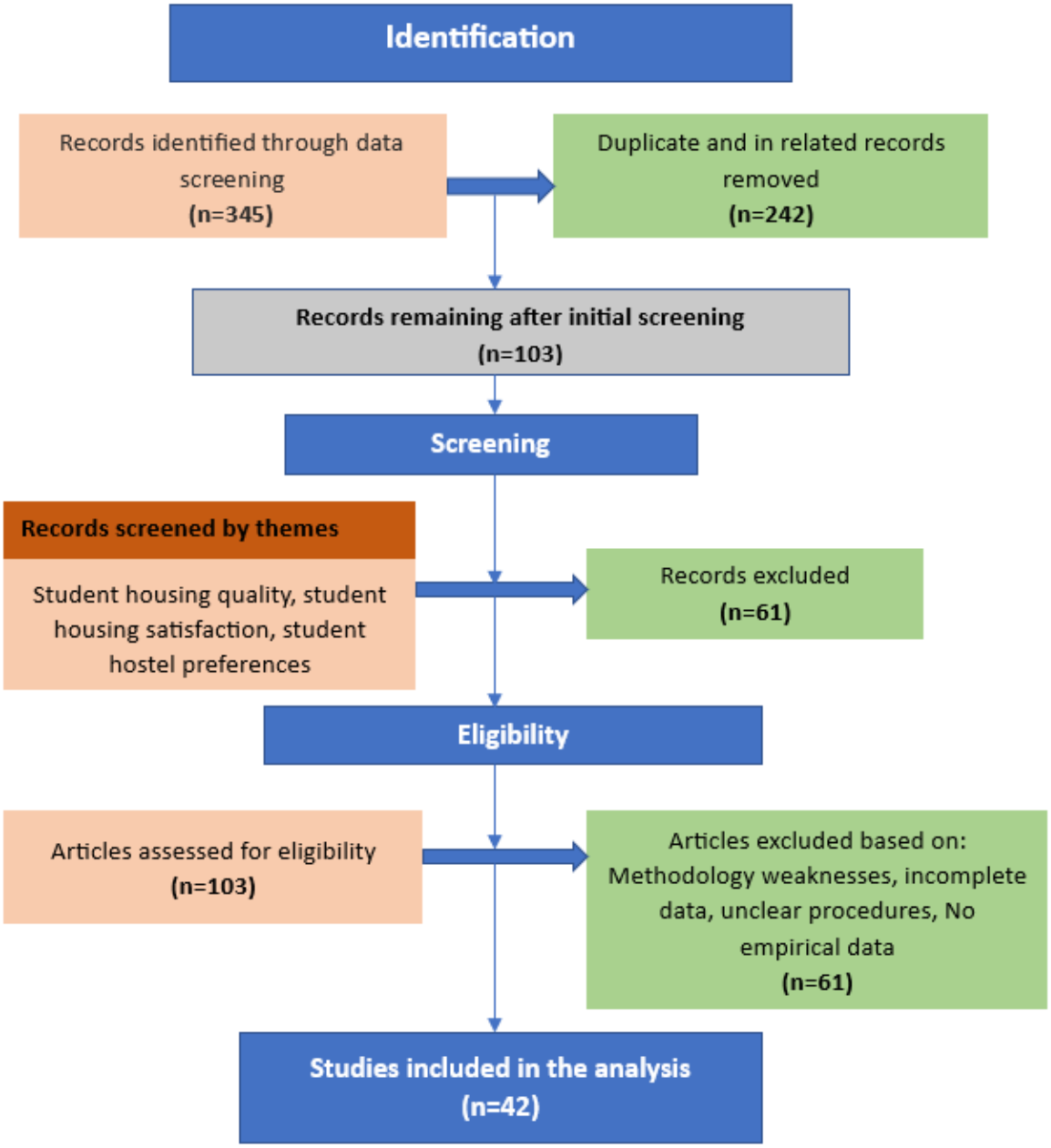

Figure 1: PRISMA process
Source: Authors' construct (2026)

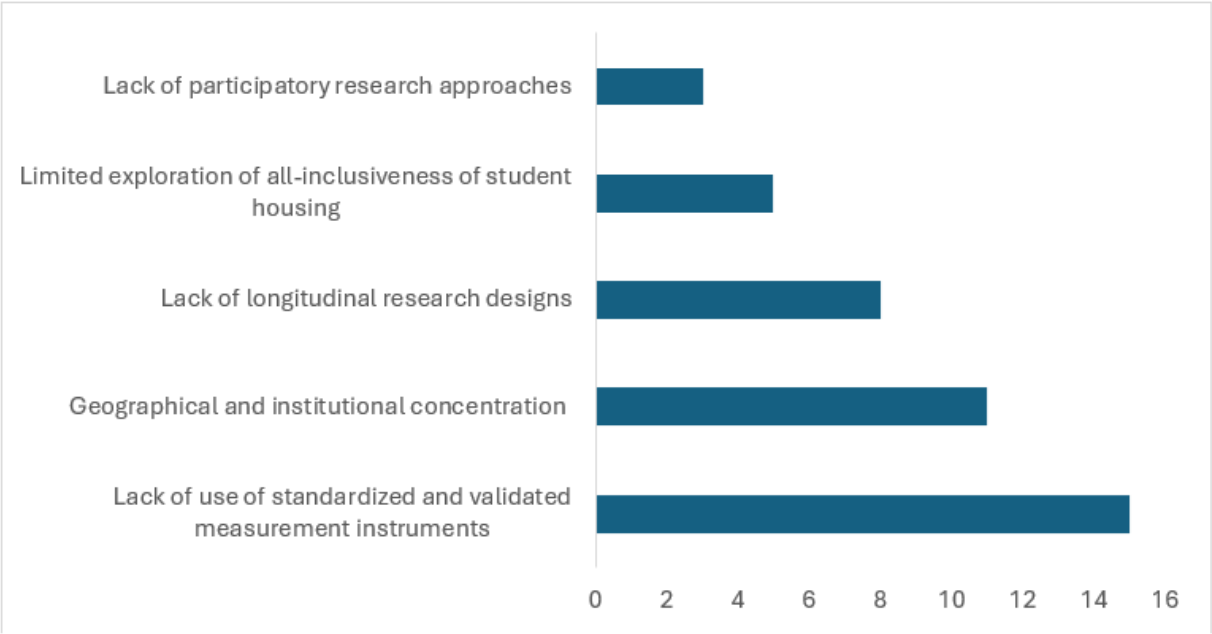

Figure 2: Methodological gaps in student housing research in Africa
Source: Authors' construct (2026)

Leveraging on digital technologies for assessing cost estimation accuracy in renovation and refurbishment projects towards improved project delivery

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Abstract

This study investigates the impact of digital technologies on improving cost estimation accuracy in refurbishment projects, with the aim of enhancing project delivery through cost certainty. Conducted in Bloemfontein, Free State, South Africa, the research utilized a mixed-methods approach, combining quantitative data from 30 structured questionnaires with qualitative insights from 4 semi-structured interviews with construction professionals. Descriptive statistics were employed to evaluate the effectiveness of various estimation tools, while thematic analysis identified key barriers and enablers influencing digital technology adoption. Single coding was applied due to the study's small, pilot nature and interpretive focus. Findings reveal that advanced tools such as Building Information Modelling (BIM) and Laser Scanning Technology (LST) significantly improve estimation accuracy; however, their use is limited by high costs, lack of technical expertise, and insufficient as-built data. Despite the superior precision of these digital solutions, manual estimating methods remain dominant due to resource constraints and resistance to change. The study contributes original insight by linking digital tool adoption directly to cost estimation inaccuracies in R&R projects, rather than only examining adoption barriers as in prior BIM research. It highlights an "effectiveness-adoption gap," where advanced technologies like BIM and Laser Scanning/LiDAR are highly valued but underused, while simpler tools such as QTO are more widely adopted due to practical constraints. Integrating digital tools with traditional estimation practices is recommended to enhance accuracy, reduce project risks, and improve project cost outcomes in the construction sector.

Keywords: Digital technologies, Construction Project Management, Renovation and Refurbishment, Cost Estimation

1. Introduction

Accurate cost estimation is widely recognised as a critical factor in achieving successful construction project outcomes (Doloi, 2012; Ahiaga-Dagbui and Smith 2014). However, it continues to present significant challenges, particularly in renovation and refurbishment (R&R) projects where incomplete project information and uncertain site conditions increase estimation complexity (Abdelsalam et al. 2026). Conventional cost estimation methods are often unable to adequately account for such uncertainties, resulting in estimation inaccuracies that frequently lead to cost overruns and project delays, thereby affecting overall project performance and stakeholder satisfaction (Mokhojane, and Makgoe 2025). Cost overruns remain one of the most prevalent risks in construction projects worldwide. In the South African context, inaccurate material quantification and unforeseen site conditions have been identified as major causes of budget increases and schedule disruptions in infrastructure projects (Mokhojane et al. 2024).

Emerging digital technologies such as Building Information Modelling (BIM), Laser Scanning Technology (LST), Artificial Intelligence (AI), and advanced Quantity Take-Off (QTO) systems have demonstrated considerable potential to improve estimation accuracy through enhanced visualisation, automated quantity measurement, and real-time data integration (Khafiso and Tjebane 2026). BIM, in particular, facilitates centralised project information management and enables the generation of more accurate 5D cost data linked to digital models, thereby reducing uncertainty and supporting informed decision-making (Mokhojane et al. 2024;Mehdipoor et al. 2026). The selection of these three technologies for purposes of de-risking cost estimation in R&R projects is because of their possible interoperability, BIM digital process that creates and manages a shared 3D model containing detailed information about a building's physical and functional characteristics throughout its lifecycle (Odeyinka, and Yusif, 1997; Azhar, 2011). LST is a data-capture method that uses laser beams to measure and record the geometry of physical structures, producing highly accurate three-dimensional point cloud models. In refurbishment projects, LST is

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commonly used to document existing conditions and generate reliable as-built information for planning and cost estimation (Eastman et al. 2011). AI refers to computer systems capable of performing tasks that typically require human intelligence, such as learning, pattern recognition, prediction, and decision-making. In construction, AI can be used to automate cost estimation, analyse project data, identify risks, and improve forecasting accuracy (Mokhojane et al. 2024; Mokhojane et al. 2024). Although the benefits of these technologies are well documented, their practical adoption remains relatively low. Existing studies attribute this slow uptake to factors such as high implementation costs, limited technical expertise, organisational resistance to change, and inadequate model data quality, challenges that are particularly evident in developing countries such as South Africa (Azhar, 2011).

Against this backdrop, this study investigates the role of digital technologies in enhancing cost estimation accuracy within R&R projects. Specifically, it explores the effectiveness of available digital tools, examines the barriers constraining their adoption, and identifies strategies that can facilitate wider implementation. In doing so, the study contributes to ongoing efforts to advance the digitalisation of cost estimation practices and improve project delivery performance in complex construction environments.

2. Literature Review

Cost estimation in rehabilitation and refurbishment (R&R) projects is widely regarded as more challenging than in new-build construction because of the high levels of uncertainty associated with incomplete information, concealed defects, and changing site conditions (Akintoye, 2000; Abdelsalam et al. 2026; Mehdipoor et al. 2026), These projects frequently involve undocumented alterations, uncertain structural conditions, and material deterioration, which complicate the estimation process and increase the risk of inaccuracies in projected costs. The literature indicates that such uncertainties often lead to cost overruns, as preliminary estimates are typically based on assumptions that may require revision as project conditions become clearer during implementation (Flyvbjerg, 2009; Love et al. 2016; Abdelsalam et al. 2026). Furthermore, the fluid nature of R&R projects, where design requirements and project scope are regularly adjusted during construction, further undermines the reliability of cost estimates (Khabisi, 2013)

The reliability of cost estimates depends heavily on the availability and quality of project information during the pre-construction phase. Inadequate site investigations, outdated or incomplete documentation (including as-built records and drawings), and ineffective information management practices often lead to inaccurate assumptions and unforeseen changes during project execution (Neupane and Jaisi 2025). Previous studies have consistently identified poor data management and limited site assessment as major contributors to estimation inaccuracies and subsequent cost overruns (Sanusi 2024; Abdelsalam et al. 2026). Similarly, insufficient project planning and weak scope definition limit project teams' ability to anticipate and mitigate project-specific risks and uncertainties, increasing estimation errors (Gilbert, 2024). These findings highlight the need for thorough site assessments, effective data collection processes, and accurate record management to improve estimation reliability.

Despite the complexity of refurbishment projects, traditional estimation techniques, including manual quantity take-offs and estimator experience-based methods, remain widely used. Although these approaches are valued for their simplicity and relatively low implementation costs, they are susceptible to human error and often fail to adequately address the complexities and uncertainties associated with R&R projects (Taherdoost 2024). Recent studies suggest that digital technologies such as Building Information Modeling (BIM), Artificial Intelligence (AI), and Laser Scanning Technology (LST) can substantially enhance cost estimation accuracy by facilitating improved data integration, visualization, and real-time project analysis. However, the adoption of these technologies remains constrained, particularly in developing countries, due to factors such as high investment costs, limited technical capabilities, and resistance to organisational change (Díaz-Arancibia et al. 2024; Barkley and Jokonya 2024.Oyenuga et al. 2025)

3. Research Methodology

The study adopted a mixed methods design to comprehensively investigate cost estimation accuracy in R&R projects in Bloemfontein, Free State, South Africa. Ethical clearance was obtained from the Faculty Research and Innovation Committee (FRIC). Purposive sampling was used to identify suitable respondents. Quantitative data were collected through structured questionnaires administered to construction professionals consisting of consultants and contractors. Qualitative data were analyzed using descriptive statistics to determine frequencies, mean values, and rankings of key factors influencing estimation precision. This analysis allowed for the identification of prevailing patterns and the relative significance of variables affecting project outcomes. Simultaneously, qualitative data were obtained through semi-structured interviews with selected industry experts, providing deeper insights into their experiences and perspectives. Thematic analysis was applied to the qualitative responses, coding and categorizing them into key themes such as barriers to adopting digital technologies and challenges in project planning. Single coding was

adopted given the study being profiled as small, a pilot and relying on the researcher's interpretive lens. By integrating descriptive and thematic analyses, the study employed methodological triangulation, enhancing the reliability and validity of the findings by linking statistical trends with practitioner insights.

4. Findings and Discussion

4.1. Quantitative Data Analysis

The survey participants were professionals in roles related to cost estimation and construction project delivery. Quantity surveyors formed the largest group of respondents (63%), followed by project managers (21%) and contractors (16%). Most respondents possessed considerable industry experience, with 72% reporting more than five years of professional practice, while 28% had between one and five years of experience. In terms of project involvement, 68% of participants were primarily engaged in private-sector renovation projects, whereas the remaining respondents worked across both public and private sectors. The strong representation of experienced quantity surveyors suggests that the study findings are informed by practitioners directly involved in critical activities such as cost planning, tender preparation, and financial management. Furthermore, the high proportion of private-sector respondents provides valuable insight into a segment of the construction industry that is generally less regulated but often more receptive to innovation and technological advancement. Table 1 below presents a summary of the demographic profile of the quantitative respondents.

4.1.2 Causes of Estimation Inaccuracies

The findings presented in Table 2 indicate that unforeseen site conditions (83%) and inadequate pre-project investigations (76%) are the most significant contributors to inaccuracies in cost estimation. This highlights the importance of thorough site assessments and effective planning during the early stages of a project. These results are consistent with the findings of Sheikhalishahi et al. (2025), Afana et al. (2024), and Alfasi and Khan (2026), who argue that insufficient front-end planning and optimism bias often result in unrealistic cost forecasts and subsequent project overruns. Likewise, incomplete or outdated project documentation (64%) emerged as a major source of estimation errors, supporting previous studies that link poor-quality information to inaccurate estimates, rework, and diminished project performance (Nnadi and Najjobyo 2025; Jayana et al. 2025; Adamu, 2020). The influence of inflation and material price volatility (53%) further reflects the impact of external economic conditions on project cost performance, corroborating the findings of Ezzat et al. (2025), AlTalhoni et al. (2026), and Raghib et al. (2023) who identify market fluctuations as a key driver of cost deviations in construction projects. In addition, weak scope definition (48%) and continued dependence on manual or outdated estimation techniques (41%) reinforce existing calls for improved project scoping and greater adoption of digital technologies, particularly BIM, to enhance the reliability and accuracy of cost estimates (Fazeli et al. 2021; Shen and Issa 2010). Overall, the results suggest that estimation inaccuracies stem from a combination of technical uncertainties and managerial deficiencies, both of which remain critical challenges in construction project delivery

Table 1: Summary of Questionnaire Respondents' Profiles

Demographic Category	Response Options	Frequency (n=30)	Percentage (%)
Professional Role	Quantity Surveyor	19	63%
	Project Manager	6	21%
	Contractor	5	16%
Years of Experience	1–5 years	8	28%
	More than 5 years	22	72%
Sector Focus	Private Sector	20	68%
	Public Sector	3	10%
	Both Public and Private	7	22%

Table 2: Leading Causes of Cost Estimation Inaccuracies

Cause of Inaccuracy	% Ranked as Top 3
Unforeseen site conditions	83%
Inadequate pre-project investigations	76%
Incomplete or outdated documentation	64%
Inflation and material price volatility	53%
Poor scope definition	48%
Use of manual/outdated estimation techniques	41%

4.1.3 Risk Factor Rankings by Respondents

The findings in Table 3 below indicate that cost estimation inaccuracies and project risks are primarily influenced by technical uncertainties, inadequate planning, and external economic conditions. Hidden defects, unforeseen site conditions, and limited pre-project investigations highlight the importance of thorough front-end planning and reliable site information to reduce uncertainty. Regulatory compliance requirements and the integration of existing and modern systems further complicate project delivery, creating additional coordination and technical challenges. Economic factors, particularly inflation and fluctuating material prices, contribute significantly to cost deviations. Similarly, incomplete documentation and continued reliance on traditional estimation methods reveal weaknesses in information management and limited digital technology adoption. These findings support previous studies that identify inadequate planning, incomplete project information, and volatile market conditions as major causes of cost overruns and project inefficiencies (Nnadi and Najjobyo 2025, Gurumayum 2025.Amini etal. 2023.Afana et al. 2024, Alshihri et al. 2022). Overall, the results underscore the need for comprehensive investigations, greater digitalisation, and robust project management practices to improve cost estimation accuracy and project performance.

4.1.4 Quantitative Assessment of Tool Usage

The results in Table 4 highlight a clear disparity between the perceived effectiveness of digital cost estimation technologies and their actual adoption in practice. Building Information Modelling (BIM) (Mean = 4.42) and Laser Scanning/LiDAR (Mean = 4.35) were rated as highly effective for improving estimation accuracy and project visualisation; however, their adoption levels remain relatively low at 36% and 18%, respectively. This suggests that barriers such as high implementation costs, limited technical expertise, and inadequate as-built information continue to constrain their use, particularly in developing-country contexts (Khafiso et al. 2026). In contrast, Quantity Take-Off (QTO) software demonstrates both strong perceived effectiveness (Mean = 4.20) and comparatively high adoption (67%), indicating that accessible and user-friendly digital tools are gaining wider acceptance despite their reliance on accurate project documentation. AI-assisted estimation records a low adoption rate (15%) despite a moderate effectiveness rating (Mean = 3.87), reflecting challenges related to data availability and technical capacity. Conversely, manual estimation methods remain the most widely used approach (82%), despite lower effectiveness (Mean = 3.65), supporting findings that traditional practices persist due to familiarity, affordability, and ease of use, even though they are more susceptible to errors and inefficiencies (Sikka and Bhayana 2024, Pirzada et al. 2026).

4.2. Qualitative Findings

The qualitative phase included four experienced professionals actively involved in private-sector R&R projects. Participants comprised three quantity surveyors and one quantity surveyor who also served as a contracts manager, with professional experience ranging from five to over fifteen years. CCS Candy emerged as the dominant cost estimation software, used

Table 3: Impact of Specific Risk Factors on Estimation Accuracy (N = 30)

Risk Factor	Mean Rating (1–5)	% Rated "4" or "5"
Latent Defects (hidden/unseen conditions)	4.64	91%
Regulatory Constraints	4.48	85%
Integration of Old & New Systems	4.36	82%
Inadequate Pre-project Investigation	4.21	79%
Inflationary Pressures	4.03	73%
Documentation Gaps	3.94	70%

Table 4: Usage and Effectiveness of Estimation Tools (N = 30)

Tool	% Usage (Always/Often)	Mean Effectiveness Score (1–5)	Notable Barriers
Building Information Modelling (BIM)	36%	4.42	High cost, low skills, poor as-built records
QTO Software (e.g., Bluebeam)	67%	4.20	Relies on accurate base drawings
AI-Assisted Estimation	15%	3.87	Limited datasets, low technical expertise
Laser Scanning / LIDAR	18%	4.35	Equipment cost, low availability, training gaps
Manual Estimation Methods	82%	3.65	Prone to error, slow, lacks automation

by three participants, while CostX and DimX were employed by two respondents alongside CCS Candy. Notably, none of the interviewees reported using advanced technologies such as Building Information Modelling (BIM) or Artificial Intelligence (AI) for cost estimation. These findings indicate that, despite considerable industry experience, the adoption of emerging digital estimation technologies remains limited within the private R&R sector (Table 5).

Table 5: Summary of Questionnaire Respondents' Profiles

Interviewee	Role	Years of Experience	Sector	Tools Used	Used BIM /AI?
Interviewee 1	QS	10+ years	Private	CCS Candy	No
Interviewee 2	CM	5+ years	Private	CostX, CCS Candy	No
Interviewee 3	QS	15+ years	Private	CCS Candy only	No
Interviewee 4	QS & CPM	5+ years	Private	CCS Candy, DimX	No

Theme 1: Barriers to Adopting Digital Technologies for Cost Estimation in R&R Projects

Participants recognised that BIM and LST can improve cost estimation accuracy and project visualisation, but their adoption remains limited by high costs, insufficient technical skills, and poor availability of reliable as-built data. Respondents also highlighted the lack of accurate drawings and training as reasons for the continued reliance on manual methods. These findings align with studies identifying cost, skills shortages, and poor information quality as major barriers to BIM adoption (Shah et al. 2026). Organisational resistance and low digital maturity further restrict technology uptake (Siewe et al. 2026). Similarly, limited AI adoption reflects challenges related to inadequate datasets and technical expertise (Nikiforova et al. 2025). Overall, financial, technical, organisational, and data-related barriers continue to hinder digital transformation in R&R projects.

Theme 2: Challenges in Project Planning and Scope Definition

The participants reported that unclear project scopes and inadequate planning are major obstacles to accurate cost estimation. Uncertainties about existing building conditions, undocumented alterations, and changing project requirements often lead to differences between initial estimates and actual project costs. Respondents noted that frequent scope changes and poorly documented previous modifications make early stage estimates less reliable and complicate planning efforts. These observations are consistent with previous studies showing that weak scope definition and insufficient pre-project investigations contribute significantly to estimation inaccuracies and cost overruns (Afana et al. 2024, Rahim et al. 2025, Onalaja 2023, Barani Shikhrobat et al. 2025). The findings highlight the importance of thorough site investigations, accurate documentation, and effective planning procedures to enhance the reliability and accuracy of cost estimates in refurbishment projects.

Theme 3: Reliance on Traditional Estimation Methods

Interview findings revealed continued reliance on manual cost estimation methods because they are familiar, affordable, and easy to use, despite their susceptibility to errors and inefficiencies. This supports earlier studies showing that traditional estimation practices remain prevalent in developing countries because of limited resources and inadequate digital skills (Salmi et al. 2025, Fietz and Lay 2023, Ndibalema 2025, Ramabodu et al. 2026). Although based on a small sample, the qualitative findings identified three key factors affecting estimation accuracy: barriers to digital technology adoption, including cost, skills shortages, and poor data quality; uncertainties arising from weak planning and scope definition; and persistent dependence on manual methods. Improving accuracy therefore requires stronger planning, better information management, skills development, and organizational support for digital transformation.

5. Triangulation synthesis

Integrating quantitative and qualitative findings provides a comprehensive understanding of cost estimation challenges in refurbishment projects. The results show that estimation inaccuracies arise from a combination of technical uncertainties, inadequate front-end planning, poor information quality, economic volatility, and limited digital technology adoption. Quantitative findings identified unforeseen site conditions (83%), insufficient pre-project investigations (76%), and incomplete documentation (64%) as major contributors to cost overruns, while qualitative evidence highlighted deficiencies in site assessments and fragmented project information. The findings further reveal a gap between the perceived effectiveness and actual use of digital technologies. Although BIM (Mean = 4.42) and Laser Scanning/LiDAR (Mean = 4.35) are recognised for improving estimation accuracy, their adoption remains low due to cost, skills shortages, and organisational constraints. In contrast, Quantity Take-Off (QTO) software shows higher adoption because of its affordability and ease of integration. Manual estimation methods remain dominant despite lower effectiveness,

reflecting entrenched practices and limited digital capability. Similarly, AI-assisted estimation remains underutilised due to insufficient datasets and low digital maturity.

Overall, the evidence suggests that improving cost estimation accuracy requires stronger pre-project investigations, better information management, targeted skills development, wider adoption of appropriate digital tools, and improved project governance. Effective digital transformation depends not only on technology adoption but also on reliable project data, standardised documentation, and enhanced organisational capacity.

6. Conclusion and Further Research

This study found that cost estimation accuracy in refurbishment projects is shaped by a combination of technical uncertainties, managerial shortcomings, economic pressures, and limited digital technology adoption. Factors such as unforeseen site conditions, latent defects, incomplete documentation, weak scope definition, and continued reliance on manual estimation methods contribute significantly to estimation errors. Although technologies such as BIM, LST, AI-assisted estimation, and QTO software can improve accuracy and project visualization, adoption remains constrained by high implementation costs, skills shortages, poor data quality, and organizational resistance. Integrating quantitative and qualitative findings highlights the interconnected nature of these challenges. To address these issues, organizations should prioritize comprehensive pre-project investigations, accurate as-built documentation, and robust front-end planning. Capacity-building initiatives are also required to enhance practitioners' digital competencies and reduce dependence on manual methods. Given their affordability and ease of use, accessible digital tools such as QTO software can serve as a practical entry point for digital transformation. Furthermore, stronger project planning, clear scope definition, systematic risk management, and early stakeholder engagement are essential for improving estimate reliability. Organizational support is equally important. Firms should allocate resources for technology adoption, strengthen data management practices, and foster a culture that embraces innovation. In South Africa, professional bodies such as the CIDB, SACQSP, and ASAQS can support digital transformation through standards, guidelines, CPD programmes, and incentives that promote BIM, QTO, and AI-enabled estimation practices. Implementing these measures can improve estimation accuracy, strengthen financial control, reduce project delays, and enhance the competitiveness of the South African construction sector.

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An analysis of the impacts of pre-contract and contract escalation for project success in Short Form Contracts

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Abstract

This. study examines the effects of pre-contract and contract-stage escalation on project success in Short Form Contracts, as escalation is usually not incorporated leading to several project delivery challenges. It also identifies key drivers of escalation and proposes strategies to mitigate associated risks in construction project delivery. A mixed-methods design was adopted, combining 22 structured questionnaires analysed using descriptive statistics with 15 semi-structured interviews analysed through thematic analysis to provide deeper insight into industry practices and challenges. Findings indicate that escalation significantly affects project performance, leading to cost overruns, schedule delays, and reduced quality outcomes. Poor consideration of escalation during the pre-contract stage results in financial inefficiencies, strained client–contractor relationships, disputes over variations, reduced profitability, and cash flow challenges. Key drivers include inflation, market volatility, and delays in applying escalation adjustments. The study highlights the importance of proactive cost management strategies such as comprehensive cost planning, life cycle costing, realistic budgeting, and strategic investment planning. It further emphasises the need for digital technology adoption, competent contractor engagement, and improved project delivery methods, alongside strengthened regulation, financial literacy, and capacity development. Overall, this research contributes to knowledge by offering an integrated framework for managing escalation across both project stages in Short Form Contracts, improving understanding of cost control, risk management, and project performance outcomes.

Keywords: Pre-Contract and Contract Escalation, Short Form Contracts, Cost Estimation, South Africa

1. Introduction

The construction industry operates in a highly uncertain environment where fluctuations in material prices, labor costs, and macroeconomic conditions consistently drive project cost escalation (Castelblanco et al. 2025; Anireddy 2024; Krupnik and Stryjewski 2023). These challenges are particularly severe in South Africa and other developing economies due to inflation, supply chain instability, and regulatory pressures (Castelblanco et al. 2025). As a result, escalation during both pre-contract and contract stages has become a key determinant of project success, particularly in Short Form Contracts (SFCs), which offer limited flexibility for accommodating price adjustments and therefore compromise cost certainty.

SFCs are simplified standard-form agreements designed for small-scale, low-risk, and less complex projects (Priestley and Doosti 2026; Leishman 2023). In South Africa, these include JBCC Minor Works, NEC Short Form, FIDIC Green Book, and GCC Short Form contracts (Lesailane 2022; Muktar 2025). Due to their short duration, they often inadequately address sharp increases in the Consumer Price Index (CPI), which directly affects material, labour, and transport costs (Tubotamuno and Akidi 2026; Pan et al. 2022.Çollaku and Hajdini 2025.Pejčić et al. 2024). Poor escalation management during planning leads to inaccurate estimates, underpriced bids, and heightened financial risk, while ineffective control during execution results in cost overruns, delays, disputes, and reduced quality outcomes (Nnadi and Najjobyo 2025; Afana et al. 2024; Sanusi 2024).Although tools such as CPAP, BCI, CPI, risk management, and the Iron Triangle exist to manage escalation, many SFC projects still underperform due to weak or inconsistent application of these mechanisms. Similarly, strategies such as life-cycle costing, comprehensive cost planning, and digital adoption remain underutilised or insufficiently effective in SFC contexts (Arslanagic-Kalajdzic 2026;Pourreza et al. 2024). Against this background, this study investigates the impact of pre-contract and contract-stage escalation on SFC project success using a mixed-methods approach, integrating quantitative and qualitative evidence to improve escalation management and support more informed decision-making in construction projects.

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2. Problem Formulation

Construction delivery failure remains a major challenge in South Africa, with studies indicating that up to 60% of short-form construction projects (typically completed within one year) are unsuccessful (Dartey-Baah 2022; Gumusburun Ayalp and Arslan 2025). Key causes include poor scheduling, inadequate planning, and uncontrolled scope changes, with the high failure rate of SMMEs further compounding these outcomes (Akinsolu 2024; Mankge et al. 2024). The construction industry is inherently exposed to uncertainty from fluctuations in labour, materials, and broader economic conditions, all of which drive cost escalation over time (Myers 2022; Zainon et al. 2025). In South Africa and other developing economies, inflation, supply chain instability, and stringent regulatory frameworks intensify these pressures (Andriantomanga et al. 2023; Wolhuter 2022; Msomi and Muzindutsi 2025). Consequently, managing escalation during both pre-contract and contract stages has become critical for project success, particularly in Short Form Contracts (SFCs), which offer limited flexibility for accommodating price changes (Gah 2024). Recent increases in South Africa's Consumer Price Index (CPI) have further elevated financial risks in SFCs without escalation provisions.

Failing to consider escalation during the pre-contract stage leads to inaccurate cost estimates, underpriced bids, reduced profit margins, and a higher risk of project failure (Ahlawat and Singh 2025). During execution, poor escalation management contributes to cost overruns, delays, disputes, and reduced quality outcomes (Mahmud et al. 2026). Therefore, understanding escalation effects is essential for improving cost certainty and project success in SFCs. Although tools such as CPI, BCI, CPAP, risk management, and the Iron Triangle exist, many projects continue to underperform due to weak integration of these mechanisms into planning and execution (Muharremi 2025). Similarly, strategies such as detailed cost planning, life-cycle costing, and digital technologies are recommended, but their effectiveness within SFC contexts remains insufficiently explored.

2.1. Exploring the Impacts of Price Escalation in the Project Lifecycle

Price escalation is a major challenge in the construction industry, affecting project cost, schedule performance, and overall delivery across the entire project lifecycle (Chammout et al. 2024; Afana et al. 2024). During the planning and estimating stage, inaccurate forecasting often results in underestimated budgets and insufficient cost allowances (Pohjonen 2025). In procurement, rising material prices can reduce purchasing power and force contract adjustments or resource reallocation to maintain project objectives (Kumar 2025). During construction, escalation negatively affects contractor cash flow, profitability, and execution efficiency (Nnadi and Najjobyo 2025). Sudden increases in key inputs such as steel, cement, and fuel commonly lead to cost overruns, delays, disputes, and claims for additional compensation (Habe 2026). From the client perspective, rising costs place pressure on budgets and may threaten project feasibility, particularly in long-duration projects that are more exposed to inflationary risk (Khanna and Bajaj 2025). Effective management of escalation requires strong cost planning, ongoing monitoring of market trends, and the use of recognised indices such as CPI, PPI, and BCI (Raydugin 2024.). Incorporating appropriate escalation clauses within contracts further supports fair cost adjustment. Together, these measures improve cost certainty, reduce disputes, and enhance overall project delivery performance.

2.2. Assessing the Implications of Not Factoring Escalation During the Pre-Contract Stage in Short Form Contracts

Although SFCs are designed for small-scale, short-duration projects, omitting price escalation considerations at the pre-contract stage can significantly compromise project performance and cost certainty (Kumar 2025). Escalation pressures from inflation, fluctuating material and fuel prices, labour cost increases, and supply chain disruptions can still arise even within short project durations (Reynolds 2024). If not properly accounted for during estimating and tendering, contractors may be forced to absorb unexpected cost increases, reducing profit margins, tightening cash flow, increasing financial stress, and, in severe cases, leading to project failure. From the client perspective, the absence of escalation allowances often results in variations, claims, disputes, and delays, particularly where contractors cannot deliver within the agreed contract sum (Chammout et al. 2024). Contractors may also respond by reducing work quality, delaying procurement, or pursuing additional claims, all of which negatively affect project outcomes (Antoniou and Tsioulpa 2024). In addition, weak escalation provisions reduce the reliability of cost estimates and undermine effective pre-contract financial planning. Contractually, the lack of mechanisms for managing market-driven price increases creates an uneven allocation of risk between parties, often increasing disputes and adversarial relationships (Long et al. 2024; Zhuang et al. 2026). Therefore, incorporating escalation measures such as contingency allowances, index-linked adjustments, or simplified escalation clauses at the pre-contract stage can improve cost predictability, enhance fairness, and support more successful SFC project delivery.

3. Research Methodology

The study adopts a mixed-methods research design grounded in pragmatism, enabling the integration of quantitative and qualitative approaches to comprehensively assess the impact of pre-contract and

contract escalation on project success in SFC. Ethical clearance was obtained from the Faculty Research and Innovation Committee (FRIC). A concurrent triangulation approach is applied, using structured questionnaires to collect quantitative data from construction professionals such as quantity surveyors, project managers, contractors, and architects, which is then analysed through descriptive statistics. A total of 22 surveys were returned. In parallel, 15 interviews were conducted. The semi-structured interviews provide qualitative insights into stakeholders' experiences and perceptions of escalation management. Guided by the research onion framework, the study combines both deductive and inductive strategies, linking hypothesis testing with in-depth contextual analysis. A case study design within a cross-sectional temporal framework is utilised, drawing on primary data (questionnaires and interviews) and secondary sources (literature, industry reports, and government statistics). Purposive sampling ensures the selection of knowledgeable participants, while validity is enhanced through triangulation and member checking, and reliability is maintained via standardised data collection procedures and adherence to ethical standards, including informed consent, confidentiality, and voluntary participation. Thematic analysis was applied to the qualitative responses, coding and categorizing them into key themes. Single coding was adopted given the study being profiled as small, a pilot and relying on the researcher's interpretive lens. By integrating descriptive and thematic analyses, the study employed methodological triangulation, enhancing the reliability and validity of the findings by linking statistical trends with practitioner insights.

4. Findings and Discussion

4.1. Quantitative Findings

4.1.1. Escalation measurement tools

A total of 22 questionnaires were completed by the selected respondents. The findings show differing perceptions of escalation measurement tools used in SFCs. Relative Importance Index (RII) was adopted alongside the mean scores. The CPAP) recorded the highest mean (3.75; SD = 0.80), indicating it is viewed as the most reliable and practical tool for managing cost escalation during project implementation, consistent with evidence that contractual adjustment mechanisms improve cost predictability in inflationary environments (Stiegler and Bailey 2022). Risk Management ranked second (3.71; SD = 2.17), reflecting relatively strong perceived usefulness but high variability, suggesting that its effectiveness depends on organisational capacity and implementation quality (Ukandu et al. 2026). The BER/BCI (3.66; SD = 0.60) and CPI (3.22; SD = 1.28) were rated as moderately effective, supporting literature that economic indices are useful for tracking cost trends but may be limited by project-specific conditions (AlTalhoni et al. 2024). In contrast, the PPPFA (2.66; SD = 0.52) and the Iron Triangle (2.30; SD = 2.63) received the lowest ratings, indicating they are viewed as less relevant for direct escalation measurement. This aligns with studies suggesting that these frameworks guide procurement and project performance but do not provide explicit mechanisms for managing price fluctuations (Kahanji and Mwanaumo 2023). Overall, the results indicate that respondents prefer practical, formula-based, and management-oriented tools such as CPAP and risk management over broader policy or conceptual frameworks for addressing escalation in Short Form Contracts (Table 1).

4.1.2. Strategies mitigating escalation impacts

The findings indicate that comprehensive cost expenditure planning is perceived as the most effective strategy for mitigating price escalation (mean = 4.75; SD = 0.51; rank 1), reflecting strong agreement that proactive and detailed financial planning is essential for controlling cost variability. This aligns with literature identifying front-end planning as a key driver of project cost performance (AlShaye et al. 2026). Life cycle costing (mean = 3.58; SD = 0.86; rank 2) and cost target setting (mean = 3.50; SD = 0.43; rank 3) were also rated as moderately to highly effective, supporting studies emphasising long-term cost evaluation and benchmarking for financial sustainability (Ali et al. 2024). In contrast, project investment planning and the use of internationally certified contractors (both mean = 2.50) showed moderate influence, suggesting their impact is indirect and context dependent. Lower-ranked strategies, including allocating resources for technological change (mean = 2.40), adopting innovative delivery systems (mean = 2.00), and

Table 1: Cost escalation measurement tools are used to manage impacts during the project lifecycle

Escalation measurement tools	1 = Near minor	2 = Minor	3 = Moderate	4 = Near major	5 = Major extent	Mean score	Standard deviation	Rank
1.CPAP	0	0	4	17	1	3.75	0.80	1
2. BCI	0	2	17	2	0	3.66	0.6	3
3. CPI)	0	2	8	14	0	3.22	1.28	4
4. PPPFA	6	18	0	0	0	2.66	0.52	6
5. Iron Triangle	3	5	14	0	0	2.38	2.63	5
6. Risk Management	1	0	2	18	0	3.71	2.17	2

technology-based mitigation (mean = 1.88), were viewed as least effective (Table 2). This contrasts with emerging research highlighting the potential of digital technologies, though adoption is limited by skills shortages and implementation constraints in developing contexts (Khafiso 2024; Khafiso et al. 2024; Khafiso et al. 2025;Khafiso et al. 2025:Khafiso et al. 2026).

Theme 2: Implications of Omitting Escalation Considerations During Construction

Failing to include escalation clauses exposes project stakeholders to significant financial and relational risks. Quantity Surveyors and Contractors note that without such provisions, projects frequently exceed budgets, sometimes by 20–30%, due to unforeseen market fluctuations. This often places strain on professional relationships, as clients may perceive contractors as inefficient or opportunistic, while contractors feel unfairly burdened by escalating costs. In some cases, projects have been delayed or even abandoned, particularly in both public and private developments during periods of rapid price increases. The consequences extend beyond immediate cost overruns, contributing to schedule delays, reduced quality, contractual disputes, and weakened stakeholder confidence. The public sector is particularly vulnerable, as fixed budgets and rigid administrative processes limit the ability to respond quickly to rising costs. Overall, the omission of escalation mechanisms undermines financial planning, project stability, and trust between parties. Supporting this, Lee (2026) found that contractors operating under fixed-price contracts without escalation clauses are often required to absorb increasing input costs, which can significantly erode or eliminate profit margins.

Table 2: Strategies effectively mitigate escalation impacts in projects for emerging companies in SA

Strategies mitigating escalation impacts	1 = Near minor	2 = Minor	3 = Moderate	4 = Near major	5 = Major extent	Mean score	Standard deviation	Rank
1. Adequate cost expenditure planning	0	0	0	3	19	4.75	0.51	1
2. Life cycle costing	0	0	6	15	1	3.58	0.86	2
3. Setting cost target	0	0	9	13	0	3.52	0.43	3
4. Project investment planning	0	10	12	0	0	2.59	0.35	4
5. Hiring contractors who are certified on international standards	11	0	11	0	0	2.50	2.24	5
6. Provision of resources that support technological change	17	3	0	0	0	1,88	0	7
7. Applying innovative delivery systems to integrate costs	2	20	0	0	0	2.40	0	6
8. Utilizing technology for impact mitigation	0	13	0	7	2	2.88	4.79	5

4.2. Qualitative Findings and Discussions

Theme 1: Impacts of Price Escalation Across the Project Lifecycle

All participants agreed that price escalation significantly affects all stages of construction projects. Quantity Surveyors noted that it introduces uncertainty during planning, often requiring contingencies that reduce tender competitiveness. During execution, escalation disrupts cash flow, triggers variation claims, and leads to delays and disputes, particularly for materials reliant on global supply chains such as steel, cement, and imported finishes. The closeout stage is also impacted through inflated final accounts and reduced stakeholder confidence. Respondents identified escalation as a key risk management issue driven by rising material and energy costs. Contractors confirmed that price increases directly influence procurement, scheduling, and profitability, with delays often caused by supplier disruptions or disputes over variation approvals. Project Managers added that escalation complicates budgeting, extends timelines, and increases contractual conflicts. Additional consequences include reputational damage, legal disputes, and reduced forecasting accuracy. Respondents indicated that many teams lack formal escalation management plans, increasing exposure to financial risk. Mahmud et al. (2026) and Hedin and Hammarstedt (2025) confirm that price escalation remains a persistent challenge across the project lifecycle and that underestimating it during budgeting frequently results in cost overruns and delays

Theme 3: Investigating how escalation can be incorporated in estimating for short form of contract (SFC)

The findings reveal strong support among construction professionals for incorporating simple, transparent, and quantifiable escalation mechanisms within Short Form Contracts (SFCs). Quantity Surveyors, Contractors, and Project Managers emphasized the importance of using objective market-based indicators such as the PPI, BCI, CPI, BER data, and supplier price schedules to account for short-term cost fluctuations. Respondents advocated for straightforward escalation

clauses and formulae that can be easily implemented without compromising the efficiency and administrative simplicity that characterize SFCs. Although respondents raised concerns about client resistance to perceived cost increases and the challenge of justifying escalation allowances on short-duration projects, most agreed that measurable escalation provisions promote contractual fairness and reduce the likelihood of disputes arising from unforeseen market volatility. The findings also align with recommendations to use indices such as BCI, CPI, and CPAP to support equitable cost adjustments, while recent inflation monitoring data from Statistics South Africa supports the reliability of CPI and BCI as indicators of construction cost trends. Consequently, the study demonstrates that incorporating index-linked escalation provisions offers a practical and balanced approach to managing escalation risk in SFCs, enabling contracts to remain both responsive to market conditions and administratively efficient.

5. Triangulation of the findings

The triangulation of quantitative data, qualitative interviews, and existing literature demonstrates a strong consensus on the importance of proactive cost management in mitigating escalation effects in construction projects. Quantitative results show that tools such as the CPAP formula and risk management are highly rated for measuring escalation, while mitigation strategies like comprehensive cost expenditure planning and life cycle costing are identified as the most effective approaches. These findings are reinforced by qualitative insights, with participants consistently noting that escalation impacts all project phases creating cost uncertainty during planning, disrupting cash flow in execution, and inflating final accounts at project closeout. Interviewees also highlighted that neglecting escalation could lead to substantial consequences, including cost overruns of 20–30%, project delays, disputes, and strained stakeholder relationships. Literature further supports these conclusions, emphasizing that escalation is a persistent challenge affecting both project performance and financial stability. The triangulated findings also reveal a notable gap between the acknowledged potential of technological and innovative solutions and their limited practical adoption, as traditional cost planning methods remain the preferred approach among respondents. Overall, the integrated results confirm that while reliable measurement tools and structured planning strategies are crucial, their effectiveness relies on early incorporation during the pre-contract phase, and ongoing risk management.

6. Conclusion and Further Research

In summary, this study demonstrates that both pre-contract and contract-stage escalation significantly influence the success of SFCs, particularly in terms of cost, time, and quality performance. The impact is often amplified in SFCs where escalation is insufficiently considered, compounded by delays between procurement and award processes that contribute to inefficiencies and increased financial exposure. Findings show that inadequate escalation planning at the pre-contract stage leads to inaccurate cost estimates and higher financial risk, while weak management during execution results in cost overruns, delays, disputes, and strained stakeholder relationships. The study highlights the importance of reliable escalation tools such as the CPAP formula, alongside effective risk management practices to improve cost predictability. Strategies including comprehensive cost expenditure planning, life cycle costing, and realistic cost target setting were identified as highly effective in mitigating escalation impacts. However, the adoption of digital and innovative solutions remains limited in practice. Overall, triangulation of quantitative, qualitative, and literature evidence confirms that effective escalation management requires a proactive and integrated approach across the project lifecycle. Early consideration of escalation before contract finalisation, supported by strong institutional frameworks and stakeholder collaboration, is essential for improving outcomes. The study contributes to both theory and practice by providing empirical insight into escalation dynamics in SFCs and emphasising the need for capacity building, policy alignment, and improved industry awareness.

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